Principles for rainforest and grassland restoration in the Anamalai hills

Nature Conservation Foundation

Mysore

&

Vattakanal Conservation Trust,

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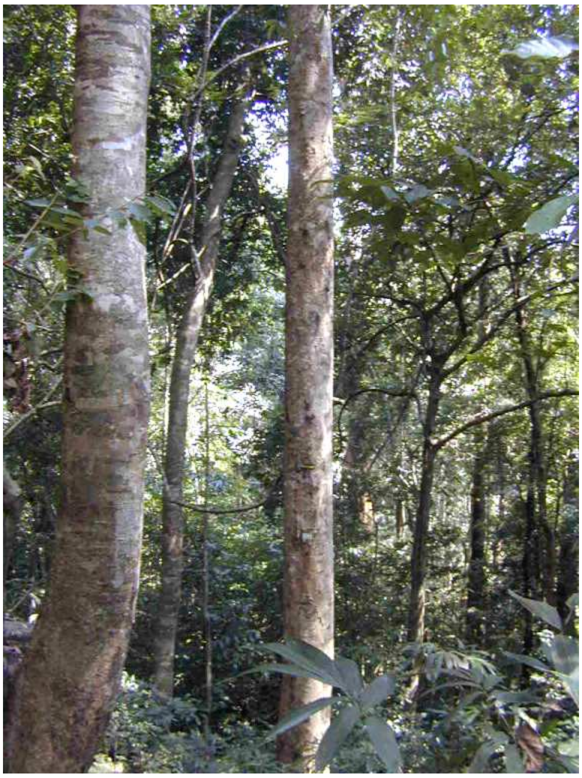

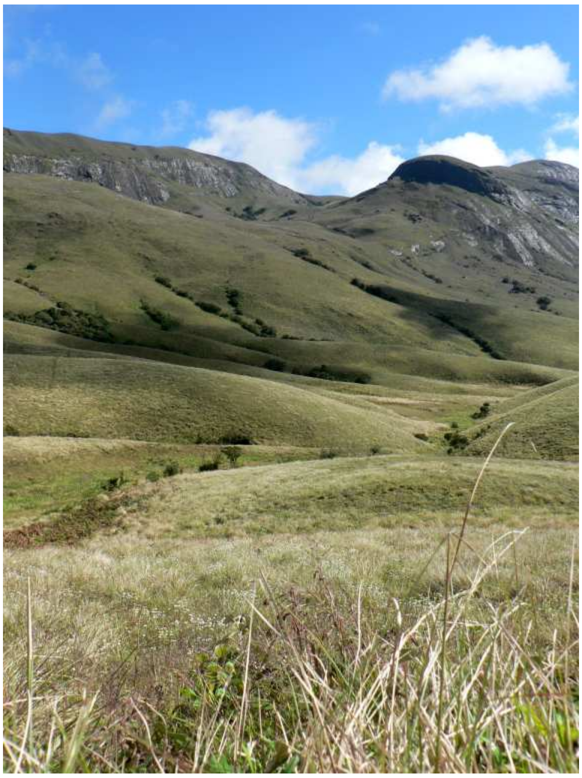

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Restoration of tropical rainforest: principles and practice

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TROPICAL RAINFOREST: AN INTRODUCTION

Among all forest types on Earth, the greatest diversity of living organisms is found in the tropical rainforest. Also called tropical wet evergreen forest, this forest type occurs in those parts around the equator with over 2,000 millimetres of annual rainfall distributed over most of the year. Dry periods with less than 60 millimetres rainfall occur only for a few weeks at most. As a result, there is luxuriant vegetation and most trees remain green year-round.

Trees and woody climbers called *lianas* dominate the vegetation of a tropical rain forest. The canopy reaches an average height of 30 metres or more, with some *emergent* trees nearly 50 metres in height, towering over the others. The tree canopy is dense, allowing <10% of the sunlight from reaching the forest floor. There is a great diversity of herbs, shrubs, ferns, orchids, and plants called *epiphytes* that grow on top of the other plants. Even tree bark and leaf surfaces are micro-ecosystems that shelter a multitude of smaller plants, fungi, lichens, and mosses. The rich tapestry of vegetation supports a diversity of animals from minute mites and springtails in the soil to elephants and hornbills. The lives of these species are closely linked to form the complex rainforest habitat.

Complexity

The complexity of these ecosystems stems from two reasons. The first is structural complexity: the forest has many layers ranging from subsoil belowground, leaf litter, to aboveground layers such as ground vegetation, understorey, mid-storey, canopy, and emergent trees. A second reason is the varied dependence and interactions among the various rainforest organisms. For example, there is competition for light and moisture among plants, mutualisms of pollination and seed dispersal between plants and animals, herbivory and predation.

Dynamics

Individual trees in tropical rainforest may live for hundreds of years and to a human observer the forest may look the same year after year. Yet, rainforests are dynamic ecosystems. Biologists have documented intricate details of many processes such as the birth and death of rainforest plants, competition among seedlings, fluctuations within years and across years in the patterns of flowering and fruiting, and their corresponding influences on animal populations and movements. In relatively undisturbed rainforest, one major natural dynamic process is what has been called tree fall gap dynamics. Occasionally, large rainforest trees fall, bringing down other nearby vegetation and creating a gap in the dense canopy through which sunlight streams down to the floor. This triggers the germination of pioneer tree species from seeds lying in the soil and stimulates the growth of many rainforest tree seedlings as well. Rapid recovery ensues and in a matter of years, the gap closes again with the growth of evergreen vegetation in the case of undisturbed forests and deep forest interiors.

Tropical Rainforests of the Western Ghats

Tropical wet evergreen forests in the Western Ghats occur all along the Western parts from Maharashtra to Kerala. The best rainforests, however, are found in the southern half of the Ghats. The region south of the Palghat gap (a 30 km-wide break in the mountain range), known as the southern Western Ghats, contains some of the highest peaks and vast stretches of climax evergreen forest types. It also contains much of the plant and animal diversity, particularly *endemic* species (species not found anywhere else in the world). The Anamalai hills region is particularly special as it contains the entire range of evergreen forest types and its representative species of plants and animals.

Major rainforest types in the southern Western Ghats

At least five major types of wet evergreen forest or rainforest are found in the Anamalai hills region depending on elevation above sea level and aspect (eastern *versus* western slopes of the main hill range):

1. *Plains and low elevation wet evergreen forest*

This type is found at elevations below 700 m, particularly on the western side of the Ghats. It is characterized by tall dipterocarp trees including many endemics: *Dipterocarpus indicus* and *Dipterocarpus bourdilloni*, *Vateria indica*, *Hopea ponga*. Historically, much of this type has been lost, especially in the plains. Examples exist in areas near Manamboli and Vazhachal.

2. *Medium elevation wet evergreen forest*

This is the most extensive wet evergreen type in the Anamalai hills today, found at elevations between 700 m and 1,400 m. It is characterized by tree species such as *Cullenia exarillata, Mesua ferrea, Palaquium ellipticum,* and *Myristica dactyloides*. Much of this rainforest type occurs as fragments, including on private lands in the Valparai plateau and Nelliampathy hills. Examples of this type can be found at Iyerpadi near Valparai, near Uralikkal-Surulimalai and in near Malakkiparai.

3. *Transitional forests with Lauraceae*

As we move higher, between 1,400 m and 1,700 m, the above forest type changes to montane forest through this transitional forest type. This type has many Lauraceae species such as *Persea macrantha, Neolitsea* sp. and *Litsea sp.* An example is Akkamalai forest.

