CEPF SMALL GRANT FINAL PROJECT COMPLETION REPORT

Organization Legal Name:	Madras Crocodile Bank Trust
Project Title:	Restoration of *Lantana camara*-invaded deciduous forests in Mudumalai Tiger Reserve
Date of Report:	*28 February 2013*
Report Author and Contact Information	**Ayesha Prasad** – *ayeshaprasad@gmail.com - +91 99806 20201*

CEPF Region: Western Ghats and Sri Lanka Region.

Strategic Direction: 1

Grant Amount: $ 19,958.04 (Dollars Nineteen Thousand Nine Hundred Fifty Eight and Four cents only)

Project Dates: 1st Dec 2011 to 28th Feb 2013

Implementation Partners for this Project (please explain the level of involvement for each partner):

Madras Crocodile Bank Trust — *Host organization and administrative partner*: (1) Managed grant money including disbursement of funds for salaries and field expenses, accounting, and financial reporting, and (2) Assisted in the procurement of research permits

National Centre for Biological Sciences — *Host organization and research partner*: (1) Assisted in raising additional support (2) Advised research (3) Provided funds for renovation of field research stations, and (4) Provided laboratory and office infrastructural support

Tamil Nadu Forest Department — *Field collaborator*: (1) Provided input regarding the design and implementation of field work, and (2) Contributed ideas (including expression of management/ conservation needs) towards future work.

Conservation Impacts

A. Please explain/describe how your project has contributed to the implementation of the CEPF ecosystem profile.

The completed project is the crucial first step in the fulfillment of IP 1.3 of SD 1 of the Western Ghats profile - "*Support civil society to establish partnerships with state agencies to implement science-based management and conservation of priority sites in the Mysore-Nilgiri corridor"*. In meeting its objectives it has provided the information required to develop and implement a long-term, landscape-scale project for controlling invasive plant species, mitigating their extant impacts, and restoring invaded habitats to native species-dominated forest in CEPF priority sites. The removal of invasive plants and the restoration of native communities is a salient objective of state agencies, and features prominently in their official management plans. By working in close consultation and co-operation with the Tamil Nadu Forest Department, the local state agency, we have successfully initiated a long-term habitat improvement study focused on the conservation of native biodiversity in CEPF priority sites in the Mysore-Nilgiri corridor of the Western Ghats.

B. Please summarize the overall results/impact of your project against the expected results detailed in the approved proposal.

Expected result (1) A map of invaded sites for *Lantana* removal and restoration

ACHIEVED
Please see Appendix 1 for map. Sites of the completed *Lantana* removal experiment are also shown (in blue).
Most of the dry deciduous forests of Mudumalai are invaded by Lantana. Therefore, uninvaded patches are not only limited in area but are also located far from the selected restoration sites, often in different forest types. The three sites we selected were the only sites that were located in the same forest type, as well as near our restoration sites, thus under similar ecological and anthropogenic influences as the restoration sites.

Expected result (2) Parameters associated with implementing the CRS and other techniques in MTR - e.g., rate of re-sprouting from root (if any), and cost of implementing CRS in MTR.

PARTIALLY ACHIEVED
The CRS method could not be tested in Mudumalai because the growth form of *Lantana*, in most places, is extremely dense and knotty, and severing the root stock below the soil is not possible without first clearing away all aboveground-stems, and exposing the main shoot. This effort translates approximately to the method by which the plant is uprooted in this region, i.e., removing the shoot, and excavating the root stump using a hoe. As simple uprooting proved faster and easier, we tested the efficacy of uprooting versus cutting (which is the method usually employed by the state agency when clearing *Lantana*). The reasons for carrying out the study in areas with moderate-dense and dense Lantana are:
(a) Most of the invaded forest in Mudumalai is heavily invaded. There are few areas that are sparsely or moderately invaded so these sites do not represent the typical invasion scenario in the study landscape.
(b) We assumed that heavily invaded sites would benefit the most from restoration. Therefore, we carried out an experiment the results of which would directly feed into landscape-scale restoration of heavily invaded areas.
(c) Time and resources were not adequate to carry out the experiment across all three levels of invasion severity, so we picked the most feasible approach.

We found that overall starting *Lantana* biomass was higher in moist deciduous forest (MDF) when compared to dry deciduous forest (DDF). Further, at the end of one year, plots where we had uprooted *Lantana* had no re-sprout from stock (all root stocks were removed), compared to plots where we had cut *Lantana* but left the root stock in the ground. Across forest type, in plots where *Lantana* had been cut, the biomass of *Lantana* re-sprouted from root-stock was over 50% that of initial biomass in those plots, indicating that cutting *Lantana* is not the way to eradicate it. Uprooting is the best way to permanently kill adult individuals, especially in this landscape. The researcher has interacted with people carrying out the CRS method in Corbett Tiger Reserve. While their technique and findings are clearly novel and important, they are NOT a broad-spectrum solution to the problem of Lantana invasion across India. The success of invasive species management and control depends on several factors including the severity of the invasion, the nature of the species concerned as well as site-specific conditions. Therefore, what works well in one system or landscape need not work in another. Where Lantana is moderate or sparse in the forests of the Mysore-Nilgiri Corridor, the CRS technique can and WILL be applied, but the researcher's decade-long experience in these forests suggests that it is not likely to work well in heavily invaded areas. Moreover, uprooting essentially does what CRS does in one key aspect – it removes the aggressively resprouting section of the main tap root. It is acknowledged that uprooting might result in higher germination of Lantana when compared with the CRS. However, this problem may be solved by weeding germinating seedlings, till such time as the native understorey can re-establish, and suppress further Lantana germination.

