

## Rufford Small Grants Project

### Final report

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**Title:** Assessing recovery of large rainforest trees and carbon storage in ecologically restored degraded rainforest fragments

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**Reporting duration:** 14 Feb 2017 to 15 Aug 2018

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### Background

Forest fragmentation and degradation drive marked shifts in the structure, composition and function of tropical rainforests, including declines of large, mature forest tree species and carbon storage. Forest restoration is widely promoted as a strategy for reversing pervasive human impacts and sustaining biodiversity and ecosystem services in the human-dominated tropics. Our RSG-funded project in India's Western Ghats biodiversity hotspot aims to evaluate the extent of recovery of forest structure, tree communities, carbon storage and soil functions in ecologically restored rainforests within formerly degraded forest fragments and to examine the factors influencing these responses. Our project also aims to build support and capacity for restoration through publications exploring ecological and climate benefits of restoration and by engaging with stakeholders and conducting workshops on restoration principles and practice.

### Objectives

(1) Assess tree community and carbon recovery in ecologically restored rainforest fragments, (2) Compare the effectiveness of ecological restoration and monoculture plantations in overcoming barriers to recovery of large-statured tree species and carbon storage in degraded rainforest fragments and (3) Engage with scientists and managers to increase awareness and training for ecological restoration as a conservation and carbon sequestration strategy in human-dominated rainforest landscapes.

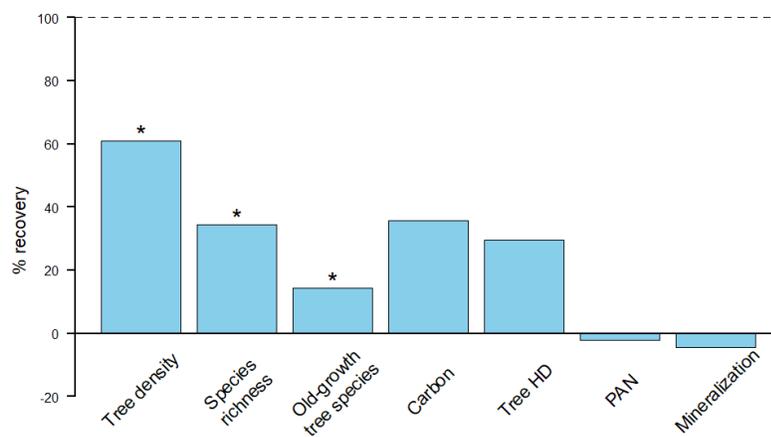
***Assessing tree community and carbon recovery in ecologically restored rainforest fragments***

(A) A study examining the effects of restoration on ten indicators of forest structure, tree diversity and ecosystem functioning in formerly degraded tropical rainforest fragments was conducted during Feb-Oct 2017. A total of 87 plots (20 × 20 m) were sampled for vegetation and soil in formerly degraded forests that have been restored (actively restored), adjacent degraded sites that were not restored (passively restored), and near-natural “benchmark” forest sites (29 sites each). All trees ( $\geq 3$  cm diameter at breast height – dbh) were identified and measured (dbh and height). Three soil cores were collected from each plot for elemental and microbial analyses.

*Table 1: Estimates of various vegetation and soil indicators in benchmark, passively restored and actively restored rainforests*

