# Management plan for invasive *Lantana camara* using UAV based photogrammetry in BRT Tiger Reserve, Karnataka

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## ABSTRACT:

Lantana camara has been known as an invasive species with heavy impacts on Indian forests. Lantana shows adaptability to a wide range of ecosystems and allelopathic traits which cause loss of vigour in the surrounding forest. BRT Tiger Reserve in Chamrajanagar district has been affected by lantana, with a dramatic increase in the invasion in the last 20 years. This invasion has known to cause harm to biodiversity as well as the indegenous inhabitants of the forest. Lantana is concealed under tree canopy, which affects the accuracy of mapping of lantana by traditional remote sensing methods. This study was conducted using UAVs, capturing overlapping aerial images of the entire reserve. 3D maps were made from these images. Orthoimagery, DEM, Canopy Height Model were extracted at 10cm resolution. Detailed land cover maps with lantana information were made. Other outputs include drainage network and hydrology maps for water conservation, individual tree shapefile with species and height information. The lantana maps were used in creating a 'lantana removal geospatial guide', which incorporated land cover, access and socio economic geodata for management of this invasive species. An attempt was made to add value to extracted lantana, so as to benefit the local ecology as well as economy.

## 1. INTRODUCTION:

### *1.1. Lantana camara* and Indian Forests*:*

*Lantana camara* is one of the top ten invasive species in the world recognised by the Global Invasive Species Network(Sharma, Raghubanshi et al. 2005). In India alone it has been roughly estimated that the invasion is upto 10 million hectares, Lantana being introduced as a single ornamental plant in the Calcultta Botanical Garden by the British in 1809. In the present it mostly thrives in forests, farm and pasture lands all across the country except the Thar desert(Bhagwat, Breman et al. 2012). Impacts of *Lantana camara* on natural and agro-pastoral ecosystems has been studied over decades(Bhatt, Rawat et al. 1994). A study in Bandipur Tiger reserve highlights the vulnerability of forest fringe ecosystems to lantana invasion, where it leads to a drastic increase in tree deaths and alters extant tree community composition(Prasad 2008). Further, Lantana contains Lantadene A and B which are toxins found in high concentrations in the foliage and ripe berries; its ingestion mainly affects the Liver and kidneys and leads to jaundice and severe diarrhoea which may result in death after 1 to 3 weeks of illness and severe weight loss in grazing animal species including ungulates(Hiremath and Sundaram 2005, Barceloux 2008).

### 1.2. Remote Sensing for Mapping of *Lantana camara*:

Lantana has been known to dominate forests in India, hence attempts have been made to map the precise extent and density of invasion using various types of multispectral satellite data and modelling (Kimothi, Anitha et al. 2010, Niphadkar, Ficetola et al. 2016). A study was also done to compare accuracy of lantana mapping using imagery from three different satellites(Taylor, Kumar et al. 2011). Lantana being an understorey species, proves challenging to detect from satellite imagery. High resolution Worldview 2 imagery was used in a study combined with Bayesian networks for lantana mapping in Swaziland, however, the statistical methods were also found to have limitations(Dlamini 2010). Moreover, BRT Tiger Reserve having ten different kinds of vegetation(Ramesh 1989), it is difficult to characterize lantana presence by any one single rule or statistical output. For on-field management of lantana, a high resolution map showing density, extent and access paths is required. Owing to the poor accessibility and rugged topography of the tiger reserve, it is also a challenge to make a complete management plan for such a large area.

## 2. OBJECTIVES:

The main objective of this study was to accurately map the extent, density and access of *Lantana camara* in the entire 575 $km^2$ of forest area using UAVs. Secondary objectives include mapping the native vegetation in fine resolution, mapping fine scale drainage streams and catchments, creation of an individual tree map with species and height information.

## 3. MATERIALS AND METHODS:

This study was conducted as a part of invasive species management program of BRT Tiger Reserve. DJI Phantom 3 professional was used as the UAV for mapping. Pix4Dmapper pro was used for processing and QGIS for analysis.

### 3.1. Study Area:

Biligiri Rangaswamy Temple Tiger Reserve (BRT) is a biodiversity rich area situated in the southern Western Ghats. The extents of the reserve lie between 11° 40′ - 12° 09′ N lat. and 77° 05′. - 77° 15′ E long(Kumara, Rathnakumar et al. 2012). This tiger reserve displays a distinguished topography (with elevations ranging from 620 msl to 1720msl) and ecology and is one of the most iconic tiger reserves in India. Precipitation in the forest varies with elevation with the average being 940mm-1850m(Niphadkar, Ficetola et al. 2016). The last 15 years have seen a dramatic increase in lantana invasion(Mallegowda, Rengaian et al. 2015), and is proving to be a major hindrance in forest management.

