The restoration and monitoring of important wildlife habitats in southern India impacted by *Lantana camara* invasion

(*Original project title*: Forest restoration meets community development - converting *Lantana camara* into fuel briquettes for indigenous communities)

INTERIM PROJECT REPORT
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Submitted by

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The original proposal sought funds for the removal of uprooted Lantana from restoration sites, and the use of machinery to convert this 'waste' Lantana into trial fuel briquettes for the local indigenous community. However, this proposal was subsequently modified to support the monitoring of native forest vegetation recovery (response) following the uprooting of Lantana from 1-ha experimental plots. The restoration of Lantana-invaded forest and subsequent forest recovery monitoring is a 3-year project that has received support from various sources, one of which is the Rufford Foundation. The project consists

of two phases, which are described below (the Rufford Small Grant supported year 2 of the project which consisted of monitoring recovering vegetation):

Phase I — Experimental set-up, Lantana removal, and baseline vegetation data
Supported by the US Fish and Wildlife Service

In February 2014 (prior to this Rufford grant), my team and I initiated a 3-year restoration experiment to (a) assess the costs and constraints associated with landscape-scale Lantana eradication in order to develop a science-based regional invasive species management protocol, (b) describe patterns of native plant recovery following Lantana removal in order to understand the role of invasion (and management interventions) in shaping forest dynamics, and (c) assess rates of recolonization by Lantana from the seed-bank, in areas from which it has been uprooted.

We selected 15 sites, across Bandipur Tiger Reserve in southern India, for locating 1-ha plots for this experiment— at each site we demarcated one 1-ha (100 m × 100 m) plot, for a total of 15 experimental plots. Around each plot we created a 5-m-wide buffer, wherein we cleared ground vegetation, to act as a firebreak in the dry months. Ten of these sites are in heavily-invaded forest, where Lantana abundance exceeds 3 kg/m^2 (dry, above-ground biomass), and were randomly assigned to either treatment (Lantana removal) or control (Lantana left untouched) groups. The remaining 5 plots are located in uninvaded forest where Lantana is absent and tall-grass (*Themeda* spp) is the dominant understory species. These uninvaded plots provide a baseline against which to compare understory community change in the restoration and control plots.

Prior to uprooting Lantana (which was determined to be the most effective way of removing the shrub, based on a 2012-13 pilot study funded by the Critical Ecosystem Partnership Fund) we also completed the first round (before restoration) of extensive forest vegetation quantification – tree structure and composition, including placing dendrometer bands on a sample of trees in each plot, as well as understory (tree regeneration, herbs, shrubs and grass) structure and composition. Our vegetation surveys sampled different classes of vegetation at different scales:

(1) Trees: measuring tree growth by taking dendrometer band measurements at 1.3 m above the ground, is a sample of trees across the 1-ha plot.
(2) Tree saplings: the number, species and height of all tree saplings within 5m × 5m plots distributed systematically across the 1-ha plot
(3) Adult forbs: the number and species of all herbs and shrubs above 50 cm in height in the same 5m × 5m plots used to sample tree saplings
(4) Tree seedlings: the number, species and height of all tree seedlings within 1m × 1m quadrats located within 5m × 5m plots (4 quadrats per plot).
(5) Forb seedlings: the number, and species all forb seedlings within the 1m × 1m quadrats
(6) Grass: The percent cover and height of grass (3 random heights taken and averaged for a quadrat-level average) in each 1m × 1m as well as whether tall-grass is present
(7) Exotic plants: The number of seedlings of exotic plants including Lantana, *Eupatorium odoratum*, *Parthenium hysterophorus* and *Ageratum conyzoides*.

Phase II — Long-term forest recovery monitoring
Year 1: supported by the US Fish and Wildlife Service
Year 2: supported by the Rufford Foundation

After uprooting all Lantana from the selected five 1-ha Restoration plots, we initiated a multi-year vegetation recovery monitoring programme, which consists of four main activities:

1. Adult tree growth — Every three months (February, May, August, and November) we monitor changes in adult tree girth (an index of adult tree growth and carbon storage) as a response to Lantana removal.
2. Understory vegetation recovery — Every six months (May and November of each year), we quantify the abundance, size, and species composition of regenerating native understory plants, according to the same protocol used to collect baseline vegetation data (described above).
3. Weeding exotic plants — These biennial rounds of vegetation recovery data field work also included the counting and weeding of ALL seedlings of Lantana, and other exotic species (including *Eupatorium odoratum*, *Parthenium hysterophorus*, and *Ageratum conyzoides*) from Restoration plots.
4. Plot maintenance — For the two months just preceding the biennial vegetation recovery monitoring, all experimental plots are checked for missing plot, transect, and quadrat markers, and tree tags. Other plot upkeep, such as clearing access paths to them, and maintaining the 5-m-wide fire buffer created around all 15 plots (to minimize the risk of losing our experimental plots to forest fires that are common in the dry season) are also conducted during these 2-month maintenance periods.