Response	Benchmark	Passively restored	Actively restored
Tree density (Trees plot <sup>-1</sup> )	65.65 (58.11 - 73.19)	29.64 (22.23 - 37.05)	51.56 (40.85 - 62.27)
Log-height: Log-diameter	1.05 (1 - 1.1)	0.88 (0.83 - 0.94)	0.93 (0.89 - 0.96)
Aboveground carbon (Mg ha <sup>-1</sup> )	293.96 (220.67 - 367.26)	63.98 (21.94 - 106.03)	146.19 (50.28 - 242.09)
Tree species richness (Species plot <sup>-1</sup> )	24.41 (21.78 - 27.04)	8.56 (6.3 - 10.82)	14 (11.8 - 16.2)
Mature forest species richness (Species plot <sup>-1</sup> )	18.35 (16.03 - 20.67)	2.52 (1.3 - 3.74)	4.8 (3.5 - 6.1)
Soil carbon (T ha <sup>-1</sup> )	26.03 (23.74 - 28.33)	24.68 (21.25 - 28.12)	25.62 (22.33 - 28.9)
Soil nitrogen (T ha <sup>-1</sup> )	2.1 (1.89 - 2.32)	2.06 (1.72 - 2.39)	2.13 (1.87 - 2.39)
Plant available N (mg kg <sup>-1</sup> )	22.18 (19.83 - 24.53)	18.2 (15.03 - 21.36)	18.11 (15.15 - 21.07)
N Mineralization (mg kg <sup>-1</sup> week <sup>-1</sup> )	48.34 (43.26 - 53.42)	38.58 (30.44 - 46.71)	38.14 (31.58 - 44.7)

Estimates of different vegetation and soil indicators in benchmark and restored forests are provided in Table 1. Our results show that different vegetation and soil indicators show varying levels of recovery under active restoration (Figure 1). Attributes such as tree density, species richness and mature forest species richness, which are directly manipulated during active restoration, showed consistent recovery (61%, 34% and 17%, respectively) over passively-restored baselines. In contrast, recovery was lower and more variable for attributes that are indirectly affected by restoration (i.e. responses that are not directly manipulated during but might still respond to restoration) – aboveground carbon storage and tree height-to-diameter ratios showed small but inconsistent increases while soil fertility showed virtually no recovery. Total soil carbon and nitrogen did not differ across the three habitat types.



*Figure 1: Recovery of eight ecological attributes under active restoration. Values indicate percent recovery towards benchmark values over passively restored baselines. Indicators that showed statistically significant recovery are marked with \**

**A key insight from this study is that active interventions can be crucial for restoring forest structure and tree diversity in degraded rainforest fragments, but their efficacy at recovering carbon sequestration and soil functions is more uncertain. Our results highlight the need for caution in promoting restoration as a carbon sequestration tool, especially when used to compensate for planned diversion of biodiverse and carbon-dense intact tropical forests.**

(B) We recently formalised a partnership with the Parry-Agro company for systematically restoring a 100 ha remnant of degraded rainforest in Murugalli -- Sheikalmudi, in the western Valparai plateau. Vegetation and soil assessments of the degraded site were initiated in April 2017, focusing on tree diversity, vegetation and soil carbon, soil nutrients and microbial activity. 100 soil samples (one per hectare) have been collected and analysed, and 30 out of 100 vegetation plots have so far been sampled. The data are not only beginning to tell an interesting story in terms of how vegetation and soil responses vary across different levels of forest degradation, but these data also constitute pre-restoration baselines which will be valuable for evaluating and monitoring post-restoration ecological recovery. In addition to research work, the RSG project team members played an active part in ongoing restoration efforts at this site – 2400 saplings belonging to 60 rainforest tree species were planted over four hectares of degraded forests during 2017.



*Figure 2: Restoration activity at Murugalli -- Sheikalmudi*

**Assessing rainforest tree regeneration under ecological restoration and monoculture plantations**

Tree plantations have been shown to enhance tropical rainforest recovery through shade and soil effects on plant regeneration, but seed and seedling performance under different types of tree plantations – such as commercial monocultures (e.g. *Eucalyptus spp.*) and mixed native species restoration plantings – remain poorly understood. We examined tree plantation effects on rainforest tree regeneration by conducting a shade-house experiment and a sample plot-based study of tree regeneration patterns. The experiment employed a factorial design combining three soil treatments – ecologically restored (ER), unplanted (UN) and monoculture Eucalyptus plantation (MP) and two shade treatments (50%, 75%). Two hundred and forty seeds each of one late-successional species (*Knema attenuata*), two mid-successional species (*Artocarpus heterophyllus* and *Elaeocarpus tuberculatus*) and one early-successional species (*Actinodaphne malabarica*) were collected and sown in June 2017 and rates of seed germination, seedling survival and growth were monitored over the next six months. A plot-based field survey was during Feb – Apr 2018 to characterize rainforest tree regeneration patterns within the three habitats, and within relatively undisturbed ‘near-natural’ rainforests (NN).