4. *Shola forest*

The typical shola forest, a kind of stunted montane wet evergreen forest, is found at elevations above 1,800 m. This type is found only in the hills of the Nilgiris, Anamalais, and Palnis in the Western Ghats. Characteristic trees include *Schefflera racemosa, Michelia nilagirica,* and *Prunus ceylanica*. Examples are seen in Konalar-Grass Hills and in Eravikulam.

Threats

Around the world, tropical rainforests are among the most threatened ecosystems today. Over 100 million hectares are lost or severely degraded every decade due to human-caused destruction. Clearing for agriculture, plantations, roads, reservoirs, logging for timber, extraction of minor forest produce, invasions by weedy species, grazing, unplanned development and urbanisation are some of the major threats to tropical rainforests today. Besides direct loss of forest cover (deforestation), these have resulted in fragmentation (leaving remnants of forest surrounded by non-forest habitats), and created large areas of secondary forest (second growth or regenerating vegetation in degraded or disturbed areas).

RESTORATION: PRINCIPLES AND GUIDELINES

What is restoration?

Restoration is the process of returning an ecosystem to its original state prior to disturbance or human impact. ***Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed*** (Society for Ecological Restoration International Science and Policy Working Group 2004).

What is recovery?

In the context of restoration, ***recovery means the process of returning to similar conditions as reference sites***:

1) The natural structural characteristics of the ecosystem such as multi-layer vegetation, tree canopy cover, etc.
2) The natural functional attributes and dynamics of the ecosystem such as pollination, dispersal, decomposition, etc., and
3) The characteristic indigenous species assemblages of the ecosystem, such as the plants, animals, fungi, etc. found in reference sites.

What are reference sites?

Restoration should always be towards a goal. ***Reference sites*** help determine that goal. Reference sites are sites containing representative examples of the area under restoration as it was prior to human disturbance. They may also be relatively undisturbed sites located in the same environmental setting (e.g., same elevation, rainfall zone, and soil type), which have been subjected to little or no human impacts.

When is restoration necessary?

It is a common misconception that if we strictly protect an area, it will naturally recover because 'Nature knows best'. This may be true for large areas of little disturbed forests, but we now know that many areas will not recover even after decades of protection. In such areas carefully planned intervention in the form of restoration becomes ***necessary*** because:

1) natural recovery of the original vegetation and associated animal communities will not occur even under strict protection following the removal or curtailment of disturbance factors,
2) natural recovery may take an enormous amount of time (decades to centuries) unless we intervene to 'assist the recovery' of the degraded site, and
3) meeting specific conservation goals requires the revival of specific sites within a specific time period.

What kinds of sites need restoration?

Restoration may be necessary in a wide variety of sites such as areas where:

1) there is heavy infestation of weeds, grasses, and vines, choking natural vegetation,
2) the soil seed bank is depleted or lost due to historical disturbance such as fire and grazing,
3) parent trees that can produce seeds are locally extinct, as in isolated fragments,
4) natural forests have been replaced by monoculture timber plantations or cash crops,
5) settlements, plantations, or other land-use existed earlier but are now abandoned,
6) soil nutrient status and symbiotic mycorrhizal fungal populations are lost or reduced,
7) large areas have been cleared or mined with top soil lost, eroded, or depleted, or
8) open areas have been created due to clear-felling, fires, or landslides.

Where should we target restoration efforts?

Sites need to be prioritized for restoration in forest landscapes using specific criteria based on ecological and conservation needs. This could include, for instance:

1) sites that are habitats of particular threatened or endemic species,
2) stream sides and river courses,
3) degraded areas within or along the edges of existing wildlife sanctuaries and reserved forests,
4) edges of forest fragments, adjoining plantations or other habitats
5) corridors linking forest fragments,
6) along linear disturbances such as roads, power-line clearings, and fire-lines, and
7) the land matrix (plantations, fields, streams etc.) surrounding fragments or reserves

What is the role for protection?

Protection efforts need to go hand-in-hand with restoration. Larger areas of forest, especially relatively undisturbed forests, need continued protection. In most such cases, one should **not** carry out restoration or planting activities (including gap or supplementation planting, 'assisted natural regeneration', food species enhancement, etc.) and allow natural processes to operate.

In sites selected for restoration using the criteria listed above, we need to ensure protection from disturbances that led to the degradation in the first place. For instance, sites degraded by grazing or fire need to be protected from cattle and fires. Sites degraded by fuel-wood removal and felling need to be protected from cutting of native species (although woody weeds such as *Lantana* may be cut and alternatives provided for local people).

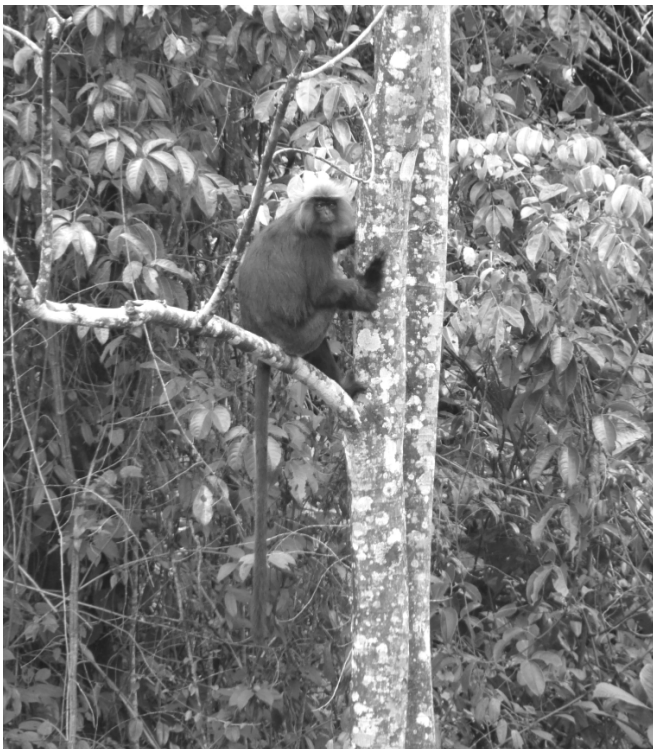
How should we deal with exotic species?

Many exotic species (e.g., *Eucalyptus* spp., *Acacia auriculiformis*, *Acacia mearnsii,* pines, *Casuarina equisetifolia*) have been planted widely, even inside wildlife sanctuaries and national parks. In addition, many herbaceous weeds have been introduced and spread due to various human activities and regular small-scale disturbances. Sometimes exotic species have been planted as they are considered to provide food for wildlife (e.g., *Maesopsis eminii*).

In general, one should **strictly avoid planting exotics** close to or within wildlife conservation areas. This is because, such species have various detrimental effects on natural ecological processes, native vegetation, and many wildlife populations through:

- Reduction in ground water table (e. g., *Eucalyptus* spp.)
- Alteration of soil characteristics and microclimate
- Suppression or alteration of native plant communities (e.g., *Maesopsis eminii*)
- Proliferation of other weeds (e.g., *Lantana camara* often grows in the understorey of *Eucalyptus* plantations)
- Change in forest structure and function (most exotics)
- Invasion into surrounding landscape (many exotics, *Maesopsis eminii, Acacia mearnsii, Spathodea campanulata*)
- Reduction in native biological diversity, particularly affecting specialized mature forest species (e. g., Malabar Trogon, Nilgiri langur)

It is however possible to restore rainforests in sites currently dominated by exotic species. In sites under *Eucalyptus* and *Maesopsis* canopies, restoration efforts by removal of herbaceous understorey weeds (without cutting native vegetation) and planting of a diversity of native species has proved quite successful.



