

# Reconstructing the history of introduction and spread of the invasive species, *Lantana*, at three spatial scales in India

Ramesh Kannan · Charlie M. Shackleton ·  
R. Uma Shaanker

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**Abstract** This study sought to reconstruct the history of *Lantana* invasion and spread in India by considering two questions; (a) from where, by who, and when were *Lantana* species introduced into India? and (b) given its long history in the country, is it still spreading or more or less stable? We critically evaluated the archival and historical information on plant imports by the European powers into India during the period before and after British colonization. We then reconstructed the path of spread by analyzing the spatio-temporal patterns of occurrence and distribution of *Lantana* in India at both the national and local scale using a GIS platform. The spread of *Lantana* across the globe started as early as the 1690s. The European colonial powers moved the plants from Latin America to Europe and to their colonial countries in the early 1800s. *Lantana* species were introduced in India from 1807 onwards and thereafter

the colonial powers moved this plant across the country. Following its introduction into India, the spread of *Lantana* across the country, either through subsequent multiple introductions from Europe to different British cantonments, or through moving the plants between cantonments within India, were reasonably rapid spanning only a few decades. In the absence of a rigorous control program, the spread of *Lantana* has gone on unabated and thereby impacting both wildlife and biodiversity.

**Keywords** Alien invasive species · Botanical gardens · Herbaria · India · *Lantana* · Spatial scale

## Introduction

Alien, or exotic, species refers to a collection of plants and animals that have been moved or imported intentionally or unintentionally by humans from their natural habitat into new habitats (Pyšek and Richardson 2008; Juan et al. 2010; Hornoy et al. 2011; Sousa et al. 2011). A number of studies have documented these movements and the associated consequences or impacts they have had on native ecosystems (Pyšek and Prach 1995; Foxcroft et al. 2004; Khuroo et al. 2012). Colonization of Africa and Asia by the European powers between the fifteenth and nineteenth centuries saw a quantum jump in transfers of alien

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R. Kannan · C. M. Shackleton  
Department of Environmental Science, Rhodes  
University, Grahamstown 6140, South Africa

R. Kannan (✉) · R. Uma Shaanker  
Ashoka Trust for Research in Ecology and the  
Environment, Royal Enclave, Srirampura, Jakkur Post,  
Bangalore 560064, India  
e-mail: kannan@atree.org

R. Uma Shaanker  
Department of Crop Physiology and School of Ecology  
and Conservation, University of Agricultural Sciences,  
GKVK campus, Bangalore 560065, India

species through the introduction of plants and animals between the colonized territories for food, fodder, energy and ornamental purposes (Pyšek and Richardson 2008; Khuroo et al. 2012). Since their introduction several centuries ago, many of the species have established and naturalized into the native ecosystems, while a few have gone on to invade and usurp the native biota and are now labeled as invasive alien species (IAS) (Pyšek and Prach 1995; Kohli et al. 2006; Dogra et al. 2009).

In India, major plant introductions can be traced to the establishment of the East India Company's (EIC) botanical garden in 1786 (Royle 1840). Within a relatively short span of 8 years, the EIC brought over 300 plant species into the first botanical garden in Calcutta (now Kolkata) (Roxburgh 1814). These introductions were accelerated by the directives of the Honorable Court of Directors of the EIC who encouraged the Agricultural and Horticultural Society of India to undertake experiments on an extensive scale for naturalizing in India useful and, at that time, desirable plants indigenous to other countries (Spry 1841). This perhaps was the first and defining moment in the large-scale introduction of exotic plants into the Indian subcontinent. The present spread of a few IAS such as *Chromolaena odorata*, *Lantana camara*, *Mikania micrantha* and *Mimosa diplotricha* (Sankaran et al. 2009) in the Indian subcontinent can be directly traced to the European and British introductions during the EIC rule. Besides these, several other introductions were made, mostly inadvertently, through imports of food grains, a notable one being *Parthenium hysterophorus*. Though it was initially and accidentally introduced in the early 1800s by the British (Paul 2010), its subsequent inadvertent reintroduction with imported wheat by the USA PL 480 scheme seems to have been the major impetus for its dramatic spread as an IAS in India (Brahmam 2003). Currently the alien flora of India amounts to 1,599 species, belonging to 842 genera in 161 families, and constituting 8.5 % of the total vascular flora now found in India (Khuroo et al. 2012).