Figure 3: The shade house experiment in progress

In the plot-based study, we found that natural regeneration in ER forests comprised as many, or nearly as many, individuals and species of tree seedlings and saplings as NN forests. Seedling and sapling densities and richness in ER forests were significantly higher in restored forests than within MP and UN habitats (Fig 4a, b). The subset of tree species closely affiliated with mature 5

rainforests showed a similar pattern, decreasing in abundance and diversity from NN and ER to MP and UN forests (Fig 4c, d).

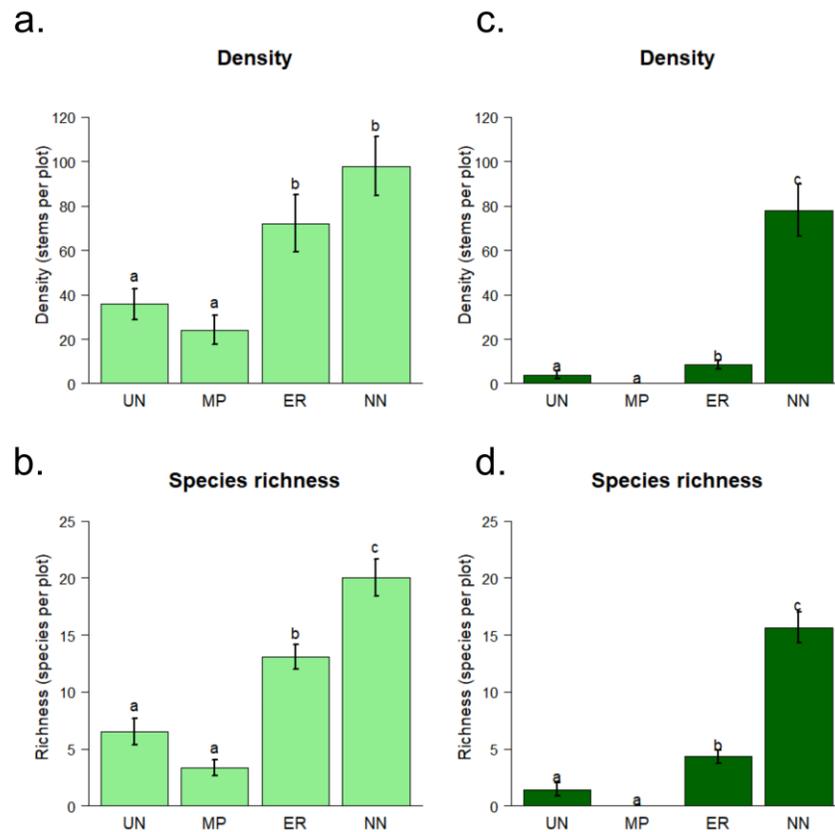


Figure 4: Seedling and sapling density and species richness of all species (a, b) and mature forest species (c, d) in unplanted areas, monoculture plantations, ecologically restored areas and near-natural forests

Preliminary results of the shade-house experiment showed that seed germination, and seedling survival and early growth, did not differ consistently across soils from ER, MP and UN habitats for all four species. By contrast, responses of the four species were more consistently related to shade, showing increased germination, growth and survival under high shade relative to low shade. **These preliminary findings indicate that both monoculture and mixed-species restoration plantations might offer conditions that favour the germination and early survival of rainforest tree species, and suggest that the strong differences in natural regeneration between ER and MP – observed in the field study – are an outcome to factors**

**other than soil and shade.** Our ongoing and future work in this system aim to examine the role of seed dispersal by mammals and birds as possible reason for greater natural regeneration in restored forests than monocultures, and to examine how these differences change over time.