Restoration Protocol: Guidelines for setting targets

From Society for Ecological Restoration International Science and Policy Working Group:

1) A legitimate and indeed important object of much ecological restoration is the reintegration of fragmented ecosystems and landscapes, rather than focusing on just a single ecosystem. A baseline ecological inventory describes the salient attributes of the abiotic environment and important aspects of biodiversity such as species composition and community structure.

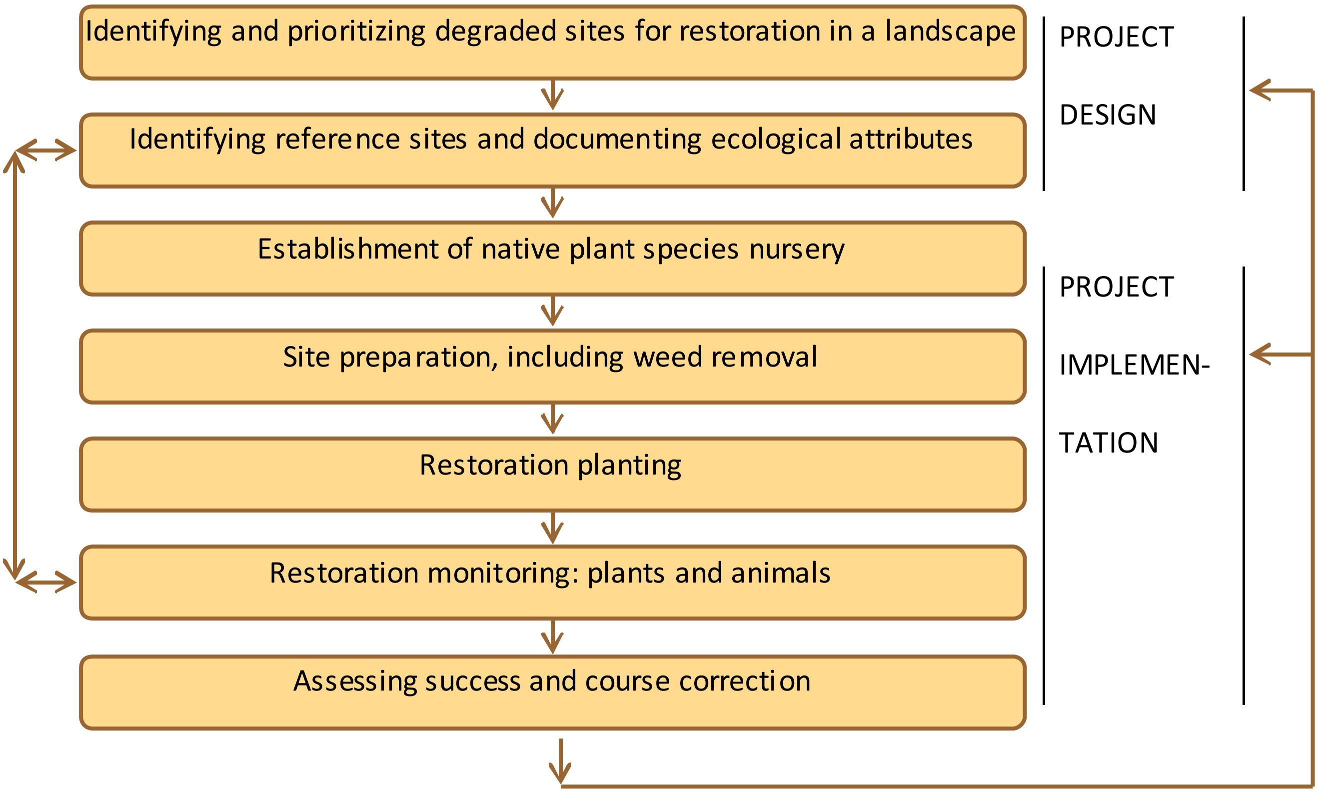
2) Highest priority is best reserved for the control or extirpation of those species which pose the greatest threats. These include invasive plant species that are particularly mobile and pose an ecological threat at landscape and regional levels, and animals that consume or displace native species. Care should be taken to cause the least possible disturbance to indigenous species and soils as exotics are removed. In some instances, non-indigenous plants are used for a specific purpose in the restoration project, for example as cover crops, nurse crops or nitrogen fixers. Unless these are relatively short-lived, non-persistent species that will be replaced in the course of succession, their eventual removal should be included in restoration plans.

3) The importance of an ample recovery in species composition cannot be overstated in restoration. All functional species groups must be represented if a restored ecosystem is to maintain itself.

4) Many cultural ecosystems have suffered from demographic growth and external pressures of various kinds, and are in need of restoration. The restoration of such ecosystems normally includes the concomitant recovery of indigenous ecological management practices, including support for the cultural survival of indigenous peoples and their languages as living libraries of traditional ecological knowledge. Ecological restoration encourages and may indeed be dependent upon long-term participation of local people.

RAINFOREST RESTORATION: PRACTICAL ASPECTS

Components of a restoration project



Nursery protocols

Nursery infrastructure establishment

The important parts of a nursery include:

- A 0.5-1 m deep trough of well aerated soil which can be used to plant small seeds such as *Ficus*, and most of the pioneer species.
- Beds of nursery sleeves (at least 15 cm tall) filled with soil in the proportion of 1:1:6 of sand, organic compost, and soil, respectively.
- A rodent-proof enclosure built of wire-mesh to protect some species whose seeds are attacked by rats and squirrels.
- Shade netting of 90%, 75%, and 50% shading. These are required for various stages between seed planting and seedling growth.

Seed collection and identification of species

Since the aim of the restoration programme is to reverse the trends of degradation, certain precautions are of utmost importance while establishing the seed and sapling bank for the nursery. These include:

- Fresh seeds fallen on the ground have to be collected only from the edges of forests, along trails or roads going through or along the edges of forests.
- Collecting seeds or seedlings from within the forests (even if they are fragments) will negatively affect the natural process of regeneration and forest dynamics and recovery in case of forest fragments. This would defeat the purpose of restoration.
- Match seeds with fruit and leaf specimens in the field itself and the species should be identified using reliable floras and field guides.
- For each species, seeds should be collected from as many different parent trees as possible to maximize genetic diversity.

- All seeds should be from trees in the same area and same vegetation type. For example, one should not collect seeds from trees in Nilgiri hills for planting in Anamalai hills, even if it is the same species.
- The seeds have to be separated as good and bad seeds. Those with fungal attacks, rotten, or with pest infestation have to be discarded. Only healthy and whole seeds from ripe fruit should be planted to maximize the returns for the efforts.
- If there are a lot of seedlings along trails or roads that are likely to get run over or cleared by the forest, public works, or highways departments, these can also be collected as “wildlings” or “rescued saplings”.

Planting in nursery

Seeds of most rainforest species have low dormancy and viability. That is, the seeds germinate within a short time after they mature and therefore have to be planted as soon as they are collected. However, in the nursery, some species may take up to a year to germinate.