In this paper we have reconstructed the introduction and spread of *Lantana* in India. *Lantana* is regarded as one of the ten worst invasive species in the world (Ghislalberti 2000; Richardson and Rejmanek 2011). The *Lantana* L. (Verbenaceae) genus has more than 100 species, largely from Latin America and a few from Africa and Asia (Day et al. 2003). Carl Linnaeus was the first to identify and record seven *Lantana*

species in his *Species Plantarum* in 1753. He found six species native to America and one species from Ethiopia. *Lantana* was believed to be introduced into the Netherlands by the Dutch explorers in the seventeenth century from Brazil and later to other countries (Ghislalberti 2000). *Lantana camara* L., a hybrid species of tropical America, popularly known as wild or red sage, is the most widespread species of *Lantana* and is now a problematic IAS in approximately 70 countries or island groups (Ghislalberti 2000; Zalucki et al. 2007). The wide distribution of *Lantana* shows its ecological tolerance and its adaptability to different habitats (Broughton 2000; Day et al. 2003). In India, *Lantana* has been recorded from the Central Himalayas in the north, to the southernmost part of India and has displaced several native species (Bhatt et al. 1994; Sahu and Singh 2008; Dogra et al. 2009). At a local scale, *Lantana* can present dense invasions, which have reduced the habitat suitability for different types of fauna and flora and the viability of local livelihoods in many regions as well as biodiversity hotspots and protected areas (Krishna et al. 2008; Sundaram and Hiremath 2012). Despite its widespread occurrence throughout much of the Indian subcontinent, there has been surprisingly little research on *Lantana* in India. Most of the effort has been on the aromatic oils for medicinal or other purposes (e.g. Deena and Thoppil 2000; Grover et al. 2002) and some on the ecology and biodiversity impacts of the species (e.g. Hiremath and Sundaram 2005; Dobhal et al. 2011). Yet, to properly assess these impacts, and importantly, how they may vary under different management and climate scenarios, it is necessary to understand the pathways of introduction and rate of spread. Thus, in this paper we consider the historical spread of *Lantana* at three scales, i.e. international, national and local. The last considers the example of the Western Ghats, which is an important biodiversity hotspot in peninsular India. Specifically, we address the following questions: (a) from where, by who, and when were *Lantana* species introduced into India? and (b) given its long history in the country, is it still spreading or more or less stable? We use a variety of tools ranging from historical analysis of archival, floristic and herbaria records as well as GIS and ecological niche modeling to address these questions. We discuss the possible applications/implications that our findings may have in monitoring and managing *Lantana* and how they could be used in studying the future spread of *Lantana*.

## Methodology

To reconstruct the history of *Lantana* introduction and its spread in India we employed broadly two approaches. The first was a critical evaluation of archival and historical information on plant imports by the European powers from their various colonies into India during the period before and after British colonization. The second was to recreate the path of spread by analyzing the spatial–temporal patterns of occurrence and distribution of *Lantana* in India at a national scale and then at a local scale in the Western Ghats biodiversity hotspot, south India, using a GIS platform. About 14 species of *Lantana* are believed to have been introduced into India (see “Results”). However, many of these names are interchangeably used in the historical and archival records with little clarity on the taxonomic distinctiveness of the different species; for the purposes of this study, we restrict our discussion to the genus, *Lantana*.

### International and national spread of *Lantana*

To reconstruct the international and national scale spread of *Lantana*, we analyzed (a) archival and historical information and (b) herbarium collections within India and from the Royal Botanical Gardens, Kew, UK.

### Archival and historical information

We compiled all archival and historical information relevant to *Lantana* from 1800 to date. This included perusal of multiple sources: (a) the *Imperial Gazetteers of India* which provide records of demographic, socioeconomic, cultural and natural resources of the areas ruled by the colonial government in India, (b) books on Indian flora published by the pioneer botanists who explored all areas to collect and record the plant diversity of India, (c) letters and communications between the colonial officials stationed in India and Europe, Curators of the botanical gardens of India and forest officers of India, and (d) online web portals such as [www.archives.org](http://www.archives.org) and <http://www.biodiversitylibrary.org> which provide access to literature published prior to 1947. Based on the analysis of these different sources we inferred the probable path of introduction and spread of *Lantana* in India.