### 3.2. Data Collection:

Entire area of tiger reserve (575 $^{km2}$) was divided into 1km x 1km grids for ease of planning. Aerial image acquisition was done using a DJI Phantom 3 professional. Each day, selected grids would be assessed for topography and accessibility. Aerial photographs over each grid would be taken with UAV. The month of March was chosen for commencing aerial survey for the following reasons:

i) Moderate wind conditions, low to no possibility of rain

ii) Lantana bushes are mostly without leaves in deciduous forest, making the distinction between lantana and other vegetation easier.

The flight specifications are as follows:
*UAV name*: DJI Phantom 3 professional
*Flight height*: 50-70m
*Camera angle*: oblique
*Image overlap*: Front 80% side 70%
*Capture app*: Pix4Dcapture for android.
GPS data of lantana density and surrounding tree species was taken per flight as ground truth information.

### 3.3. Data Processing and Classification:

Aerial images were used to produce 3D maps in Pix4Dmapper Pro. Pix4Dmapper is known to use raycloud photogrammetry as opposed to the traditional stereo photogrammetry(Unger, Reich et al. 2014). This software, using the external and internal camera parameters, performs dense matching for creation of a 3D mesh and point cloud(Strecha 2014). The following outputs were exported for further use: Digital Surface Model, Digital Terrain Model, Orthoimage, 3D mesh and Point cloud. The 2D outputs (DSM, DTM and orthoimage) were used for lantana classification.DSM, DTM and orthomosaic had a resolution of 6-10cm (depending on flight height and topography). They were resampled to a standard of 10cm to avoid errors. A Canopy Height Model was extracted by subtracting DTM from DSM using raster arithmetic in QGIS. Object based classification was selected for this study. When it comes to classifying very high resolution data, pixel based classifiers can produce errenous results as well as salt and pepper effect(Kamagata, Akamatsu et al. 2005). Given the extreme heterogeneity of BRT Tiger Reserve and the similarity of lantana with other vegetation, object based classification was found to be best suited for the purpose. The orthoimage and CHM were stacked and segmentation was executed on the data set. Rules were used for each stack for classification. The image was primarily classified into 5 classes: Lantana, Trees, Bamboo, Bare soil, Water. Exceptions were made at locations where any significant presence of other classes was present. Height values from the Canopy Height Model, brightness, layer statistics and texture based algorithms were used for classification. Since lantana has fairly homogeneous texture as compared to the surrounding trees, separation of lantana class was facilitated. Water was easily distinguishable from the brightness values, as was the bare soil class.
Lantana in BRT Tiger Reserve ranged from completely dry twigs to green thickets, which is why independant rule sets had to be developed for each flight area. The resultant classification was initially visually assessed(owing to the high resolution) and exported as shapefiles and raster images.
GPS points of lantana were used for accuracy assessment of the classification.

### 3.4. Tree Delineation

Segmentation process was executed with parameters such that tree crowns were segmented as single objects. Post classification, tree class objects were classified for species using GPS locations of ground truth for training. Height value was assigned as the highest pixel value within the tree object. Finally, a shapefile with each tree's crown boundary as geometry and height and species information was made.

### 3.5. Lantana Information Geodatabase:

Orthoimage classification results were used for building this geodatabase. GIS operations were used to assign each lantana polygon a density class, and information about surrounding vegetation. Roads, walking paths, open areas and slope value was used to assess the accessibility to each lantana patch. Tribal settlements with population information were added into this geodatabase.
Lantana invasion area, access paths to each area and closest tribal settlements were visualised spatially. This geodatabase, with each lantana polygon

containing density, surrounding vegetation, slope, access routes and available labour was used for further management of lantana.

### 3.6. Spatially Planned Lantana Removal:

Lantana camara has been proven to cause severe ecological damages to forest. A removal plan was made so as to assess the impacts of absence of lantana in the forest. The lantana information map was divided into grids and ranges.. Each grid would be visited by forest staff after referring to GPS input, and the start point would be determined depending on local conditions. Tribal people from the nearest settlement would be employed, and removal would be undertaken.