- Most rainforest fruits and seeds are prone to predation and fungal attack especially if they are planted deep in the soil. Therefore, the seeds must be placed in such a way that half of each seed is exposed above the soil surface.
- Care should be taken to identify species that could get predated (based on past knowledge or field experience) and these have to be planted in the enclosure only.
- Sometimes seedlings tend to get browsed by snails or hare. These also can be protected largely within a nursery enclosure.
- Although water is very important, sleeves should not remain waterlogged.
- Weeds have to be regularly removed from the sleeves containing seeds or seedlings, taking care that the roots of the seedlings are not damaged. Weeds compete with seeds and seedlings for nutrients and affect their growth.
- An occasional caterpillar or most other pests need not be considered a major problem in most cases.
- Use of pesticides is not necessary at all. If the shade is managed well, based on the seasons, even fungal attacks can be avoided without the use of fungicides.

Care of seeds and seedlings

Water is a major limiting factor for the germination and growth of seedlings. Therefore, in the first few weeks/months (depending on the species), they have to be watered everyday, being mostly wet evergreen forest or shola species. Only saplings earmarked for planting in the following season may be watered less frequently during the period of hardening.

Site Preparation

The boundaries of each restoration site should be measured and clearly demarcated. Invasive weeds such as *Lantana camara*, *Eupatorium glandulosum*, and *Mikania sp*. should be cut with machetes and all *L. camara* uprooted with mattocks one to four months prior to planting. Two practices should be strictly followed during weed clearing. First, take special care not to cut any naturally regenerating native vegetation, including shrubs and climbers, found growing amidst the weeds. Second, larger (>1 cm girth) woody stems of *Lantana camara* may be cut into small lengths and removed outside the fragment to prevent their sprouting. The people in near-by settlements can also use this as fuel-wood. The finer cut stems and all green leafy material should be left on the site to form a mat-like ground layer to avoid soil exposure and erosion.

Selection of species for planting

The primary restoration protocol to be used is multi-species planting of rainforest trees (with some lianas and shrubs). The species to be planted should be native species typical to the vegetation type, region, and altitude, as evidenced from their occurrence in the reference site. Factors such as slope, aspect, distance to water, canopy openness, and soil status need to considered in the selection of which seedling is to be planted at a specific location within a restoration site. Two main species selection methods are used in rainforest restoration:

Framework species method: This involves the planting of one or, more often, a few species of pioneer and mid-successional species along with a mixture of mature forest species. Framework species are those that establish and grow well in disturbed areas, that produce flowers and fruits that attract animals relatively quickly, that have robust germination and vigorous production of branches and litter. One can plant 'keystone species' such as *Ficus* species, which attract many frugivorous animals to their fruit resources especially during periods of food scarcity. The main advantages of this method are that it involves only one planting, it is self-sustaining, and it incorporates the need for attracting and sustaining wildlife and linking them with recovery of natural dynamics such as seed dispersal and regeneration. The method is best suited for sites that are close to other seed sources or habitats with populations of mammals and birds that can colonise and bring seeds into the restoration site.

Maximum diversity method: This involves the re-establishment of as many of the original pre-disturbance species as possible. In sites with few adjoining seed sources or for plant species that are locally extinct or have poor dispersal, this may be the only means to bring back plant populations in restoration sites. This method involves more labour and maintenance (e.g., to raise seedlings, monitor survival, weeding) and may be slower as many mature forest species are likely to have slow growth rates. Also, recolonisation by animals may be poorer or slower if the sites are highly isolated. Although this is a highly preferable approach where the major goal is conservation of biological diversity, because of relatively high cost and effort it will be useful in select situations and in key areas for conservation.

Selection of seedlings

Planted seedlings need to be at least 45-60 cm tall at the time of planting. The seedlings are hardened in the nursery through regular exposure to direct sun and reduced watering for 3 – 4 months prior to planting. A subset of seedlings can be raised in larger 'jumbo' sleeves to large sapling size (c. 1.5 m tall) for planting. Large seedlings may be expected to better withstand episodes of grazing and drought.

Planting protocol

Seedlings are planted in pits of around 10 – 15 cm diameter and 45 cm depth. At the time of planting, the are also provided with fertilizer (circa 100 g organic manure mixed with the soil and 25 g rock phosphate on the sides and bottom of the pit) and with a layer of litter mulch around the base. Post-planting hand-weeding may be needed four to six times within the site during the first year and two to three times in the second year after planting. All seedlings must be tagged conspicuously to be located easily for survival monitoring.

Fertilization

Although growth rates of seedlings vary substantially according to species, in most cases providing planted seedlings with fertilizer at regular intervals over the first two years will help speed up vegetative growth. Standard nitrogen-phosphorous-potassium (NPK) mixtures and dosages may be used for this purpose.

Monitoring protocol

Monitoring restoration efforts is very important. It involves monitoring at regular intervals (every six months or annually) various aspects such as: seedling survival, regeneration, and recovery of forest structure and function, and animal population and community, following standard methods of sampling.

Indicators of success

According to the *Society for Ecological Restoration International Science and Policy Working Group*, an ecosystem has recovered and is restored when:

1) It contains sufficient *biotic and abiotic resources* to continue its development without further assistance or subsidy.

2) It is suitably *integrated into a larger ecological matrix, landscape, or contiguous ecosystems*, with which it interacts in terms of biotic and abiotic flows and cultural interactions.

3) It contains a *characteristic assemblage of the species* that occur in the reference ecosystem and that provide appropriate community structure.

4) It consists of *indigenous species* to the greatest practicable extent.

5) All *functional groups* necessary for the continued development and/or stability are represented or, if they are not, the missing groups have the potential to *colonize* by natural means (corridors, river systems, row of trees).

6) The physical environment of the restored ecosystem is capable of sustaining *reproducing populations* of the species necessary for its continued stability or development along the desired path.

7) Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible.

8) The restored ecosystem is self-sustaining to the same degree as its reference ecosystem, and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure and functioning may change as part of normal ecosystem development, and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change.

Tree species of mid-elevation rainforests for rainforest restoration plantings

S. No.	Species	Sites with moderate to high shade	Highly degraded open areas	Along streams and swamps	Growth rate
1	*Actinodaphne angustifolia*		X		Fast
2	*Antidesma menasu*	X			Slow
3	*Artocarpus heterophyllus*	X	X	X	Fast
4	*Atalantia racemosa*	X	X		Medium
5	*Bhesa indica*	X			Medium
6	*Bischofia javanica*	X	X		Fast
7	*Calophyllum austroindicum*	X			Slow
8	*Canarium strictum*	X		X	Medium
9	*Chrysophyllum lanceolatum*	X			Medium
10	*Cinnamomum malabathrum*	X	X	X	Fast
11	*Clerodendrum viscosum*		X	X	Fast
12	*Cullenia exarillata*	X			Slow
13	*Debregesia longifolia*			X	Fast
14	*Dimocarpus longan*	X	X		Medium
15	*Diospyros assimilis*	X			Slow
16	*Diospyros sylvatica*	X			Slow
17	*Drypetes wightii*	X	X		Medium
18	*Dysoxylum binectariferum*	X			Slow
19	*Elaeocarpus munronii*	X	X	X	Fast
20	*Elaeocarpus serratus*	X			Medium
21	*Elaeocarpus tuberculatus*	X	X	X	Fast
22	*Euodia lunu-ankenda*	X	X		Fast
23	*Euonymus angulatus*	X	X		Medium
24	*Ficus beddomei*	X	X		Slow
25	*Ficus nervosa*	X	X	X	Medium
26	*Ficus tsjahela*	X	X	X	Medium
27	*Filicium decipiens*	X	X		Medium
28	*Gomphandra coriacea*	X			Medium
29	*Heritiera papilio*	X	X		Medium
30	*Holigarna nigra*	X			Slow
31	*Lepisanthes decipiens*	X	X	X	Fast
32	*Ligustrum perrottetii*		X	X	Fast
33	*Litsea floribunda*		X		Fast