### Herbarium records

Herbarium records of *Lantana* lodged between 1814 and 2000 were accessed from the four largest and oldest herbaria in India. In the east, this was the Central National Herbaria in Howrah, in the west, Botanical Survey of India in Pune, the north was covered by the Forest Research Institute in Dehradun, and the south by the Botanical Survey of India in Coimbatore. We also obtained the herbarium records of *Lantana* from the Royal Botanical Garden, Kew, UK for the same period. Data from specimens such as collection area and date were incorporated into a geographical information system (GIS) tool Quantum GIS (Q GIS) (Delisle et al. 2003), which allowed mapping of the spread of *Lantana*.

### Local scale case study

As a specific local case study, we investigated the rate of spread of *Lantana* over the Western Ghats. This was achieved by different means, which then provided the opportunity for triangulation of results and interpretations. Firstly, we approached 351 retired forest officials who had worked at various forest stations in the Western Ghats between 1950 and 2000.

A two-page survey was administered requesting details of where they were stationed in their first decade of work as a forest officer, their second decade, and their third decade. For each station and each decade they were asked whether or not *Lantana* had been present when they first arrived and when they left and how it was managed. A total of 73 valid completed questionnaires were returned (21 %).

Secondly, we interviewed the elder community members of two different tribal groups, Soligas, in the southern parts and Mahadeo Koli in northern parts of the Western Ghats. Within each community we selected elder people (male and female) above 60 years and asked them questions related to the presence and changes in extent of *Lantana* in their area over the last 25–30 years. The average age of the respondents was 74 years ( $\pm 10.4$ ).

Lastly, based on the occurrence data from the surveys and herbaria sheets for the Western Ghats we predicted the habitat suitability of *Lantana* within the Western Ghats region using Ecological Niche Modeling (ENM) tools. MaxEnt (Version 3.3.2) (Maximum entropy model) was used for prediction of the *Lantana* spread. The program uses the following

**Table 1** Records of *Lantana* species grown at the Royal Botanical Garden, Kew and details of introduction

Sl. no	Lantana species	Year of introduction	Details (superscript reflects the source)
1	<i>L. involucrate</i>	1690	Native of West Indies and cultivated in the Royal Garden at Hampton Court, London <sup>a,b,c</sup>
2	<i>L. camara</i>	1691	Native of the West Indies. Cultivated in the Royal Garden at Hampton court, London <sup>a,b,c</sup>
3	<i>L. aculeate</i>	1692	Native of the West Indies. Cultivated in the Royal Garden at Hampton court, London <sup>a,b,c</sup>
4	<i>L. africana</i>	1731	Native of the Cape of Good Hope and cultivated by Mr. Philip Miller <sup>a,b</sup>
5	<i>L. melissifolia</i>	1732	Native of West Indies and cultivated by James Sherard <sup>a,c</sup>
6	<i>L. trifolia</i>	1733	Native of the West Indies and introduced before 1733 by Willam Houstoun, M.D. <sup>a,c,d</sup>
7	<i>L. annua</i>	1733	Native of South America and introduced before 1733 by Willam Houstoun, M.D. <sup>a,c</sup>
8	<i>L. recta</i>	1758	Native of Jamaica and cultivated by Mr. Philip Miller <sup>a</sup>
9	<i>L. odorata</i>	1758	Native of the West Indies and cultivated by Mr. Philip Miller <sup>a,b,c</sup>
10	<i>L. scabrida</i>	1774	Native of the West Indies and introduced by Mr. Gilbert Alexander <sup>a,c</sup>

<sup>a</sup> William (1789) p. 352

<sup>b</sup> Donn (1796) p. 72

<sup>c</sup> Loudon (1830) p. 245

<sup>d</sup> Sims (1812)

variables such as mean of diurnal range (mean of monthly  $\times$  (max temp–min temp)), isothermality, temperature seasonality, temperature annual range, annual precipitation and precipitation seasonality to predict habitats of different suitability categories. Based on these predictions, we analyzed the pattern of spread of *Lantana* over the 150 years from 1850 to 2000 in the Western Ghats. Finally, based on these data, we projected the possible potential distribution of *Lantana* in the Western Ghats.