We also found that MDF had higher *Lantana* germination (as indexed by *Lantana* seedling density in each season; seedlings were removed at each season after counting) than DDF. Furthermore, despite some variation in germination between *Lantana*-cut and *Lantana*-uprooted plots, at the end of one year, *Lantana*-uprooted plots had higher germination. This is likely because *Lantana* is shade-intolerant, and in plots where *Lantana* was cut, rapidly re-sprouting *Lantana* shades the ground reducing the germination of *Lantana* seed. *Lantana*-uprooted plots, however, have no re-sprouting *Lantana*, and within one year have little native vegetation also, and hence *Lantana* seeds are able to germinate better in the absence of shade. The solution that we propose is to carry out at least 3 rounds of weeding *Lantana* seedlings (>10 cm in height because these are easy to find in a plot with regenerating native vegetation) until recovering native plants provide the shade required to suppress *Lantana* germination.

See Appendix 2 for detailed results.
Where the CRS method can be used, that will be recommended. Where Lantana is too dense, and the CRS technique becomes too tedious, simple uprooting will be recommended. Regardless of the method used to kill and remove the adult plant, what is clear from this study, and what will be strongly recommended to managers, is that removal and restoration cannot be a one-time operation. Rather, it requires weeding, secondary removal in some cases, and long-term forest recovery monitoring to determine whether restoration interventions are working.

Expected result (3) Profile of native tree and understory communities in *Lantana*-free forest including data on structure, abundance and composition of trees, tree saplings and seedlings, understory herbs and shrubs, and grass

ACHIEVED – *please see Appendix 2 (Table 1 and Figure 4-6) for detailed results*

Expected result (4) List of the 5 most common understory plants across all plots.
ACHIEVED – While there was quite a bit of variation in the common or dominant native understorey plants in un-invaded (*Lantana*-free) plots, the 4 species that were found in all sampled plots (n=3) were *Grewia hirsuta*, *Argyreia cuneata*, *Indigofera cassioides*, and *Desmodium triquetrum*. *Please see Appendix 2 for detailed results.*

Expected result (5) Names of 3 understory plant species to be used for assisted regeneration.
Expected result (6) Seed pellets to be re-introduced for large-scale restoration.

NOT ACHIEVED
The Tamil Nadu Forest Department, who have carried out several attempt to plant native species in degraded and burned areas, strongly advised us against planting of any kind. Based on their past experience the emphasized that high herbivore densities in these forests made planting futile – planted saplings are very quickly browsed and do not survive long. Thus, rather than waste time and resources in developing seed pellets or saplings for planting, we were advised to simply allow natural regeneration to occur in cleared plots, in addition to the sowing of tall-grass (*Themeda* spp.) seeds. So, we followed their advice and did not harvest native forb seeds or prepare seed pellets. We sowed tall grass seeds at the onset of the monsoon and monitored natural native plant recovery, the results of which are given in detail in Appendix 2.

Expected result (7) Guidelines for landscape-scale work to restore *Lantana*-invaded forest

ACHIEVED
See Appendix 3 for detailed guidelines for the long-term restoration of *Lantana*-invaded MDF and DDF in Mudumalai.

Expected result (8) Better understanding of the role of native plants in *Lantana* invasion

NOT ACHIEVED
This is a result which can be achieved only through long-term monitoring. Consequently, at the end of this short, 1-year study we have not been able for draw conclusions regarding how the structure, abundance and composition of native plants might influence *Lantana* invasion. We hope to be able to understand these patterns and processes better during the course of long-term (multi-year) vegetation monitoring.

Expected result (9) trained field staff for *Lantana* removal, restoration and monitoring

ACHIEVED
Despite several changes to the field team and personnel-related challenges, at the end of one year we are fairly confident that the local indigenous youth who currently work with us will continue long-term. These three individuals have quickly learned to identify (in Latin) and measure forest plants and shown both interest and aptitude towards improving their quantitative skills. These youth have also promised to help recruit others to join the work and are committed to doing good research. They are also key players in drawing the local community (from which they also hail) into long-term monitoring and conservation in the region.

Expected result (10) greater synergy between scientists and managers

ACHIEVED
The field staff and officers of Mudumalai Tiger Reserve have been very helpful in the implementation of this project. We extended a hand of partnership to them in interacting with them as project collaborators, seeking their advice on various field aspects of the work, and keeping them closely aware of our work at every stage. Consequently, they have not only extended support but also seem interested in participating in the implementation of the long-term work, and have committed to providing logistical help as well. We believe that this partnership will prove critical to the science-based, sustainable restoration of these invaded forests, and the management of various habitat-level factors, such as clearing and fire, that are likely to influence it.

C. Please provide the following information where relevant: Not relevant

Hectares Protected: NIL

Species Conserved: NIL

Corridors Created: NIL

D. Describe the success or challenges of the project toward achieving its short-term and long-term impact objectives.

Objective (1) To identify sites distributed across MTR (~320 km^2) within which to remove *Lantana* (clearing sites), together with the nearest *Lantana*-free sites to serve as 'control sites'

Success – see Appendix 1 for map of these sites.
Challenge – Post-identification 2-3 of these sites were badly burned. New sites will, therefore, be selected to replace the lost ones.