S. No.	Species	Sites with moderate to high shade	Highly degraded open areas	Along streams and swamps	Growth rate
34	*Litsea glabrata/oleoides*	X	X		Fast
35	*Litsea insignis*	X			Slow
36	*Macaranga peltata*		X		Fast
37	*Maesa indica*		X	X	Fast
38	*Mallotus tetracoccus*		X		Fast
39	*Mastixia arborea*	X			Slow
40	*Meliosma pinnata*		X	X	Fast
41	*Meliosma simplicifolia*		X		Medium
42	*Mesua ferrea*	X			Slow
43	*Myristica dactyloides*	X			Slow
44	*Neolitsea scrobiculata*	X			Slow
45	*Neolitsea zeylanica*	X	X		Medium
46	*Nothopegia racemosa*	X			Slow
47	*Olea dioica*	X	X		Medium
48	*Oreocnide integrifolia*	X	X	X	Medium
49	*Ormosia travancorica*	X			Medium
50	*Palaquium ellipticum*	X			Medium
51	*Persea macrantha*	X	X		Medium
52	*Poeciloneuron indicum*	X		X	Slow
53	*Prunus ceylanica*	X	X		Medium
54	*Scolopia crenata*	X	X		Slow
55	*Semecarpus travancorica*	X			Medium
56	*Sterculia guttata*		X		Fast
57	*Symplocos cochinchinensis*	X	X	X	Slow
58	*Syzygium densiflorum*	X	X	X	Medium
59	*Syzygium gardneri*	X	X	X	Medium
60	*Toona ciliata*		X		Fast
61	*Trichilia connaroides*	X	X		Fast
62	*Turpinia malabarica*	X			Medium
63	*Vateria indica*	X	X	X	Medium
64	*Vepris bilocularis*	X			Slow
65	*Vernonia arborea*	X	X	X	Fast

Ripe fruit and seed availability of mid-elevation rainforest trees in Anamalai hills

S. No.	Species	J	F	M	A	M	J	J	A	S	O	N	D
1	*Actinodaphne angustifolia*				●	●	●	●					
2	*Antidesma menasu*									●			
3	*Artocarpus heterophyllus*			●	●	●	●	●	●	●			
4	*Atalantia racemosa*				●	●	●	●				●	
5	*Bhesa indica*		●	●					●	●	●		●
6	*Bischofia javanica*									●	●		
7	*Calophyllum austroindicum*	●		●	●			●					
8	*Canarium strictum*		●	●	●		●	●	●	●	●		
9	*Chrysophyllum lanceolatum*		●	●	●								
10	*Cinnamomum malabathrum*						●						
11	*Clerodendrum viscosum*									●			
12	*Cullenia exarillata*	●	●	●	●	●	●	●	●		●	●	●
13	*Debregesia longifolia*		●	●									
14	*Dimocarpus longan*							●	●				
15	*Diospyros assimilis*				●								
16	*Diospyros sylvatica*			●	●	●					●		
17	*Drypetes wightii*							●					
18	*Dysoxylum binectariferum*		●	●	●		●	●					
19	*Elaeocarpus munronii*		●	●	●	●							
20	*Elaeocarpus serratus*	●		●			●	●	●	●	●		
21	*Elaeocarpus tuberculatus*		●	●	●		●	●	●	●	●		
22	*Euodia lunu-ankenda*												●
23	*Euonymus angulatus*		●	●									
24	*Ficus beddomei*	●		●	●								
25	*Ficus nervosa*										●		
26	*Ficus tsjahela*									●			
27	*Filicium decipiens*		●										
28	*Gomphandra coriacea*				●	●		●			●		
29	*Heritiera papilio*			●			●						
30	*Holigarna nigra*						●	●	●	●	●		
31	*Lepisanthes decipiens*		●	●	●								
32	*Ligustrum perrottetii*	●											●
33	*Litsea floribunda*			●	●								

S. No.	Species	J	F	M	A	M	J	J	A	S	O	N	D
34	*Litsea glabrata/oleoides*			●	●	●	●	●					
35	*Litsea insignis*					●	●						
36	*Macaranga peltata*					●							
37	*Maesa indica*								●	●			
38	*Mallotus tetracoccus*		●	●						●		●	
39	*Mastixia arborea*			●	●	●		●		●			●
40	*Meliosma pinnata*							●					
41	*Meliosma simplicifolia*								●				
42	*Mesua ferrea*		●	●					●				
43	*Myristica dactyloides*		●	●	●	●	●	●					
44	*Neolitsea scrobiculata*		●	●							●		
45	*Neolitsea zeylanica*			●		●	●	●					
46	*Nothopegia racemosa*		●	●	●	●							
47	*Olea dioica*				●								
48	*Oreocnide integrifolia*									●	●		
49	*Ormosia travancorica*	●	●	●	●								●
50	*Palaquium ellipticum*		●	●	●	●	●	●	●	●			
51	*Persea macrantha*		●	●	●								
52	*Poeciloneuron indicum*			●	●								
53	*Prunus ceylanica*		●	●						●	●		
54	*Scolopia crenata*				●	●					●		
55	*Semecarpus travancorica*		●	●	●				●				
56	*Sterculia guttata*		●	●									●
57	*Symplocos cochinchinensis*												●
58	*Syzygium densiflorum*						●			●			
59	*Syzygium gardneri*				●		●	●					
60	*Toona ciliata*	●	●										
61	*Trichilia connaroides*							●	●	●	●		
62	*Turpinia malabarica*							●	●	●	●		
63	*Vateria indica*						●	●	●	●			
64	*Vepris bilocularis*				●	●							
65	*Vernonia arborea*			●									

Restoration of shola-grassland ecosystems: Insights from the Palni hills

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INTRODUCTION

The shola-grassland ecosystem is a unique ecosystem found in the upper reaches of the Western Ghats. The altitude range of this ecosystem varies in different locations. Some scientists have fixed the lower limit as low as 1500 m. Others, for example in Karnataka, often refer to mid-elevation (1100 m to 1200 m) areas as shola/grasslands. In the Palni hills, some sholas cover slopes from 1600 m to over 2000 m, with only a few species specialising at the extremes of this range. The picture is further complicated by the migration of several species to higher altitudes in recent years. This could be an ongoing process of post-glacial migration or the product of a more recent warming phenomenon or both.

For all practical purposes during 18 years of maintaining a shola tree nursery, our reference sholas for seed collections begin at 1700 m (1600 m) rising to 2400 m. It is common for sholas to be described as stunted, with a canopy like a tightly-knit carpet or a cauliflower. Individual trees can, however, be massive in girth and spread of canopy, with some very notable individuals reaching heights of 40 m to 60 m.

When talking of this ecosystem, it should also be noted that there is significant variation in both structure and species composition between and within different hill ranges. The Palni hills climate is notably warmer, drier, and more sheltered than its westerly counterparts. The trees here are not only larger, but apparently older as indicated by the common occurrence of hollowed trees.