## Results

Historical introduction and spread at the international and national scales

### *Early history of Lantana spread*

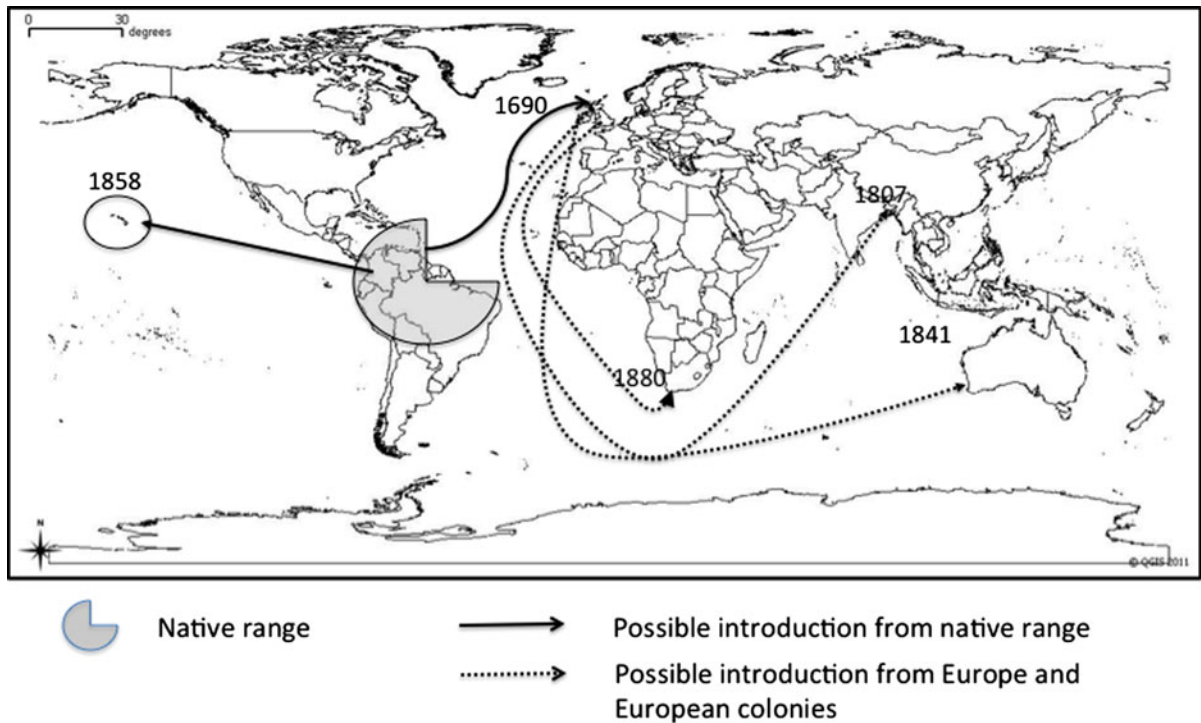
The trade vessels of the Dutch West India Company [popularly known as Geoctroyeerde Westindische Compagnie (GWC)] transported economically important plants including ornamental and vegetable species from the Caribbean and Latin America to Europe. To preserve the plants or parts of plants such as seeds, bulbs, and roots until they were sown or planted or dispatched to destinations the world over, the early

explorers established extensive holdings in the botanical gardens in Europe (Dawson et al. 2008). Among these plants there were several species of *Lantana*, which were transported from the Caribbean and Brazil to the Netherlands by the Dutch and from there to botanical gardens throughout Europe (Table 1).

For example, the *Hortus Kewensis* (a catalogue of the plants cultivated in the Royal Botanic Garden at Kew) recorded the introduction of 10 *Lantana* species to the Kew Gardens in London between 1690 and 1770; eight of the 10 species were from the Caribbean Islands. *L. involucrate* was introduced and cultivated in the Royal Garden in Hampton court, London in 1690. Since then *Lantana* species were introduced at different intervals to different botanical gardens in London. As per the available archival information, *Lantana* was transported mainly from the Caribbean region into Europe in the late seventeenth century and it was exported as an exotic plant to the European colonies between 1800 and 1900 (Fig. 1).