This work was presented as a poster during a session on restoration ecology at the annual meeting of the Ecological Society of America 2018 (New Orleans, USA, 4-9 Aug) (Appendix A).

### **Building support and capacity for ecological restoration and monitoring**

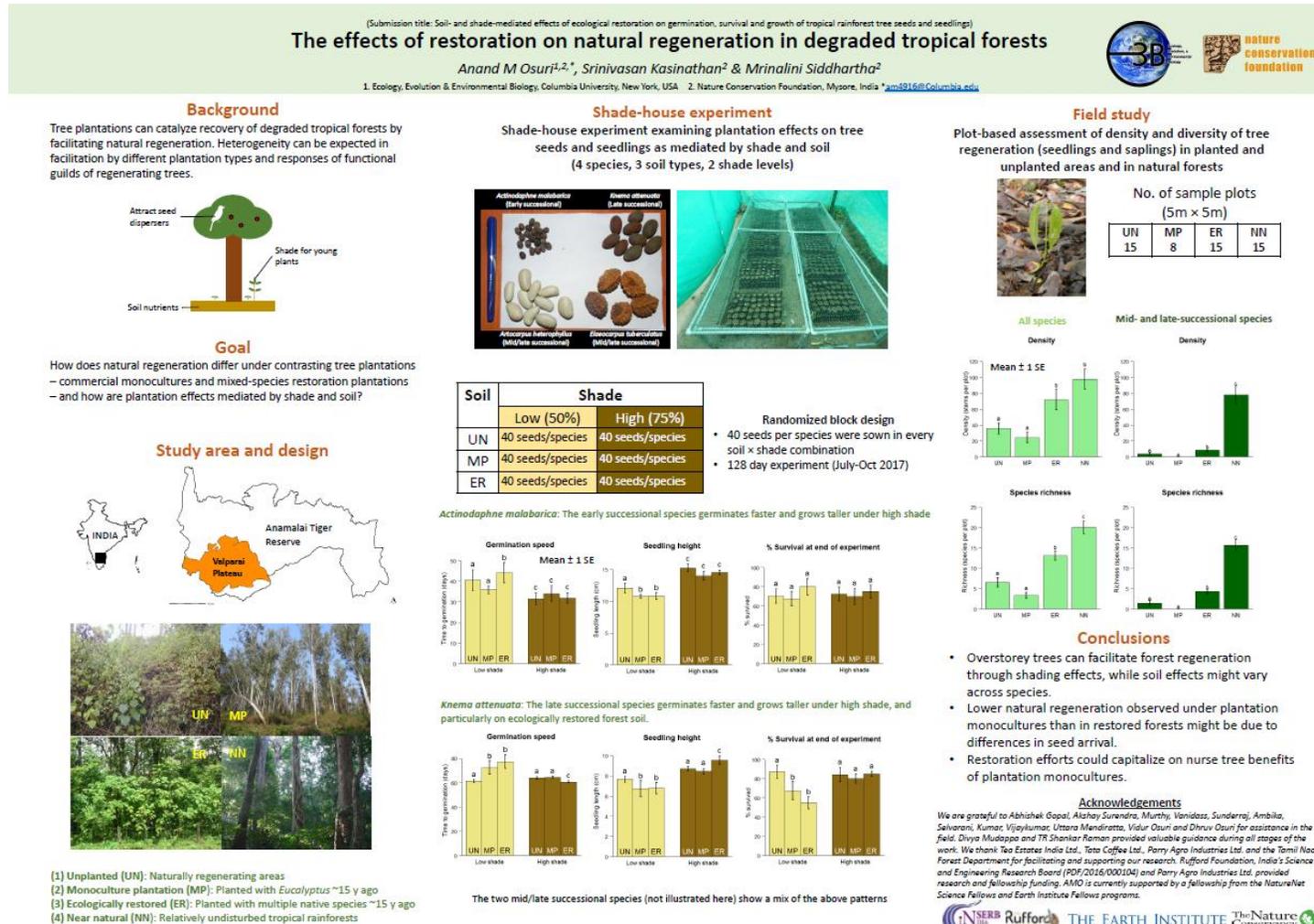
A week-long workshop titled “Ecological restoration: Principles, practice and monitoring” was organized in Valparai and surrounding areas during 1-5 May 2017. The ten workshop participants, who were selected from a competitive group of 60 applicants, came from a background of research and/or practice of ecological restoration in different parts of India. The workshop comprised classroom sessions focusing on principles and theory of ecological restoration, combined with field visits for sharing experiences in nursery techniques, restoration planting, stakeholder engagement and scientific monitoring (a detailed account of the workshop is provided in Appendix B). A notable outcome of the workshop is an initiative taken by a group of participants to establish Ecological Restoration Network of India (ERN-India). Currently a 29-member strong email-based forum for topics pertaining to restoration science and practice, discussions are underway for how best to further develop ERN-India as a platform for restoration scientists and practitioners in India.