Community involvement

Our successful restoration of Pambar and Vattakanal Sholas depended on the active cooperation of local communities especially during the early years. The year 1991 was a benchmark year with community meeting, films, guest speakers, and the engagement of a newly formed youth group in tree planting. The meetings not only won a generalised, although uneven, commitment to save the shola, but were the key to distributing thousands of utility tree species for firewood, timber, and fodder needs. This phase ended in 1993, with 16,000 saplings planted including shola species. *Acacia* species were particularly important, quickly supplying an abundance of firewood that probably accounted for most of the cutting in the sholas. Having the local communities on board also kept out logging gangs who had previously been processing large-sized timber trees.

The other side of community involvement crucially focused on social and economic development, especially in Vattakanal, an extremely poor community with absolutely no infrastructure barring a rough jeep track linking it to Kodaikanal. The engagement of the youth group in particular resulted over the years in the building of a community centre, a crèche, a water harvesting cum delivery system and electrification for the village.

Restoration work

From 1993, we focused almost exclusively on shola and grassland species, including shrubs, lianas, and herbs. Vattakanal Shola was able to restore its wasted understorey with almost no further intervention, but the arms and extremities of Pambar Shola had shattered canopies and weed-infested understories. Worst of all a weed-infested basin of some 11 hectares, once under potato cultivation, threatened to burn again as it had in 1989. Beneath the weeds lay over 4000 of our saplings planted with the cooperation of the Forest Department in 1992.

It wasn't until 2001, that we managed to achieve further cooperation and we were able to return. Suppression of the tangled mass of weeds such as bracken (*Pteridium aquilinum*), *Rubus* species, and *Eupatorium adenophorum* (= *Ageratina adenophora*) quickly allowed our earlier plantings to emerge together with some natural regeneration. A further planting of 3000 (exact figure) dominant species since 2001 have been individually tagged, regularly monitored, with annual censuses.

NURSERY AND AFTERCARE METHODOLOGY

Perhaps the most important difference in practice between VCT and NCF is in our nursery and aftercare methodology. Our colder climate allows for only agonisingly slow growth of most of our species. After three years of nursery care, we might expect only a stick-like plant of c. 1 m. Planting out at this age means they would have to survive for up to 7 years before they could be regarded as safe from predation. During the current phase of restoration, we have shifted steadily to a minimum of 5 years nursery care and intensive aftercare (wire-mesh and poles) at the cost of Rs 15/- per tree for species vulnerable to gaur grazing (*Bos gaurus*). We prefer these species to be taller than 2 m so that their period of vulnerability is much reduced. The wire-mesh can be shifted upwards as the crown rises. We are only one year into this practice and no protected trees have been damaged. We feel we have the potential for 100% survival rate but put it conservatively at 97%.

Damaged trees protected thus are also recovering despite repeated grazing over several years. Shola trees live for many hundreds of years so maximum investment in each individual plant is well warranted. If you are pursuing a longer period of nursery care, it is essential that saplings are given a suitably sized container/plastic/cement bag. Overgrown saplings will "ossify" in their bags. Fortunately, most shola trees have a branching root habit well adapted to container life, only a few have fast tap root growth.

Species selection

Our planting methodology regarding species selection follows the *maximum diversity method*. Species that were not found in the immediate locality of the restoration site were also planted if they were found in reference sholas. Most of these reference sites are within easy walking distance of the restoration site and may be reasonably considered to belong to one ecosystem. This also allowed us to introduce rare, threatened, and even locally extinct species into the restoration areas. This reasoning would also apply in the Palnis to surviving fragments of grassland in grassland restoration. No particular reference site would provide an adequate species composition and structure to make a definitive model.

We have broken guidelines with a few species, bringing propagules from the Anamalais or Nilgiris where Palni materials have either become locally extinct or so scarce that no propagules for all practical purposes are available. Regarding extra costs using the maximum diversity method, evaluation is difficult. As the nursery is a permanent fixture, it is hard to say what extra cost a slow species entails. It would have been impossible for us to refuse any species and we could not have known then what constituted a *framework species*. Growing is knowing! Budgets should, if possible, accommodate maximum diversity.

ROLE OF WEEDS AND EXOTIC SPECIES

Role of weeds in shola restoration 1992 - 2001

Shola degradation is usually accompanied by weed invasion that prevents shola regeneration even if the shola is protected. In our planting of 1992, a large number of exotics (our utility species) were planted accidentally in our absence. This in most cases proved to be beneficial because, unlike shola species, they were able to beat the ensuing regrowth of weeds. When we re-entered the plot in 2001, we found many of our shola plantings benefiting from the proximity of exotics that had suppressed the worst of the weeds. *Acacia* species had also provided a good deal of firewood locally in what were the early days of restoration.

Use of exotic trees as weed suppressants

In some instances, where labour is scarce and weeds an impediment to shola regeneration, the inclusion of some exotics may be appropriate. Probably the most promising species for weed suppression in the Pambar restoration was *Euodia fraxinifolia*, a fast-growing tree from the Himalaya that has a tendency to die off in its second decade, eventually being replaced by long-lived shola trees. *Acacia mearnsii* is also an excellent nurse tree for shola and does not sucker from the roots. *Acacia melanoxylon, A. decurrens*, and *A. dealbata* are seriously problematic as they sucker from the roots when cut. Another Himalayan species, *Prunus cerasoides*, also made it into the planting. It is the only truly invasive plant able to quickly overtop the shola canopy. The plant needs serious control here and should never be raised outside of the Himalaya.

Weed eradication 2001 - 2006

In our expanded plantings in this plot since 2001, we have resorted to labour-intensive manual weeding. This involves primary slashing, pulling, and composting, with a second weeding a year later. This is enough to get saplings up and away, but we have indulged in the luxury of repeated weeding that has assisted our shrub and herbaceous plantings and allowed for the early recruitment of other native species.

After 15 years of restoration within the areas of shattered canopy, there is copious regeneration. The earliest plantings have attained forest status while the plantings since 2001 are attaining heights in excess of 4 m.

Where not to restore shola

All shola tree plantings should be aimed at restoring existing, usually weed-infested, sholas or as roadside ornamentals. Other plantings, for example in plantations, are a waste of resources as these usually shelter naturally occurring native saplings. They should never be planted in grassland either within or outside protected areas.

GRASSLAND RESTORATION

We are still at the embryonic stage of development regarding grassland restoration. Restoration of grassland is important for biodiversity and essential for the recovery of water bodies destroyed by industrial timber plantations. Water security is a key issue here.

The immediate priority in all montane grassland ecosystems is the removal of exotics that are currently invading pristine grasslands, or that have been recently planted in grasslands. This applies also to the very rare mid-range forest and grassland landscapes at c. 1100 m still to be found in Kerala (Periyar).

Restoration of destroyed wetlands and catchment areas will require the removal of all exotic tree species and the manipulation of what is termed the Initial Floristic Community (IFC, following Egler 1954), in a way that nudges or propels the successional recovery in a desirable direction. There are no examples as yet for us to reference where manipulation has been practiced. We do know that without restorative intervention, felling of dense plantation usually leads to a succession along a weedy path to a weedy climax, as seen in the Palnis. Apart from the re-emergence of *Acacia mearnsii*, for example, from the seed bank, thorny *Rubus* species are an emerging new threat. *Rubus,* normally a species of the wayside or the shola border, spreads through plantations and forms dense thickets following removal of plantation species.

Therefore, influencing the IFC requires secondary weeding and introduction of desirable species either by broadcasting seed, or "island" plantings that can spread into the wider landscape. Experimentation and pilot projects are required here.