Introduction of alien plant species in India based on archival information

Much as plants were introduced into the botanical gardens in Europe and specifically in London, in India too, a number of alien plants were introduced to



**Fig. 1** Probable routes of *Lantana* introductions from Latin America to the rest of the world (updated from Cronk and Fuller (1995)). Note that our study suggest that *Lantana* moved from Latin America to Europe as early as 1690. Source: William (1789). p. 352. Hortus Kewensis, Roxburgh (1814) Hortus Bengalensis. p. 46, Schomburgk R. (1878) Catalogue of plants

under cultivation in the Government Botanic Garden, Adelaide, South Australia p. 136, Hillebrand W. F. (1888) Flora of the Hawaiian Islands: A description of their phanerogams and vascular cryptogams p. 341, Thiselton D. W. (1912). Flora of Capensis: being a systematic description of the plants of the Cape colony, Caferaria and Port Natal. 5. pp 189–192

various botanical gardens in the country. Mughal Kings, who ruled India from 1526 to 1700, developed a string of botanical gardens in the country, including the famed Lalbagh Botanical Garden in Bangalore. Following the Mughal, the East India Company (EIC) established its first botanical garden with the help of Colonel Kydd in 1786 in Serempur. This garden was later incorporated into what would become the national botanical garden of the country, the East India Botanical Garden of Calcutta.

William Roxburgh, a Scottish surgeon and a botanist, was appointed to be in charge of this botanical garden in 1798. *Hortus Bengalensis* or *A Catalogue of the Plants Growing in the Honorable East India Company Botanic Garden at Calcutta*, compiled by him, was posthumously published by a British missionary, William Carey in 1814. The *Hortus* provides some rich insights into the early records of spread of plants from the rest of the world into India. Since the inception of the Calcutta garden,

more than 3,200 plant species were introduced. Of these, 992 were from outside British India and as far away as the Caribbean and Latin America. Forty-one species were accidental introductions. A large number of plants were introduced by William Hamilton (1745–1813), a landscape designer, botanist and avid plant collector from Philadelphia, America. Of about 240 plants introduced from America, he alone brought in 137.

That the British were serious in their introduction plans is evident from a number of correspondences during the EIC period. For example, Dr. Henry Harpur Spry, then Secretary of the Agricultural and Horticultural Society of the EIC, gathered detailed information pertaining to the tree and other plant species existing on the Indian subcontinent, the list of species requested from outside India, the soil and precipitation patterns, etc. Based on this information, Dr. Spry sought to improve the agriculture and horticulture industries in India by introducing and naturalizing

plants from Europe, the West Indies and North America and vice versa in 1839.

Prof. J. F. Royle, wrote to Mr. James Cosmo Melville, Esq. Secretary at the India House and stated the following: “*The seeds obtained from various sources may be sent in separate parcels as intended for warm or for cool climates, as for Bombay, Madras, Calcutta, and Saharunpore, or for the Hills of Mahabhaleshwur, Neilgherries, Darjeeling, Mussooree, and Simla*”

Dr. Nathaniel Wallich, a Danish surgeon and botanist who took charge of the EIC botanical garden in 1817, after the demise of Dr. William Roxburgh, served as a superintendent of the garden till 1846. He wrote to the Honorable Court of Directors on 24th August 1839 and requested seeds from South America and the West Indies, as he noted that they succeeded, in general, remarkably well. He also requested to be sent as many flower seeds as possible, for sowing in the hills and plains. The kinds of seed most valued were those of ornamental or useful flowering plants and shrubs (such as *Lantana*) (Spry 1841).

#### History of *Lantana* introduction in India

The earliest writings on plants of India were those of Dr. William Roxburgh, including the *Plants of the Coast of Coromandel* (1795) and two volumes of the *Flora of Indica*. None of these have any reference of *Lantana* of an American origin. However, in the *Flora of Indica*, there is a mention of *Lantana indica* Roxb, a plant native to the Mysore presidency in southern India. Thus, at least as far as these records go, there is no mention of the presence or introduction of *Lantana* from South America as early as this time. Thus, it can be assumed that alien *Lantana* species were not found on the Indian subcontinent until approximately 1800.

The first record of *Lantana* species of a Latin American origin was found in the *Hortus Bengalensis* (Table 2). Dr. William Carey donated *Lantana trifolia* to the Calcutta garden in 1807 followed by William Hamilton, a fervent plant collector and gardener from Philadelphia, who donated *Lantana aculeate* in 1809. J. O. Voigt, in his book *Hortus Suburbanus Calcuttensis*, compiled information on plants cultivated in the EIC's Calcutta botanical garden, beginning from 1786 until August 1834. There he recorded seven species of *Lantana* cultivated in the garden, namely *L. aculeate*, *L. canescens*, *L. gochana*, *L. nivea*, *L. odorata*,

*L. selloviana*, and *L. trifolia*. Thus, based on these records, it appears that four more new species of *Lantana* were introduced between 1807 and 1834.