### 3.7. Economic Value for Lantana:

Lantana removal activity requires a significant amount of money given the arduous nature of work and amount of lantana present in the entire reserve. On an average, lantana removal labour costs are at around 37000 INR (568USD) per hectare. It was needed to fetch economic value for extracted lantana to make this project economically sustainable. An agricultural shredder was acquired, which would crush the lantana into coarse powder, which would further be pressed into briquettes, which are used as fuel in various industries. This helped make the whole process endurable, as well as provide a source of income for local people.

## 4. Results:

### 4.1. 3D mesh:

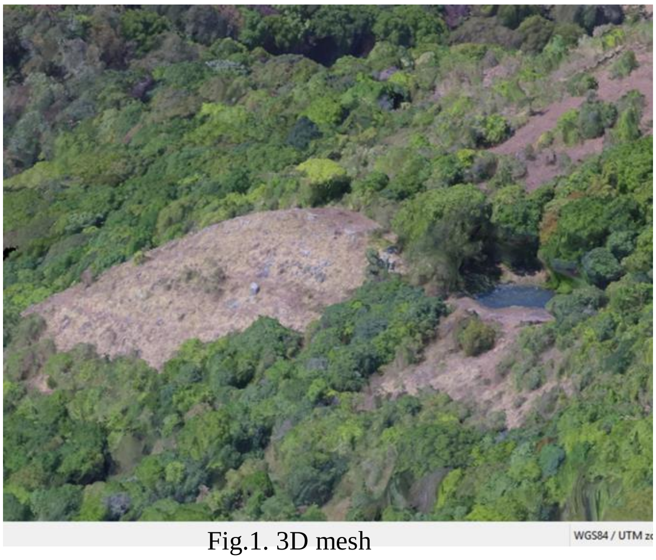

Fig.1. 3D mesh

### 4.2. Othomosaic and DSM

A sample orthomosaic and a Digital Surface Model are shown in Fig.2:

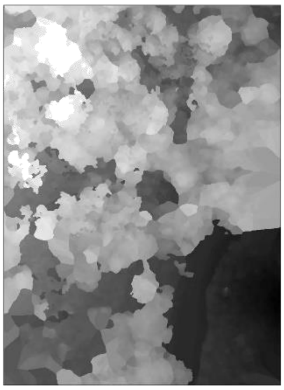

Fig.2.1 DSM

Fig.2.2 Orthomosaic

### 4.3. Aerial Image Classification:

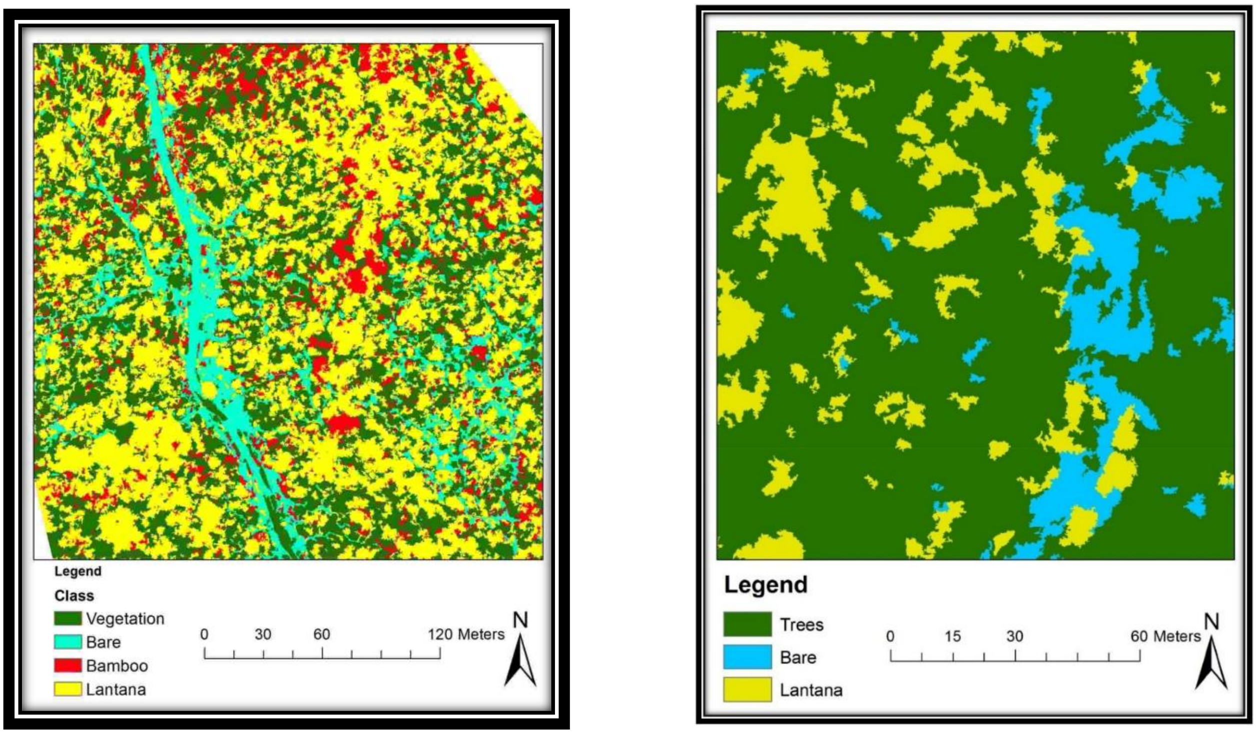


Fig.3. Aerial image classification (samples)

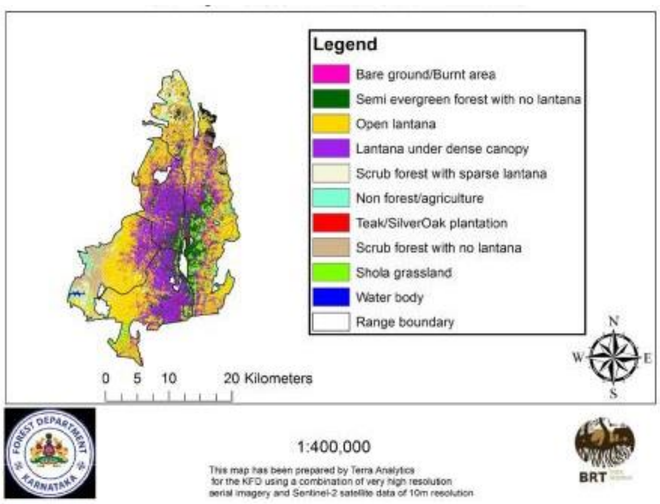


Fig. 4. Lantana map, BRT Tiger Reserve

### 4.4. Statistics:

Table.1. Lantana and other categories by area

| Class | Area ($km^2$) |
|---|---|
| Lantana open | 225.07 |
| Lantana dense canopy | 164.41 |
| Non forest/agriculture | 32.87 |
| Sparse lantana | 33.97 |
| Evergreen with no lantana | 48.37 |
| Silver Oak/Teak plantation | 11.16 |
| Scrub with no lantana | 23.22 |
| Bare ground/burnt area | 10.41 |
| Shola grasslands | 34.56 |
| Waterbodies | 0.96 |

**Total Lantana covered area**: **423.45 $km^2$**
**Accuracy**:
Users accuracy: 87.3%
Producers accuracy: 82.8%

## 5. Discussion:

Lantana camara invasion is a well researched problem in peninsular India(Murali and Setty 2001, Ramaswami and Sukumar 2011). Mapping of extent of lantana has been done by various methods, ranging from multispectral satellites(Kimothi, Anitha et al. 2010) to predictive modelling(Niphadkar, Ficetola et al. 2016). This study aimed at eliminating the shortcomings of satellite data by increasing the resolution several folds. Also, given the huge price of high resolution satellite data, it proved more cost effective to use a UAV, given the very high resolution. Previous studies also indicate that for studying vegetation in high detail, UAV is producing results competitive to those of satellite data(Matese, Toscano et al. 2015). In a forest like BRT Tiger Reserve, where there is high vegetation species diversity, distinguishing lantana from surrounding vegetation needs a very high resolution image.
UAV data acquisition in a forest can however, produce some effects which have to be considered while classifying the data. Lighting conditions, shadow, presence of haze/clouds are the factors because of which it is very difficult to get radiometrically calibrated images which are uniform across all areas. Multiple flights produce multiple types of spectral combinations, and it is impossible to characterize any vegetation class spectrally by using UAV data. Each classification system has to be developed in situ.
The lantana removal geospatial guide proved to be of great help in systematically planning the allocation of workforce and logistics of extracted material. The Government of India has also sanctioned additional funds for facilitating the lantana removal.

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