VCT have been cultivating key grassland species for many years, but only began a grassland nursery for restoration purposes in April 2005. We have c. 300 species in cultivation of open grassland, marsh, and forest border (ecotone). In the area of the ecotone, plants are found that belong neither to open grassland nor within the closed shola canopy. It is a very large plant community consisting of trees, shrubs, lianas, vines, ferns, and grasses.

We suggest that wherever foresters are growing trees for restoration they begin to add grasses and ecotone species to their nurseries without waiting for a programme of grassland restoration. Grasses anyway help in forest restoration by establishing a desirable ground-level vegetation thereby helping to suppress weeds.

When not to restore

Very old exotic plantations with mature trees do not consume vast quantities of water; they are usually home to a growing number of native species. Some manipulation may be useful but destruction of these maturing ecosystems would cause more harm than good.

Tips on cultivation

1. Specimen plants should be brought to the nursery for easy seed collection and division.
2. Most grasses divide easily for rapid multiplication.
3. Small seeds should be sown in trays under glass without direct sunlight.
4. Turfs made in trays from disturbed lumps of grassland are easily sliced for reproduction, providing instant biodiversity from the seed bank.
5. Fire-line collections provide excellent material, are easy to harvest and no harm is done to the ecosystem.
6. No plastic bags should be used. Reusable plastic pots and trays are very labour saving.
7. Potted plants and turfs make well-rooted materials for easy planting in the field.

Full range of woody species for shola restoration in the Palni Hills

The list in the Table below is designed to indicate to foresters what trees and shrubs are desirable for cultivation according to planting circumstances, marked by ease of cultivation, vulnerability, and imperatives of biodiversity and conservation.

Plants that are ***framework species*, indicated by an asterisk (*)**, fall into four categories. There are 14 fast and reliable species with 4 being typically edge and nurse species. In addition, there are 9 fast but vulnerable species, 4 slow but reliable species, and 5 rare but reliable species.

S. No.	Name	Growth rate	Ease	Seed availability	Bison palatability	Status
1	*Actinodaphne bourneae*	slow	difficult	scarce	resistant	rare
2	*Actinodaphne malabarica*	slow	moderate	scarce	resistant	rare
3	*Alseodaphne semecarpifolia*	slow	difficult	scarce	resistant	rare
4	*Alstonia venenata**	fast	easy	abundant	resistant	common, pioneer
5	*Antidesma menasu*	slow >1900m	easy	abundant	vulnerable	common, esp. >1800m.
6	*Ardisia rhomboidea*	slow	difficult	scarce, cuttings	?	rare, understorey
7	*Bentinckia condapanna*	slow	difficult	scarce	vulnerable	rare, established > 1800m.
8	*Bischofia javanica**	fast	easy	abundant	resistant	common c. 1800m.
9	*Beilschmeidia wightii*	slow	easy	moderate	resistant	common
10	*Casearia thwaitesii*	slow	easy	scarce	resistant	restricted
11	*Casearia zeylanica*	slow	easy	fairly scarce	resistant	common
12	*Cassine paniculata**	slow	easy	locally abundant	resistant	restricted, rare
13	*Celtis tetrandra**	fast	easy	moderate	vulnerable	common
14	*Celtis timorensis**	fast	easy	abundant	vulnerable	common
15	*Chionanthus ramiflora var. peninsularis**	fast	easy	abundant	vulnerable	common
16	*Cinnamonum wightii*	slow	difficult	fairly scarce	resistant	common
17	*Cryptocarya stocksii**	slow	easy	fairly scarce	resistant	restricted
18	*Daphniphyllum neilgherrense**	moderate	easy	abundant	resistant	common, pioneer
19	*Elaeocarpus blascoi*	slow	difficult	scarce, cuttings?	?	only one tree
20	*Elaeocarpus munronii**	fast	easy	locally abundant	vulnerable	rare
21	*Elaeocarpus tuberculatus**	fast	easy	fairly abundant	vulnerable	common esp. c. 1800m.
22	*Elaeocarpus recurvatus*	slow	difficult	fairly scarce	vulnerable	common
23	*Elaeocarpus variabilis (= E. glandulosus)**	moderate	easy	abundant	some resistance	common
24	*Euodia lunu-ankenda*	fast	?	scarce	?	FD. Introduction > 2000m.
25	*Eurya nitida*	slow	slow	scarce	?	common, pioneer
26	*Euonymus crenulatus*	slow	easy	fairly scarce	vulnerable	common, understorey

S. No.	Name	Growth rate	Ease	Seed availability	Bison palatability	Status
27	*Glochidion velutinum*	moderate	easy	viable seed scarce	some resistance	common
28	*Gomphandra coriacea*	slow	easy	fairly scarce	vulnerable	common, understorey
29	*Gordonia obtusa*	slow	easy	fairly scarce	some resistance	restricted
30	*Ilex denticulata*	slow	difficult	scarce	some resistance	rare
31	*Ilex wightiana**	fast	easy	abundant	vulnerable	common
32	*Isonandra perrottetiana*	slow	easy	scarce	vulnerable	locally abundant
33	*Ixora notoniana*	slow	easy	fairly scarce	?	common, edge species
34	*Lasianthus species*	slow	difficult	moderate, cuttings	?	common, understorey
35	*Ligustrum perrottetii**	fast	easy	abundant	some resistance	common, edge species
36	*Litsea floribunda*	slow	easy	scarce	resistant	common
37	*Litsea glabrata**	fast	easy	abundant	resistant	common
38	*Litsea sp.*	slow	difficult	occasional abund.	resistant	restricted, plateau Sholas
39	*Litsea quinqueflora*	slow	easy	scarce	resistant	common, edge species
40	*Litsea wightiana**	moderate	easy	abundant	resistant	common, pioneer
41	*Macaranga indica**	fast	easy	abundant	vulnerable	common, pioneer
42	*Mallotus tetracoccus**	fast	easy	fairly abundant	resistant	common esp. c. 1800m. P
43	*Meliosma pinnata ssp. arnottiana**	fast	easy	abundant	resistant	common, pioneer
44	*Meliosma simplicifolia ssp. pungens**	moderate	easy	abundant	resistant	common
45	*Memecylon randerianum*	slow	difficult	scarce	?	restricted, rare
46	*Michelia nilagirica var. nilagirica**	fast	easy	abundant	vulnerable	common, pioneer
47	*Microtropis ramiflora*	moderate	easy	locally abundant	some resistance	common
48	*Myrsine wightiana*	slow	easy	scarce	vulnerable	rare
49	*Neolitsea fischeri**	slow	easy	scarce	resistant	restricted, rare
50	*Neolitsea foliosa var. caesia*	slow	easy	fairly abundant	resistant	common, edge species
51	*Neolitsea zeylanica**	slow	easy	abundant	resistant	common
52	*Nothapodytes nimmoniana*	slow	slow	fairly abundant	resistant	common, edge, understorey
53	*Nothopegia monadelpha*	slow >1800m	moderate	locally abundant	?	common < 1800m.
54	*Olea paniculata*	slow >1900m	moderate	scarce	vulnerable	fairly common
55	*Osbeckia reticulata**	fast	easy	abundant	resistant	common, edge, large shrub
56	*Pavetta breviflora*	slow	easy	fairly abundant	resistant	common, understorey
57	*Persea macrantha**	fast	easy	abundant	resistant	common c. 1800m.