Objective (2) To test the efficacy of a recently developed *Lantana* removal technique (Cut Root Stock or CRS method; Babu et al 2009) in the MTR forest system.

Success – Partial.

Challenge – This technique was found to be impractical for the form of *Lantana* found in the study area. Instead, uprooting, was tested and found to be significantly more effective in killing adult *Lantana* in comparison with cutting.

Objective (3) To describe the structure and composition of native tree and understory communities in *Lantana*-free forest (template for restored communities).

Success – See detailed results section for profile of native vegetation in uninvaded forest.
Challenge – *Lantana* has invaded vast tracts of these forests leaving very few patches of uninvaded forest. Locating these patches was challenging, and we were unable to find one uninvaded site for every invaded proposed restoration site.

Objective (4) To identify 5 of the most common understory plants (in addition to the tall grass *Themeda cymbaria*) for assisted regeneration.

Success – The 5 native understorey species that were found most frequently in uninvaded forest are *Grewia hirsuta*, *Argyreia cuneata*, *Indigofera cassioides*, *Desmodium triquetrum*, and *Grewia orbiculata*
Challenge – none

Objective (5) To harvest seeds of these five species to be prepared as seed-pellets for introduction into clearing and control sites.
Objective (6) To determine germination/regeneration rates of each of the 5 understory species and tall grass in plots from which *Lantana* has been removed using the CRS technique, and identify 3 species of understory plants with the highest germination and survival rates for planting post-removal.

Success – Objectives 5 and 6 were not met because it was decided that native species should not be planted (see section A under Conservation Outcomes for explanation)

E. Were there any unexpected impacts (positive or negative)?
No

Lessons Learned

F. Describe any lessons learned during the design and implementation of the project, as well as any related to organizational development and capacity building. Consider lessons that would inform projects designed or implemented by your organization or others, as well as lessons that might be considered by the global conservation community.

None

G. Project Design Process: (aspects of the project design that contributed to its success/shortcomings)
One aspect of the design of the project that failed was the introduction of tall-grass seeds to cleared sites. None of the seeds that were sown germinated. This is because either we harvested them too early and the seeds were not yet mature or we harvested them too late so that only husks were harvested with the seed having already dropped. A study that looks at the germination of tall grass seeds will shed important light on when to harvest tall-grass seeds for native species assisted regeneration efforts.

H. Project Implementation: (aspects of the project execution that contributed to its success/shortcomings)

The identification of invaded sites for long-term restoration should have been carried out after the fire season. 3 of the sites identified in February 2012 burned in March 2012. Immediately prior to restoration in 2013, a few new sites will need to be identified.

I. Other lessons learned relevant to conservation community:
None

ADDITIONAL FUNDING

J. Provide details of any additional donors who supported this project and any funding secured for the project as a result of the CEPF grant or success of the project.

Donor	Type of Funding*	Amount	Notes
United States Fish & Wildlife Service – Asian Elephant Conservation Fund	A	36097 USD	

****Additional funding should be reported using the following categories:***

- ***A*** *Project co-financing (Other donors contribute to the direct costs of this CEPF project)*
- ***B*** *Grantee and Partner leveraging (Other donors contribute to your organization or a partner organization as a direct result of successes with this CEPF project.)*
- ***C*** *Regional/Portfolio leveraging (Other donors make large investments in a region because of CEPF investment or successes related to this project.)*

Sustainability/Replicability

K. Summarize the success or challenge in achieving planned sustainability or replicability of project components or results.

This project was a pilot study to assess the sustainability of different approaches to long-term *Lantana* removal and forest restoration. Based on the results of this first stage experiment, we have designed and raised funds for a landscape-scale experiment to assess the economic viability of clearing Lantana across protected forests. In this upcoming, large-scale project we will use uprooting followed by at least 2 seasons of weeding Lantana seedlings, as the removal technique, and calculate per hectare costs of removing Lantana using this technique.

Most of the Lantana-invaded forests of southern India are Asian elephant habitats. The proposed landscape-scale restoration project, that dovetails with the completed CEPF-funded, small-scale, pilot project (reported here), will seek to determine whether these invaded Asian elephant habitats can be made forage-rich once again. Owing to the critical importance of forage-rich and safe habitats to the conservation of elephants, the USFWS – Asian Elephant Conservation Fund, has come forward to fund the second phase of our project – **the restoration of Lantana-invaded Asian elephant habitats, and long-term monitoring**.

The forest department is yet to realize the long-term adverse effects of cutting Lantana. We hope that as the project progresses, and landscape-scale restoration approaches become clearer, the forest department will start to incorporate science-based restoration, especially vis-à-vis Lantana removal, into their management plans.

L. Summarize any unplanned sustainability or replicability achieved.

None

Safeguard Policy Assessment

Provide a summary of the implementation of any required action toward the environmental and social safeguard policies within the project.

Not relevant

Performance Tracking Report Addendum

CEPF Global Targets

(01 December 2011 – 28 February 2013)

Provide a numerical amount and brief description of the results achieved by your grant.
Please respond to only those questions that are relevant to your project.