Year 1: supported by the US Fish and Wildlife Service:
Baseline vegetation data were collected in May 2014, Lantana was uprooted between May and September 2014, the first two rounds of tree growth data collection were conducted in August and November 2014, respectively, and the first round of understory vegetation recovery monitoring was conducted in November 2014, with support from the USFWS. The weeding of exotic plants and plot maintenance during this period (February – November 2014) were also supported by the USFWS.

Year 2: supported by the Rufford Foundation
The Rufford grant was raised to support the second year of the forest restoration and monitoring project consisting of the following timeline (their completion status - 'Complete' or 'To Be Completed' – TBC – are also provided):

Year	Month	Adult tree growth	Understory vegetation recovery	Weeding of regenerating exotic plants	Plot maintenance
2014	December				
	January				
	February	Complete			
	March				Complete
	April				Complete
	May	Complete	Complete	Complete	
2015	June				
	July				
	August	Complete			
	September				Complete
	October				TBC
	November	TBC	TBC	TBC	

INTERIM RESULTS

Thus far, we have understory vegetation recovery data from three rounds of sampling – May 2014 (at time zero, just prior to the removal of Lantana), November 2014 (six months

after Lantana was uprooted from the Restoration plots), and May 2015 (one year after restoration was initiated). These data were collected with support from both the USFWS as well as the present Rufford Small Grant.

Understanding patterns of understory community recovery and re-assembly following disturbances, such as invasion and/or the removal of invasive species, requires long-term data that subsume the effects of variables such as seasonal precipitation. The data that we have collected thus far are too limited to provide us with a reliable picture of the patterns that are likely to succeed the large-scale uprooting of Lantana. Nevertheless, in order to provide some sense of the native understory recovery trajectory that is unfolding within each of our plot types, we present some salient observations from our preliminary analyses [**Note**: the dendrometer data are yet to be analyzed because the dataset that we currently have is yet too limited to provide any meaningful information on patterns of tree growth in post-Lantana-removal scenario]:

1. The uprooting of Lantana, followed by the weeding of Lantana seedlings (emerging from an extensive seed-bank), appears to be correlated with increased tree seedling density.
2. Mean tree seedling height, however, does not appear to be related to any type of treatment.
3. One year after Lantana was uprooted, the species composition of the tree seedling community appears to resemble that in the Uninvaded plots, more closely than that in either the Control plots, or in the Restoration plots at the start of the experiment.
4. Tree sapling density is significantly higher in the Uninvaded plots, in all seasons, than the Control and Restoration plots, which are similar to one another, as expected; uprooting Lantana may have had a small negative effect on the density of tree saplings (in Restoration plots) by opening up the dense understory, and exposing saplings to greater herbivory by elephants and ungulates.
5. Tree sapling height, appears similar across all three types of plots, and does not seem to be linked to the presence/removal of Lantana.
6. The removal of Lantana does not appear to have had an effect on the species composition of the tree sapling community, other than an increase in the proportion of *Diospyros montana* (DIOMON) after one year. As expected, the diversity of the tree sapling community is much greater in the Uninvaded plots than in either Restoration or Control plots.
7. The uprooting of Lantana appears to have triggered a large increase in grass cover (% of the plot covered by grass) within just the first 6 months, with Restoration plots having greater grass cover, both in November 2014 and May 2015, than (a) Control plots, and (b) Restoration plots prior to Lantana removal.
8. As with the case of tree saplings, the height of grass was not related to Lantana removal, but was similar across Control and Restoration plots. However, Uninvaded plots had much taller grass than the other two types of plots, likely a function of grass being able to achieve greater heights in the long-term absence of a restrictive Lantana 'ceiling'.
9. Finally, the occurrence of tall grass in each plot does not yet appear to be influenced by the removal of Lantana– the recolonization of the understory by this dominant native species (*Themeda cymbaria*, primarily), which was shaded out by Lantana, is likely to take much longer than the time-frame within which these data were collected.

Project completion

Short-term — The last round of data collection – November 2015 understory vegetation, exotic plant and tree growth data – has had to be postponed to December 2015-January 2016 due to various bureaucratic delays that we are in the process of resolving. The

remaining funds will be used to complete this last proposed field session. Results drawn from the up-to-date dataset, that includes this last season of data, will be provided in the final report, to be submitted by the end of February 2016. A summary of project expenditure from the Rufford Small Grant is provided below:

Category	**Amount (INR)**	**Amount (GBP)**[1]
Salaries & Wages	146850	1528.49
Per diem field expenses	9360	97.42
Transportation & Travel	12092	125.85
Field vehicle maintenance	73659	766.68
Fuel for field vehicle	10700	111.37
Field supplies and utilities	1259	13.10
TOTAL	**253920**	**2642.93**
Grant received	474899	4943
Balance	220979	2300.07

[1] The exchange rate at the time of receiving the grant (1 GBP = 96.07506 INR) was used.

Long-term — Additional funds have been raised to complete the proposed 3-year monitoring programme. By February 2017 this restoration project will be concluded, and management recommendations for controlling and mitigating Lantana invasion in these heavily invaded southern Indian deciduous forest landscapes (also critical wildlife habitats) will be submitted to the concerned government agencies. Additionally, if we are successful in raising long-term funding support for ongoing forest recovery monitoring, we will continue collecting biennial vegetation data.