S. No.	Name	Growth rate	Ease	Seed availability	Bison palatability	Status
58	*Phoebe wightii**	slow	easy	locally abundant	resistant	common
59	*Photinia integrifolia var. integrifolia*	moderate	easy	abundant, cuttings	vulnerable	common, edge, grassland
60	*Pittosporum neelgherrense**	fast	easy	abundant	vulnerable	common, edge species
61	*Pittosporum tetraspermum*	fast	easy	locally abundant	vulnerable	restricted to Pambar Shola
62	*Prunus ceylanica**	fast	easy	abundant	vulnerable	common
63	*Psychotria nilgiriensis var. nilgiriensis*	slow	difficult	common, cuttings	?	common, understorey
64	*Psydrax ficiformis**	slow	easy	scarce, cuttings	resistant	rare
65	*Rhododendron arboreum ssp. nilagiricum*	slow	difficult	abundant, cuttings	resistant	common, pioneer, edge
66	*Schefflera racemosa**	fast	easy	occasional abund.	vulnerable	common, pioneer
67	*Scolopia crenata**	moderate	easy	locally abundant	resistant, armed	common, esp. c. 1800m.
68	*Symplocos cochinchinensis ssp. laurina*	slow (white fly)	difficult	abundant	some resistance	common, pioneer, edge
69	*Tarenna flava*	slow	easy	scarce	some resistance	restricted
70	*Toona ciliata ssp. ciliata*	?	?	scarce	?	common c. 1800m.
71	*Turpinia nepalensis*	moderate	easy	abundant	vulnerable	common
72	*Syzigium caryophyllatum**	slow	easy	locally abundant	resistant	occasional
73	*Syzigium cumini**	moderate	easy	abundant	resistant	common esp. c. 1800m
74	*Syzigium densiflorum**	slow	easy	abundant	resistant	common, pioneer
75	*Vaccinium leschenaultii*	slow	difficult	abundant	vulnerable	common, grassland, edge
76	*Viburnum cylindricum**	fast	easy	abundant	resistant	common, pioneer, edge
77	*Viburnum punctatum*	moderate	easy	abundant	some resistance	common, pioneer, edge
78	*Xantholis tomentosa var. elengioides**	slow	easy	scarce	resistant, armed	restricted, rare

All nomenclature according to *The Flora of the Palni Hills*, K. M. Matthew, 1999
Note: Some pioneers are also climax species.

Basic definitions

Biodiversity refers to the naturally occurring taxonomic and genetic diversity of life forms present and the community structure thereby created, and the ecological roles performed. Two related aspects of biodiversity are **species composition**, i.e. the taxonomic array of species present, and **species richness**, i.e. the number of different species present.

Ecological processes or ecosystem functions are the dynamic attributes of ecosystems, including interactions among organisms and interactions between organisms and their environment. Ecological processes are the basis for self-maintenance in an ecosystem.

Landscape is a mosaic of two or more ecosystems that exchange organisms, energy, water and nutrients

Ecological restoration: The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed

Ecosystem management: Action intended to guarantee the continued well-being of either a relatively undisturbed or restored ecosystem

A destroyed ecosystem is that in which when **degradation** or **damage** has removed all macroscopic life, and commonly ruins the physical environment as well

Exotic species of plant or animal is one that was introduced into an area where it did not previously occur through relatively recent human activities. **Invasive** exotic species commonly compete with and replace native species. **Weeds** are proliferating species that are usually exotic and often invasive, which establish and propagate widely.

Succession is the dynamic and continuous process of establishment and maturation of an ecosystem in a newly exposed or disturbed area.

Pioneer species are species that first appear, easily establish, and grow in open, highly degraded sites; in forest areas, these may include grasses, herbs, vines, and trees such as *Macaranga* species.

Mid-successional species are species of regenerating forest that establish under pioneer vegetation and gradually replace them before giving way to mature forest species.

Sustainable cultural practices are traditional human land uses that maintain biodiversity and productivity. In this context, the biota is valued as much for its importance to ecosystem stability as it is for its short-term worth as commodities. Perhaps all natural ecosystems are culturally influenced in at least some small manner, and this reality merits acknowledgement in the conduct of restoration.

Characteristic tree species in rainforests at different altitudes

Rainforest type	Top canopy species	Mid-storey species
Low-elevation (below 700 m)	*Dipterocarpus indicus* *Hopea parviflora* *Palaquium ellipticum* *Palaquium bourdilloni* *Mesua ferrea* *Vateria indica* *Calophyllum polyanthum* *Poeciloneuron indicum* *Myristica dacytloides* *Holigarna beddomei* *Bombax ceiba*	*Drypetes longifolia* *Reinwardtiodendron anamallayanum* *Fahrenheitia zeylanica* *Baccaurea courtallensis* *Harpullia arborea* *Filicium decipiens* *Polyalthia fragrans* *Cleidion spiciflorum* *Knema attenuata* *Dimocarpus longan* *Hydnocarpus pentandra*
Mid-elevation (700 to 1,400 m)	*Cullenia exarillata* *Mesua ferrea* *Palaquium ellipticum* *Myristica dactyloides* *Elaeocarpus tuberculatus* *Syzygium gardneri* *Ormosia travancorica* *Litsea glabrata/oleoides* *Bischofia javanica* *Artocarpus heterophyllus*	*Olea dioica* *Drypetes wightii/malabarica* *Trichilia connaroides* *Cinnamomum malabathrum* *Actinodaphne angustifolia* *Oreocnide integrifolia* *Antidesma menasu* *Gomphandra coriacea* *Semecarpus travancorica* *Persea macrantha*
High-elevation (1,400 to 1,700 m)	*Syzygium densiflorum* *Bhesa indica* *Gordonia obtusa* *Litsea bourdilloni* *Cryptocarya sp.* *Casearia rubescens* *Actinodaphne malabarica* *Prunus ceylanica* *Dysoxylum binectariferum* *Elaeocarpus serratus*	*Ardisia rhomboidea* *Gomphandra coriacea* *Symplocos racemosa* *Symplocos kanarana* *Isonandra lanceolata* *Garcinia kova* *Garcinia pictorius* *Persea macrantha* *Antidesma menasu* *Oreocnide integrifolia*
Montane shola (> 1,700 m)	*Syzigium densiflorum* *Celtis timorensis* *Litsea wightiana* *Cinnamomum wightii* *Prunus ceylanica* *Meliosma simplicifolia* *Ilex wightiana* *Michelia nilagirica* *Schefflera racemosa* *Elaeocarpus variabilis* *Chionanthus ramiflora*	*Gomphandra coriacea* *Euonymus crenulatus* *Nothapodytes nimmoniana* *Memecylon randerianum* *Ardisia rhomboidea* *Mahonia leschenaultii (edge)* *Pavetta breviflora* *Ixora notoniana* *Lasianthus venulosus* *Lasianthus acuminatus* *Psychotria nilgiriensis*

Exotic species to note in the mid- and high-elevation areas of the Anamalai hills

Understorey species	
1. *Lantana camara*	Highly invasive
2. *Eupatorium glandulosum*	Highly invasive
3. *Mikania mikrantha*	Highly invasive
4. *Coffea canephora* (Robusta coffee)	Highly invasive
5. *Coffea arabica* (Arabica coffee)	Moderately invasive
6. *Montanoa bipinnatifida*	Highly invasive
7. *Ipomoea indica*	Highly invasive
Exotic tree species	
1. *Spathodea campanulata*	African tulip, invasive in forests
2. *Maesopsis eminii*	African tree, invasive in forests
3. *Acacia mearnsii*	Australian wattle, invasive in grasslands
4. *Eucalyptus sp.*	Australian species, disturbs vegetation
5. *Pinus sp.*	

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