The EIC continued to establish botanical gardens in several places such as the Saharanpur botanical gardens (known as Company Garden) in 1817, Dapooore garden near Pune (erstwhile Poona) in 1828 (Royle 1840), Lalbagh in Bangalore in 1857 (though first initiated by local kings Hyder Ali and Tipu Sultan in 1760), Sim's park in the Nilgiris in 1874, and the Lloyd Botanical Garden in Darjeeling in 1878. In all these gardens, multiple introductions of *Lantana* species were made at different periods (Table 2). Based on the floristic records published between 1800 and 1900, 12 species of *Lantana* find mention, 11 of which are of American origin.

The first citation that we could find of an alien *Lantana* species outside a botanical garden in India is found in the book on *Flora of North, West and Central India* (1874) by Dr. Dietrich Brandies. He reported that *Lantana* was widespread in the Nilgiris and Deccan India. After 1874, the spread of *Lantana* was periodically reported in popular articles in the *Indian Forester* and *Gazetteer of India*.

#### Herbaria records of *Lantana* collection in India

We found 344 herbaria sheets of *Lantana* collections in the four national herbaria in India, along with 30 herbaria records accessed from the Royal Botanical Garden, Kew, UK. The herbarium records of *Lantana* species increased from three in 1800–50 to 340 in 2000 (Fig. 2). The oldest herbarium collection dates to 1814 and was collected near Pachmargi, Central India. The first record of herbarium collection in the Western Ghats dates to 1835 in Courtrallam and Dr. J. S. Gamble collected the herbaria record of *Lantana camara* in 1887 in the Nilgiris. According to the herbaria records, 14 species of *Lantana* with American origin are found in India (Table 2).

It is noteworthy that the majority (86 %) of herbaria records between 1800 and 1900 were from areas of concentrated British presence, such as British Cantonnments (65 %), botanical gardens (13 %) and tea or timber plantations (8 %). This is not surprising as these were the places where *Lantana* was first introduced into the botanical gardens (Fig. 3). As mentioned earlier, the Court of Directors of the EIC supplied economically valuable and ornamental

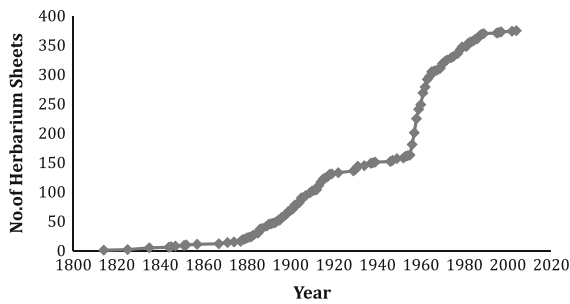
**Table 2** *Lantana* species introduced into India (based on archival and Herbaria records from 1814; ordered by earliest to most recent)