Project Results	Is this question relevant?	If yes, provide your numerical response for results achieved during the annual period.	Provide your numerical response for project from inception of CEPF support to date.	Describe the principal results achieved from December 1, 2011 to February 28, 2013. (Attach annexes if necessary)
1. Did your project strengthen management of a protected area guided by a sustainable management plan? Please indicate number of hectares improved.	Yes		96 experimental plots of 25 m^2 each adds up to 0.24 ha	Indirectly, by informing the formulation of habitat-scale restoration experiment that will directly strengthen the management of a PA . See Appendices 1-2 for empirical results of experiment and Appendix 3 for guidelines for the restoration of *Lantana*-invaded forest derived from these results
2. How many hectares of new and/or expanded protected areas did your project help establish through a legal declaration or community agreement?	No	-	-	Please also include name of the protected area. If more than one, please include the number of hectares strengthened for each one.
3. Did your project strengthen biodiversity conservation and/or natural resources management inside a key biodiversity area identified in the CEPF ecosystem profile? If so, please indicate how many hectares.	Yes		Hectares not relevant	Same as Q1
4. Did your project effectively introduce or strengthen biodiversity conservation in management practices outside protected areas? If so, please indicate how many hectares.	No	-	-	-
5. If your project promotes the sustainable use of natural resources, how many local communities accrued tangible socioeconomic benefits? Please complete Table 1below.	No	-	-	-

Additional Comments/Recommendations

Recommendations for future workers on Lantana eradication & native vegetation restoration

1. All restoration efforts that require clearing Lantana should switch, immediately, from cutting to uprooting or CRS.

2. Clearing, by removing the root, is likely to be successful only if it is succeeded by regularly weeding germinating exotic plants, particularly during the rainy season.
3. The limited resources available for restoration might provide better pay-offs if invested in areas where rainfall is relatively high (over 1200 mm per year).

Information Sharing and CEPF Policy

CEPF is committed to transparent operations and to helping civil society groups share experiences, lessons learned, and results. Final project completion reports are made available on our Web site, www.cepf.net, and publicized in our newsletter and other communications.

Please include your full contact details below:

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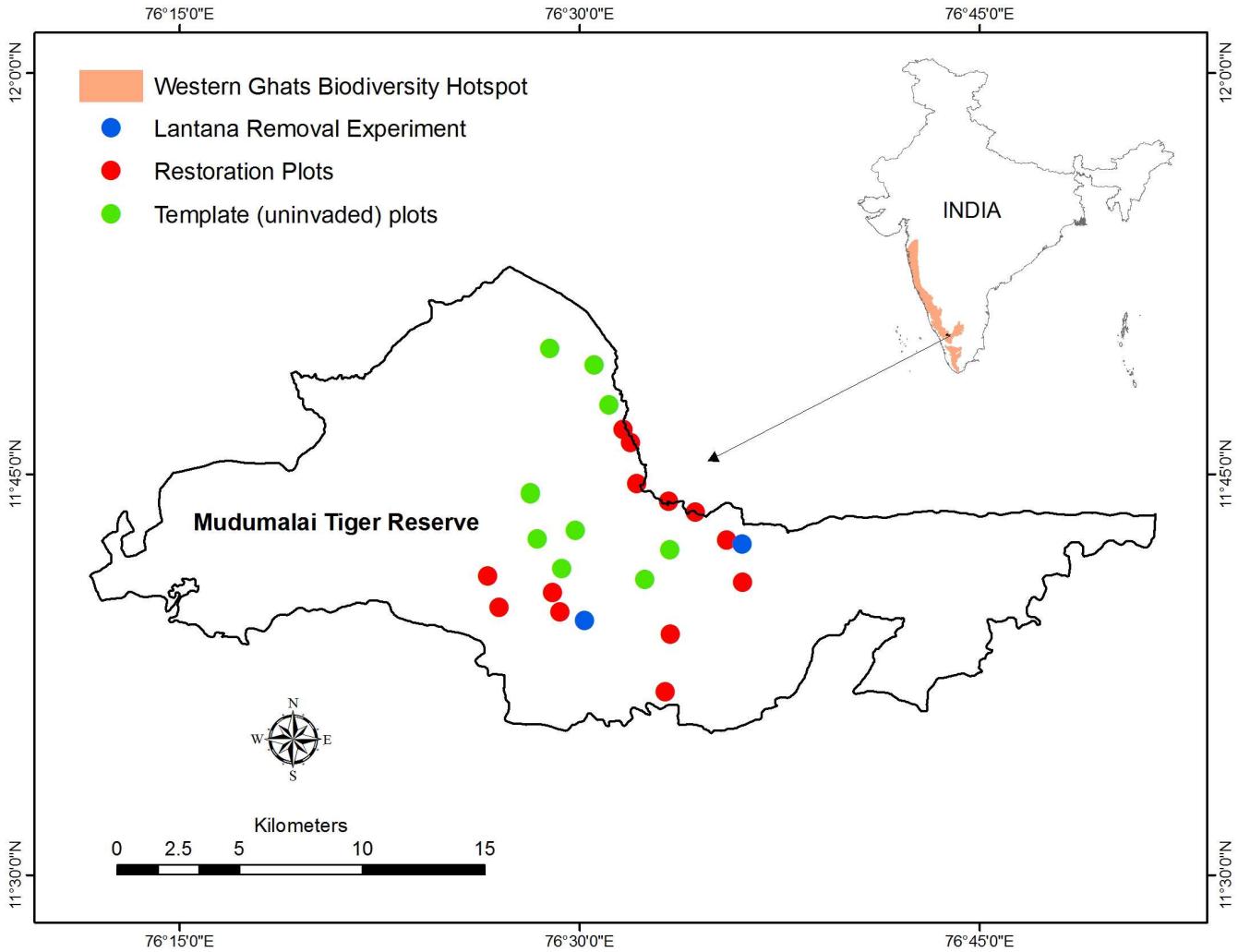
List of Annexures:

1) CEPF final report_Appendix1_Map of restoration sites_MCBT_Prasad
2) CEPF final report_Appendix2_Detailed Results_MCBT_Prasad
3) CEPF final report_Appendix3_Restoration guidelines_MCBT_Prasad

CEPF Final Report – Appendix 1. Map of proposed sites for long-term Lantana removal and native plant restoration



CEPF FINAL REPORT — APPENDIX 2. DETAILED RESULTS

Recolonisation by *Lantana camara*

Moist deciduous forest had not only higher overall *Lantana* biomass at the start of the experiment, but also higher *Lantana* biomass in the uprooted plots at the end of the experiment ($F_{1, 58} = 9.9$, $p < 0.05$; Figure 1). *Lantana* removal 'treatment' method had a significant effect on how much *Lantana* recolonized the plots from rootstock – across forest type, over 40% and 87% of the initial biomass returned to plots in DD and MD forest respectively, over a 1-year period ($F_{1,58} = 82.95$, $p < 0001$; Figure 2).

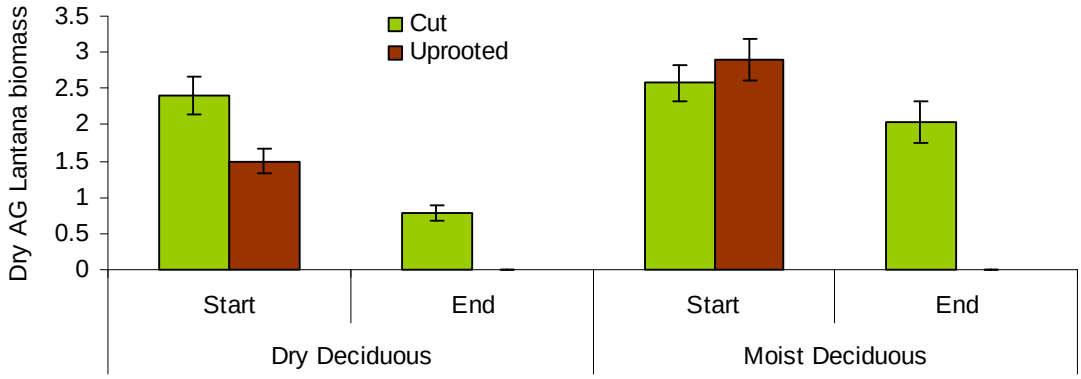


Figure 1. Difference in dry aboveground (AG) biomass at the start and end of the experiment between plots where *Lantana* was cut and those where it was uprooted.

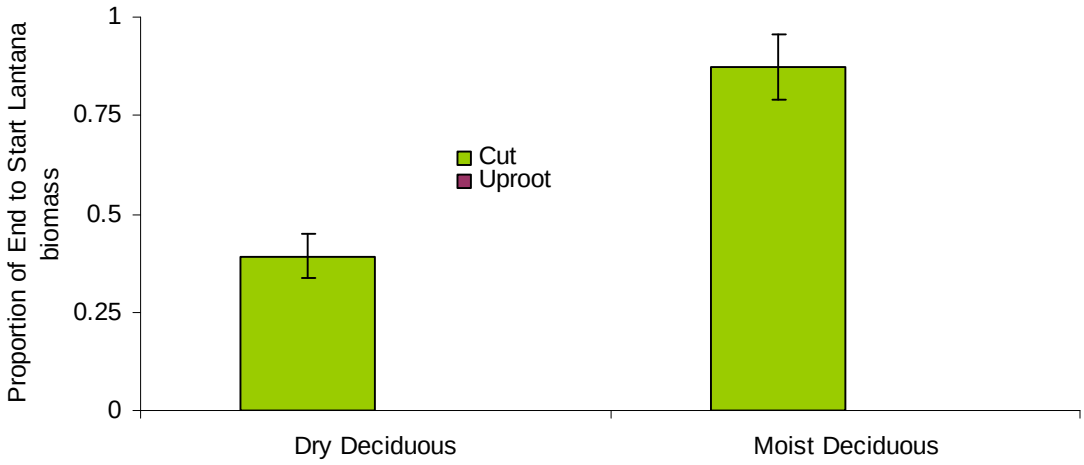


Figure 2. The ratio of final to initial dry above-ground Lantana biomass in dry and moist deciduous forest in plots where *Lantana* was either Cut or Uprooted (n=62)

The number of Lantana seedlings which germinated, overall, was higher in moist deciduous forest ($F_{1, 58} = 9.0748$, $p < 0.05$) and, as may be expected, highest in the wet season across both forest types. ($F_{3, 174} = 55.92$, $p < 0.001$; Figure 3) *Lantana* removal method had no effect on the density of *Lantana* seedlings (Figure 3).