### **Acknowledgements**

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## Appendix A

Poster based on Rufford project work presented at the annual meeting of the Ecological Society of America (New Orleans, USA, 4-9 August 2018)



## Appendix B

Restoration workshop report

# **Ecological restoration: Principles, practice and monitoring**

**Valparai, 1-5 May 2017**

## **Workshop Report**

### **Background**

Ecological restoration of fragmented and degraded habitats plays an important role in conserving biodiversity and improving the supply of ecosystem services in human-dominated conservation landscapes. Practising restoration requires skills and knowledge that span multiple disciplines, ranging from biogeography and plant community ecology to fostering partnerships with local communities, administrators and other stakeholders.

A week-long workshop titled “Ecological restoration: Principles, practice and monitoring” was organized in Valparai and surrounding areas of the Anamalai Hills in the southern Western Ghats, where NCF runs a long term rainforest restoration project. The workshop comprised classroom sessions focusing on principles and theory of ecological restoration, combined with field visits for sharing experiences in nursery techniques, restoration planting, stakeholder engagement and scientific monitoring.

### **Selection procedure**

On 20 Jan 2017, a flyer announcing the workshop was forwarded to colleagues and acquaintances in fields of ecology and conservation, posted on mailing groups such as Young Ecologists Talk and Interact (YETI), and posted on NCF’s blog and social media platforms.

Applicants were asked to submit a covering letter explaining their reasons for wanting to attend the workshop, along with a *Curriculum Vitae*. The workshop was open to applicants from all backgrounds. Applications were accepted till 10 Feb 2017.

A total of 51 applications were received and independently evaluated by four reviewers. Applicants were scored based on the strength of their cover letters, in terms of the rationale provided for applying and descriptions of how the workshop would benefit them. The applicants' ability to develop and implement projects was also assessed from their CVs. Upon completion of individual assessments, the reviewers met to collate scores and shortlist candidates. Ten high quality candidates from a wide range of backgrounds were selected, including students, researchers, conservation practitioners and farmers.

## **The workshop (1 May – 5 May 2017)**

Location: Sinna Dorai's Conference room – Upper Parlai, and field sites

### Organizers and main resource people:

Divya Mudappa, Scientist, Nature Conservation Foundation

T R Shankar Raman, Scientist, Nature Conservation Foundation

Anand M Osuri, Research Associate, Nature Conservation Foundation

Mrinalini Siddhartha, Project Associate, Nature Conservation Foundation

K Srinivasan, Project Associate, Nature Conservation Foundation

### Guest speakers:

M M Venkatachalam, Chairman, Parry Agro Industries Limited

Abi Tamin Vanak, Fellow, Ashoka Trust for Research in Ecology and the Environment

Manjunatha H Chandregowda, Project Associate, Nature Conservation Foundation

### Participants:

Balu Hegde, Amruta Chavan, Meenakshi Singh, Rohit Jha, Aniruddha Dhamorikar, Nikita Rao, Niren Jain, Vijaylakshmi Suman, Zabna AB and Jui Pethe

**Day 1 – Introduction and concepts**

Day 1 comprised a series of lectures aimed at understanding the need for restoration, restoration concepts and techniques, and core components of ecological restoration programmes. This was followed by a field tour aimed at familiarising participants with conservation challenges and opportunities in the Anamalais landscape, including NCFs work on biodiversity assessments, ecological restoration and human-wildlife interactions.