Sl. no	<i>Lantana</i> species	Year	Record	Location
1	<i>L. trifolia</i>	1807	Archival	Introduced in the East India Company's Botanical Garden, Calcutta <sup>a,b</sup>
2	<i>L. aculeata</i>	1809	Archival	Introduced in East India Company's Botanical Garden, Calcutta <sup>a,b</sup>
3	<i>L. camara</i>	1814	Herbaria	Found wild in Pachmarhi
4	<i>L. gochana</i>	1845	Archival	Found wild in the banks of the Jumna, Saharanpure, Peer punjal, Assufghur in Rohilkund and cultivated in the East India Company's Botanical Garden, Calcutta <sup>b</sup>
5	<i>L. nivea</i>	1845	Archival	Cultivated in the East India Company's Botanical Garden, Calcutta <sup>b</sup>
6	<i>L. odorata</i>	1845	Archival	Cultivated in East India Company's Botanical Garden, Calcutta <sup>b</sup>
7	<i>L. selloviana</i>	1845	Archival	Cultivated in the East India Company's Botanical Garden, Calcutta <sup>b</sup>
8	<i>L. canescens</i>	1845	Archival	Cultivated in the East India Company's Botanical Garden, Calcutta <sup>b</sup>
9	<i>L. alba</i>	1847	Herbaria	Found in the Herbaria of Nicol Alexander Dalzell, Bombay
10	<i>L. aculeata</i>	1857	Herbaria	Found wild in the Bombay presidency
11	<i>L. dubia</i>	1871	Herbaria	Found in the upper Himalyan area of Kumoun
12	<i>L. alba</i>	1874	Archival	Found wild in the plains of North India, Sub-Himalayan tract ascending to 3,000 ft. also found wild in Sindh, Dekkan, Nilgiris, Ceylon <sup>c</sup>
13	<i>L. trifolia</i>	1878	Herbaria	Found wild in Conoor, Ooty
14	<i>L. odorata</i>	1880	Herbaria	Found cultivated in the Serampore Botanical Garden, Howrah
15	<i>L. crenulata</i>	1885	Archival	North Western India. Royle Falconer; Moradabad (cultivated) <sup>c</sup>
16	<i>L. wightiana</i>	1885	Archival	Found wild in South Madras in or near hills. Palani Mountains and Courtallum in the Western Ghats <sup>c</sup>
17	<i>L. camara</i>	1891	Archival	Extensively used as a hedge plant in Bangalore <sup>d</sup>
18	<i>L. nivea</i>	1894	Herbaria	Found wild in the Mussorie hill
19	<i>L. crenulata</i>	1898	Herbaria	Kotdwara, Kheri, Oudh
20	<i>L. wightiana</i>	1901	Herbaria	Found wild in the River Aliyar, Pollachi
21	<i>L. mista</i>	1909	Herbaria	Found wild in Rangpoo, Sikkim
22	<i>L. involucrata</i>	1914	Herbaria	Cultivated in the Botanical Garden, Saharanpur
23	<i>L. mouteridensis</i>	1956	Herbaria	Found wild in Kothagiri, Nilgiris around 4,500 ft
24	<i>L. urticaefolia</i>	1956	Herbaria	Found wild in Dehradun
25	<i>L. selloviana</i>	1957	Herbaria	Found wild in Kothagiri, leaves were very small and no prickles

<sup>a</sup> Roxburgh (1814) p. 46<sup>b</sup> Voigt (1845) Hortus Suburbanus Calcuttensis. p. 472<sup>c</sup> Brandis (1874) p. 369<sup>d</sup> Cameron (1894) pp. 214–215<sup>e</sup> Hooker (1885) pp. 562–563

plants, seeds and plant materials to the horticulture and botanical gardens, and to colonial officers to propagate them in their respective areas. That explains that the earliest *Lantana* herbaria collections accrued in cantonment areas namely Pachmarhi, Nilgiris, Shillong, Mussorie, Chamba, Kouduru, Delhi, Quilon, and botanical gardens such as Darjeeling, Pune, Serampore, Saharanpure, Bangalore and Udhagamandalam (Ooty).

*Lantana* appears to have been introduced into multiple sites over a relatively short period. *Lantana* was seen as an excellent hedge plant and was planted widely for fencing which helped the plant to escape into the wild and proliferate (Tireman 1916). However, it is not clear if these multiple introductions within India were derived from a single introduction into India from Europe and then transferred rapidly between nodes of British activity, or different nodes