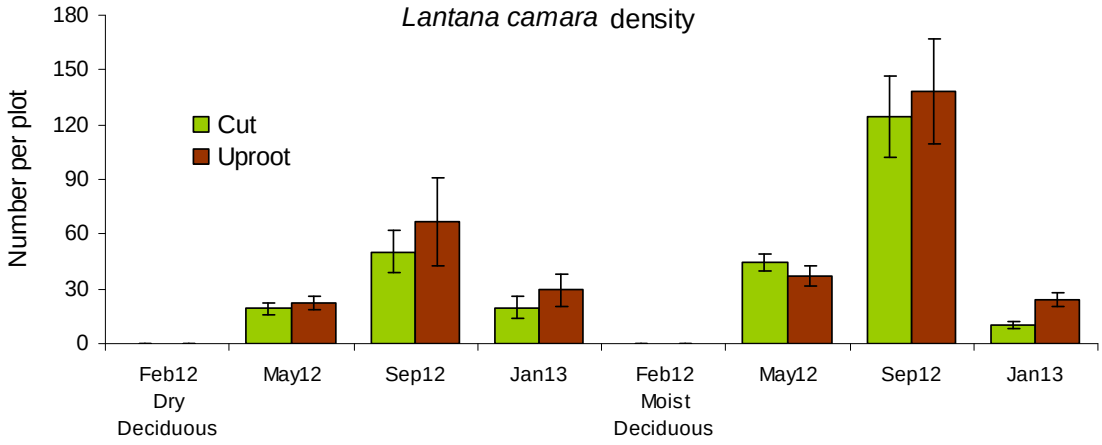


Figure 3. Difference in number of germinating *Lantana* seedlings between plots where it was Cut (aboveground biomass removed), and those where it was Uprooted.

Appendix 2 - Detailed results

Profile of native vegetation in un-invaded (*Lantana camara*-free) plots

Table 1. Summary of various aspects of native vegetation taken at 3 un-invaded sites in Mudumalai Tiger Reserve in March 2012

Plot	T7			T8			T10		
	Mean	SE	Median	Mean	SE	Median	Mean	SE	Median
Tree density (inds/ha)	248.18	60.71	-	229.09	27.37	-	515.45	51.70	-
Tree height (m)	10.87	0.34	-	12.88	0.43	-	10.28	0.44	-
Tree GBH (cm)	70.67	4.67	-	116.50	8.85	-	57.24	2.87	-
Tree basal area (%)	0.11	0.01	-	0.30	0.04	-	0.16	0.01	-
Tree SR	-	-	4	-	-	3	-	-	7
Tree sapling density (inds/ha)	4760.00	628.17	-	1349.09	325.98	-	2672.73	632.53	-
Tree sapling height (cm)	140.55	5.38	-	70.85	2.85	-	143.16	8.27	-
Tree sapling SR	-	-	7	-	-	2	-	-	6
Tree seedling density (inds/ha)	7200.00	1854.72	-	4400.00	1166.19	-	14000.00	5440.59	-
Tree seedling height	20.95	2.02	-	22.06	2.67	-	25.85	3.94	-
Tree seedling SR	-	-	1	-	-	2	-	-	3
Forb density (inds/ha)	1374.55	232.60	-	865.45	157.94	-	458.18	95.24	-
Forb SR	-	-	3	-	-	2	-	-	2
Grass cover (%)	70.80	4.37	-	58.12	5.87	-	57.00	5.46	-
Grass height (m)	0.66	0.07	-	0.44	0.04	-	0.91	0.06	-
Grass volume (m^3/ha)	5015.40	586.24	-	2768.32	440.09	-	5545.00	647.83	-

Adult tree species composition

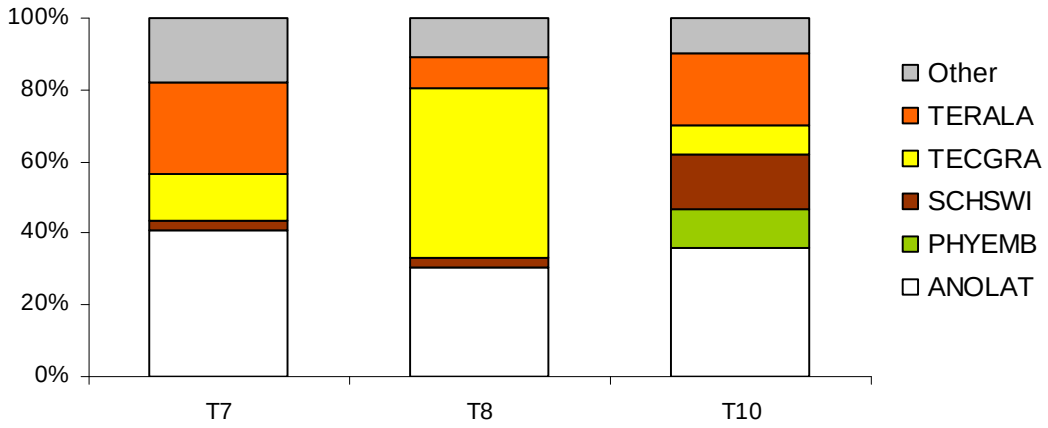


Figure 4. Proportion of species of adult trees in each plot where ANOLAT – *Anogeissus latifolia*, PHYEMB – *Phyllanthus emblica*, SCHSWI – *Schrebera swietenoides*, TECGRA – *Tectona grandis*, and TERALA – *Terminalia alata*. The 'Other' category consists of species with less than 5% contribution to overall number of trees.