**Day 2 – Components of an ecological restoration programme**

The focus of day 2 was on experiencing and understanding different components of an ecological restoration project. The day began with an introduction to phenology monitoring and seed collection protocols, followed by a visit to NCF's rainforest nursery, where participants were involved in soil preparation, seed processing and sowing, and other core aspects of nursery management. Participants were then taken on a tour of previously restored rainforest fragments. The afternoon session featured a talk on grasslands and savannas by Dr Abi Tamin Vanak, focusing on their misclassification as 'wastelands' and the threats posed by misguided 'restoration' efforts that plant trees in these naturally open ecosystems. The day ended with a visit to the Anamalai Tiger Reserve, which gave participants a chance to spend time within a relatively undisturbed rainforest, and to think about whether and how the myriad and complex components and interactions of an intact rainforest can be effectively restored.



**Day 3 – Planning and managing an ecological restoration project**

On day 3, we visited the Candura project, which is an ongoing effort by NCF and the Parry Agro group to restore a degraded 100-ha rainforest site. The goal for the day was to introduce aspects of planning and management related to restoration. Participants visited the field to observe site preparation (weed removal, digging of sowing pits), and took part in restoration planting. Participants also got to interact with Mr Oliver Praveenkumar, General Manager at Parry Agro Limited, who shared his perspectives on and motivations for supporting ecological restoration. The day ended with a lecture and interactive session led by Mr. M M Venkatachalam, which focused on improving engagement with plantation companies and other corporate groups for conservation.



**Day 4 – Research and monitoring, and participant presentations**

The forenoon of day 4 was spent in the field discussing the role of research and monitoring within restoration projects, and introducing participants to basic field techniques for mapping, photographic monitoring and vegetation sampling. Manjunatha H Chandregowda, a researcher with NCF, also delivered a lecture on soil processes, functions and monitoring. The afternoon and evening sessions were dedicated to presentations by the workshop participants, who discussed their ongoing or planned restoration projects, incorporating into their presentations concepts, frameworks and techniques learned during the workshop.



**Day 5 – Data management and analysis**

A session on data management and analysis was organised as a follow up to the field data collection exercises of the previous day. Participants were introduced to basic GIS techniques, spreadsheet management and simple data analyses. There was also a session on forums and resources, focusing on sources and platforms containing various kinds of information relating to ecological restoration and monitoring. The workshop ended with a feedback session during which participants shared their thoughts on what they had gained from the workshop, and ideas for improvement in the future.



## **Feedback and future direction**

All the participants expressed their overall satisfaction with the workshop, and said that it helped to improve their understanding of ecological restoration, particularly in the context of their own conservation and restoration projects. Participants appreciated the emphasis given to field visits and hands-on training, as well as the sessions devoted to ecological research and monitoring. A few participants said they would have liked the workshop to focus a bit more on stakeholder engagement, including, for example, involving forest administrators in some of the sessions. Others felt it would be useful to include sessions on communication and outreach, given that garnering wider support is often a key challenge faced by ecological restoration projects. There was strong agreement regarding the utility of the current workshop, and many participants underscored the need for organizing similar workshops for other ecosystems and in different parts of the country in the future.

## **Acknowledgements**

### Workshop logistics:

Meenu Nair, Manager, Sinna Dorai's Bungalow

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Naveen Raj, Project Manager, NCF

M Shivakumar, Project Associate, NCF

Thomas, George Travels

Field work logistics and assistance (NCF field staff):

Sathish

Stella

Murthy

Sunddarraj

Vanidas

Ambika

Selvarani

Kumar

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