Rufford Small Grants Project
One-Year Report

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

Principal Investigators: Anand Osuri, Divya Mudappa and TR Shankar Raman

Report date: 28 Feb 2018

Reporting duration: 14 Feb 2017 to 28 Feb 2018

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

1. 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 (≥ 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 $plot^{-1}$)	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^{-1})	293.96 (220.67 - 367.26)	63.98 (21.94 - 106.03)	146.19 (50.28 - 242.09)
Tree species richness (Species $plot^{-1}$)	24.41 (21.78 - 27.04)	8.56 (6.3 - 10.82)	14 (11.8 - 16.2)
Mature forest species richness (Species $plot^{-1}$)	18.35 (16.03 - 20.67)	2.52 (1.3 - 3.74)	4.8 (3.5 - 6.1)
Soil carbon (T ha^{-1})	26.03 (23.74 - 28.33)	24.68 (21.25 - 28.12)	25.62 (22.33 - 28.9)
Soil nitrogen (T ha^{-1})	2.1 (1.89 - 2.32)	2.06 (1.72 - 2.39)	2.13 (1.87 - 2.39)
Plant available N (mg kg^{-1})	22.18 (19.83 - 24.53)	18.2 (15.03 - 21.36)	18.11 (15.15 - 21.07)
N Mineralization (mg kg^{-1} $week^{-1}$)	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.

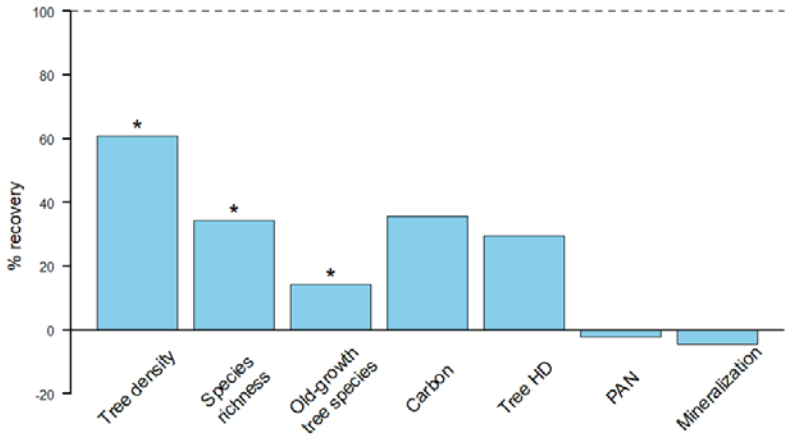

*Figure 1: Recovery of eight ecological attributes under active restoration. Values indicate percent recovery towards benchmark values over passively restored baselines. Indicators that showed statistically significant recovery are marked with **

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.

2. 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 (actively restored, passively restored, Eucalyptus plantation) and two shade treatments (50%, 75%). Two hundred and forty seeds each of three old-growth species (*Artocarpus heterophyllus*, *Knema attenuata* and *Elaeocarpus tuberculatus*) and one secondary forest 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 is currently underway (Feb – Apr 2018) to characterize rainforest tree regeneration patterns within the three habitats.

In the shade-house experiment, seed germination and survival were 14% higher (preliminary result – figures may change) under high than under low shade, while seedling growth rates were 9% higher in the low-shade treatment. Seed germination and survival were unrelated to soil treatments while growth rates

were highest in the UP soil treatment. Species-level responses to soil and shade are currently being examined. **These preliminary results suggest that plantation monocultures might play similar roles as diverse restored forests within the relay floristic framework, at least in terms of enhancing rainforest tree seed germination and growth. Differences in rainforest recovery under these contrasting plantation strategies might still arise due to differences in incoming seed dispersal and other longer- term influences on seedling and sapling mortality.** The results of our ongoing plot-based study will likely provide insights connecting our experimental findings to other factors shaping rainforest regeneration and improve understanding of tropical forest relay floristic dynamics under monoculture tree plantations and ecologically restored forests.

Figure 3: The shade house experiment in progress

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 uploaded separately under the name

"Restoration workshop report".

Pending Tasks

- Completion and submission of scientific manuscript on forest and soil recovery in ecologically restored rainforests. The first draft of the manuscript is nearly complete and we are targeting submission to a high quality international peer-reviewed journal in the applied ecology field by May 2018.
- Completion of field plot sampling of tree regeneration in actively restored, passively restored and Eucalyptus plantation forests. This task got delayed due to a number of reasons including unseasonal rain during end-2017, and is now slated for completion by April 2018. Once completed, these plot data and data from the soil and shade experiment will be developed into a scientific manuscript on the factor governing natural regeneration and recovery of rainforests on deforested and degraded lands. The target date for submitting this manuscript to a high quality international journal with a restoration or vegetation science focus is December 2018.
- A project report that summarizes key research findings in a semi-technical format is being prepared. Stakeholder specific versions of this report will be submitted to forest administrators and plantation company owners by August 2018.
- An artistic poster showcasing various aspects of tropical rainforest ecology and restoration is in preparation. It will be displayed at the Anamalai Nature Information Centre.

Expenses Statement

S No.	Budget head	Sanctioned amount	Expended (Jan 2018)	Remaining
1	Project research assistant salary	£2,734.00	£2,495.52	£238.48
2	Field assistant salary	£2,760.00	£2,304.48	£455.52
3	Accommodation and utilities	£281.00	£286.57	-£5.57
4	Vehicle hire	£2,070.00	£2,005.97	£64.03
5	Travel and transport	£442.00	£371.00	£71.00
6	Field equipment	£140.00	£139.19	£0.81
7	Consumables	£143.00	£89.43	£53.57
8	Soil elemental analysis	£347.00	£278.35	£68.65
9	Workshop	£844.00	£597.92	£246.08

10	Publications	£150.00	£0.00	£150.00
11	Office costs/communication	£76.00	£31.71	£44.29
	Total	**£9,987.00**	**£8,600.14**	**£1,386.86**

Acknowledgements

We gratefully acknowledge valuable contributions made by project assistants K Srinivasan and Mrinalini Siddhartha, and field assistants Ambika, Kumar, Murthy, Satish, Selvarani, Sunderraj, Vanidas and Vijaykumar. We thank the Tamil Nadu Forest Department for granting research permits to work within the Anamalai Tiger Reserve. The support and encouragement from our partner plantation companies, Parry Agro Industries Ltd., Tata Coffee Ltd. and Tea Estates India Ltd., has been highly beneficial for our work. We are grateful to Rufford Small Grants Foundation for primarily funding this work, and also acknowledge contributions from Parry Agro, Nilekani Philanthropies, Science and Engineering Research Board (Govt. of India), Arvind Datar and T R Rajagopalan.