Tree sapling species composition

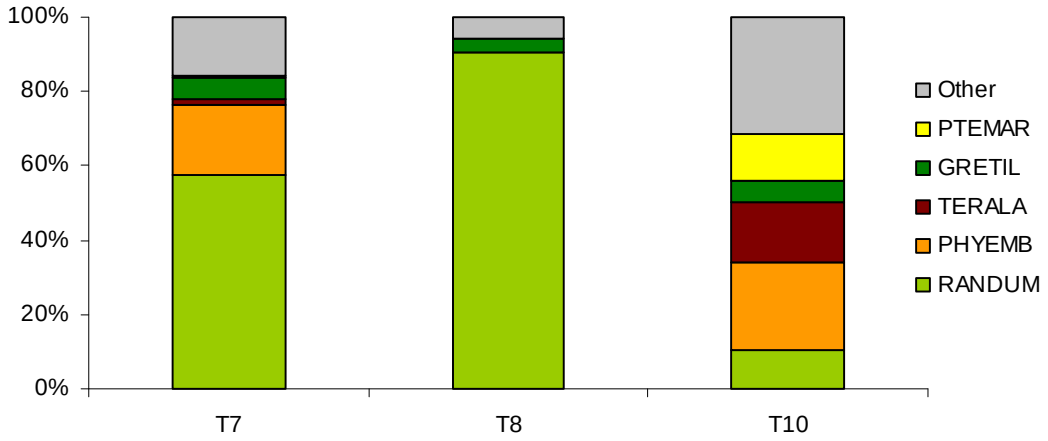


Figure 5. Proportion of species of tree saplings in each plot where RANDUM – Randia dumetorum, PHYEMB – *Phyllanthus emblica*, TERALA – *Terminalia alata*, GRETIL - *Grewia tilaefolia*, and PTEMAR - *Pterocarpus marsupium*. The 'Other' category consists of species with less than 4% contribution to overall number of trees.

Tree seedling species composition

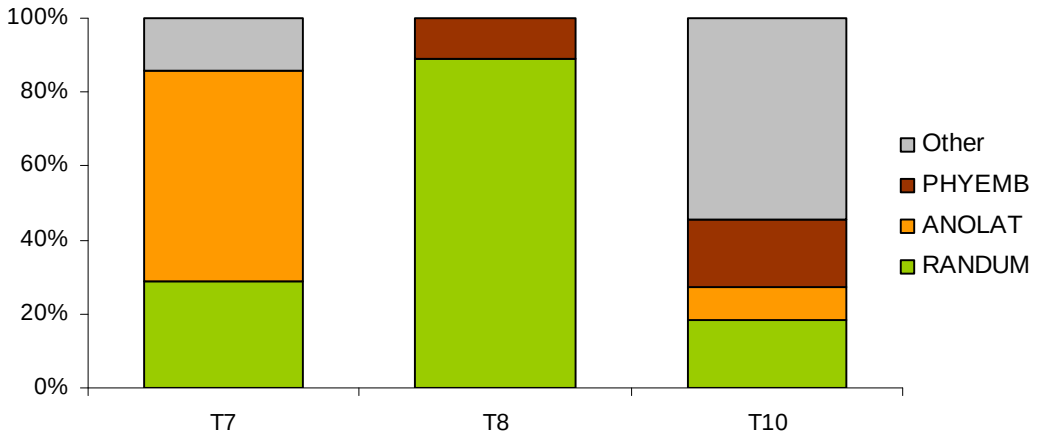


Figure 6. Proportion of species of tree seedlings in each plot where RANDUM – *Randia dumetorum*, ANOLAT – *Anogeissus latifolia*, and PHYEMB – *Phyllanthus emblica*. The 'Other' category consists of species with less than 10% contribution to overall number of trees.

Forb species composition

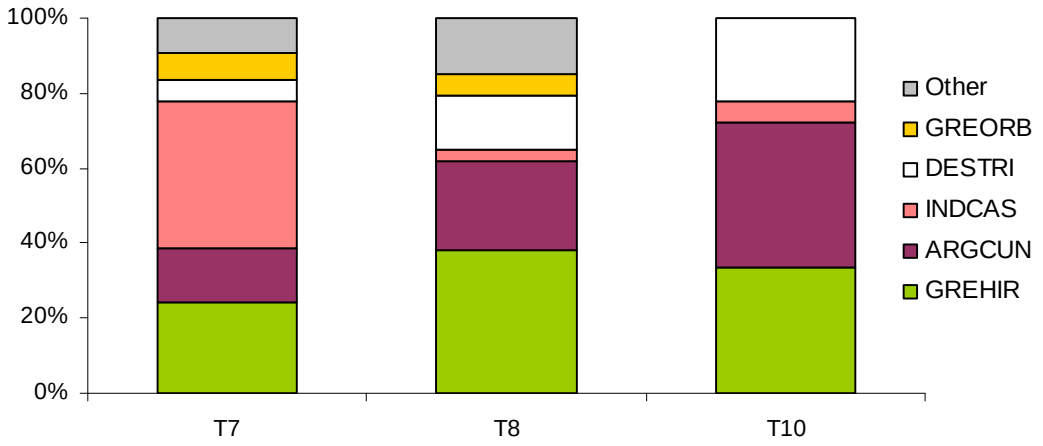


Figure 7. Proportion of species of tree seedlings in each plot where GREHIR – *Grewia hirsute,* ARGCUN – *Argyreia cuneata,* INDCAS – *Indigofera cassioides*, DESTRI – *Desmodium triquetrum*, and GREORB – *Grewia orbiculata*. The 'Other' category consists of species with less than 5% contribution to overall number of forbs.

CEPF final report — Appendix 3. Guidelines for the restoration of *Lantana*-invaded forest

Based on the results of the completed 1-year small-scale study we propose to carry *out landscape-scale, long-term restoration of* Lantana-*invaded forest in Mudumalai according to the following guidelines*. Based on 2-3 years of data from the proposed work we will submit management recommendations to state agencies responsible for habitat management/improvement in CEPF priority sites in the Mysore-Nilgiri corridor region of the Western Ghats. However, state agencies currently interested in trying out restoration according to these guidelines may do so as no harm can be done. The worst outcome will likely be that what was effective at the small scale over a 1-year period will not work over larger temporal and spatial scales, or in more heterogeneous (vis-à-vis vegetation, terrain and climate) landscapes.

LANTANA REMOVAL

Areas with the heaviest invasion (>3 kg/m^2 of dry above-ground biomass) should be priority restoration sites in order to (a) free up impenetrable tracts of forest for wildlife use, (b) reduce the risk of devastating fires, and (c) maximize the biomass of *Lantana* made available for conversion to fuel briquettes for local communities. A fixed number of hectares, distributed across forest with such heavy invasion, must be cleared each year. Gradually, heavily invaded forest will be converted to native species-dominated forest. These sites should preferably be located near roads in order to increase access, and improve logistical feasibility.

***Lantana camara* must be uprooted**. Cutting the shoot does not kill the plant; the cut shoot regenerates to up to 50% of its initial biomass (kg/m^2 of dry above-ground biomass) within one year of cutting.

Uprooting consists of 2 steps

(1) Cutting the shoot and all above-ground parts in order to expose the root stock. This is ideally done in the months leading up to the pre-monsoon rains (between January and April) so that uprooting can be done during and immediately following the rains. Cutting may be done with machetes or power saws.
(2) Uprooting is best done when the ground is wet or damp because *Lantana* tap roots can grow deep and wide and will be very difficult to pull up when the ground is hard. During and immediately after the pre-monsoon rains is best

The weeding of *Lantana* seedlings is important. We recommend 3 rounds of weeding per cleared area per year for the first 2 years, and subsequent weeding as required depending on *Lantana* germination rates. The first round of weeding may be in September after the SW monsoon rains are over. The second round may be in December-January during and after the NE monsoon rains, and the third round during or after the pre-monsoon rains of the following year (April-May). The third round of weeding in existing restoration sites will, thus, coincide with uprooting activities in new sites.

NATIVE PLANT RECOVERY

Tall grass recovery may be facilitated by seeding. At present, we do not have sufficient data to suggest when tall-grass seeds are to be harvested. Trials with seeds harvested at different times in the months leading up to the SW monsoon should reveal the time at which the seeds are most viable. Seeds may then be harvested and sown in restoration sites during uprooting so that seeds are in the soil when the monsoon rains arrive. The establishment of tall-grass (*Themeda cymbaria, T. triandra, Cymbopogon flexosus, and Imperata cylindrica*) in the understorey should reduce *Lantana* recolonisation through shading.

Planting of native species is not recommended for two main reasons. First, the establishment, and maintenance of a nursery as well as actual planting is very time- and resource-intensive. It is not likely to be practical for restoration landscapes several hundred square kilometers in area. Two, the density of large mammalian herbivores is very high in the deciduous forests of the Mysore-Nilgiri

corridor. Herbivory-related mortality rates of planted species will therefore be high rendering plant somewhat futile. Native trees, herbs, and shrubs should be allowed to regenerate naturally. Native plants have historically regenerated within tall-grass-dominated understorey. It is therefore likely that an intact tall-grass understorey will facilitate the natural regeneration of native species.

Fire is an important factor in exotic and native plant colonization and regeneration. Existing data do not suggest how to control or manage fire for restoration in these forests. However, opportunistic field observations and conversation with local indigenous elders seem to link the invasion of tall-grass-dominated understorey by *Lantana* with the mismanagement of fire. It appears that tall-grass understorey, if allowed to burn early in the dry season (December-January), will regenerate with the first rains and remain intact (uninvaded). If, however, fires are suppressed in consecutive years, the inevitable burn that will result will destroy the tall-grass understorey rendering it vulnerable to colonization by *Lantana* whose seeds have been accumulating in the seed-bank. We recommend that while studies to elucidate the role of fire in invasion and the maintenance of native plant communities are underway, currently uninvaded forest be allowed to burn. Heavily invaded forest must, however, be protected from fire so as to prevent long-lasting intense fires that can kill adult trees.