**Fig. 2** Herbarium records of *Lantana* species in India

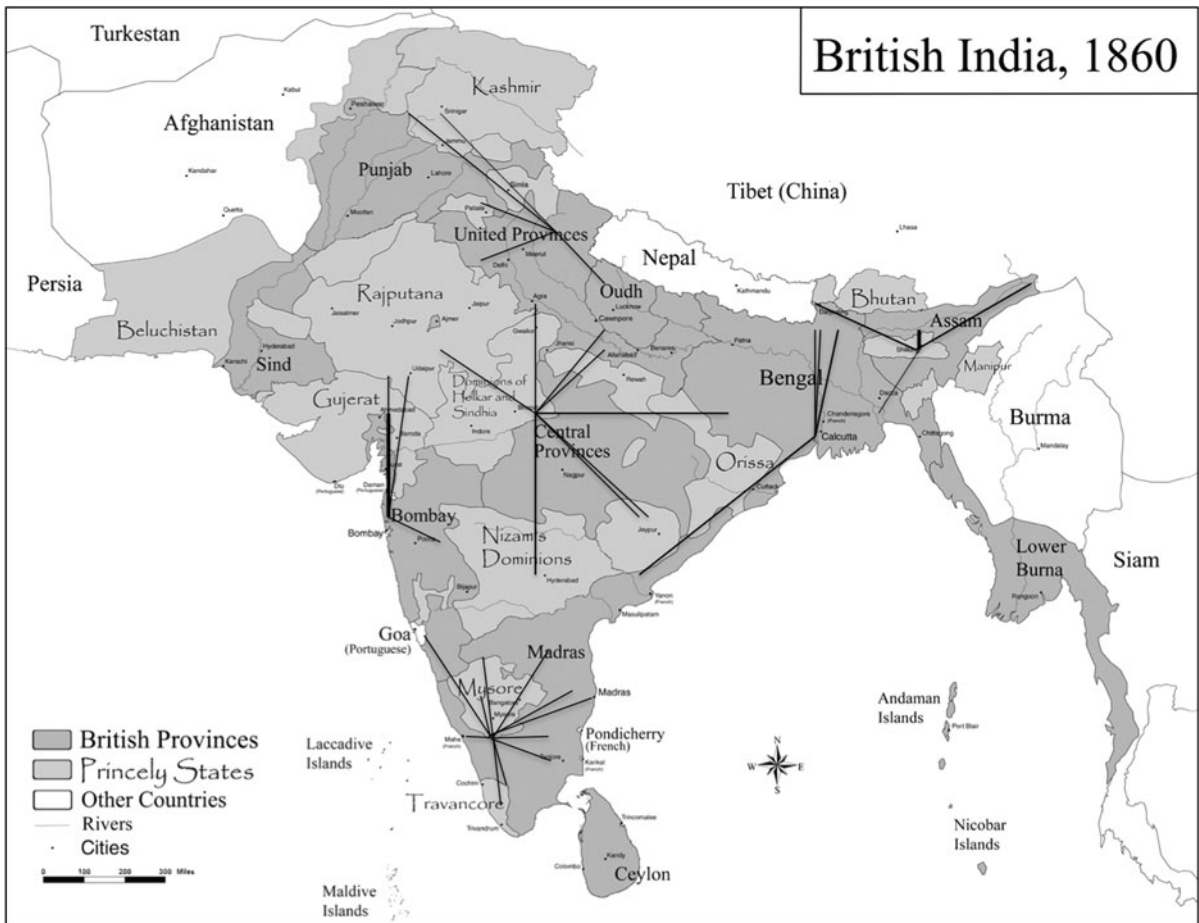
received different material from Europe. But once established at these nodes *Lantana* spread across the country.

We attempted to trace the spread of *Lantana* following the various *Gazetteers*, especially the *Imperial Gazetteer of India* Vol. 1–25 and *Gazetteer*

*of Bombay* Vol. 1–25 and *Gazetteer* of other provinces in India, and *Indian Foresters Journal* 1885–1950. However, there was very little reference on *Lantana* spread in the *Gazetteers*. Lewis Rice mentioned in the *Gazetteer of Mysore* (1897) that *Lantana* grew with the rankness of a weed; another reference in the *Imperial Gazetteer* (1908) mentioned that *Lantana* was spreading in Bangalore as early as the 1900s.

Spread into the wild in India

A number of references to *Lantana* were found as early as 1894 in the *Indian Forester*. Most of these articles highlighted the different management practices such as manual removal and bio-control of *Lantana*. In Coorg, Karnataka, for example, *Lantana* was being managed mechanically by measures such as



**Fig. 3** Probable *Lantana* introduction and spread pathways from the British cantonments and botanical gardens. (British India Map Source: Wikimedia commons)



cutting, burning, and uprooting. Often these programs were coupled with planting of bamboo to replace *Lantana*, as was done in Savanthavadi, Maharashtra for 4 years (1911–1914) (Pereira 1920). Between 1900 and 1965 we found 15 articles that dealt with control measures such as manual and biocontrol.

Manual removal of *Lantana* was deployed in the early 1900s in south India. The forest officers of Mysore, Madras and Central province deliberated the importance of eradicating *Lantana* to protect important forest species such as sandal and teak. The forest officers in southern India felt that *Lantana* was a troublesome weed in Wayanad and Coorg more than anywhere else. They felt that *Lantana* grew densely and prevented the growth of grass on arable and pasture lands as well as lands where grass was grown and harvested. They observed that *Lantana* was a light-loving plant and thrived in the areas where the forest or woodland canopy was incomplete and that it threatened the existence of the forest. Further comments related to *Lantana* patches preventing grazing and destroying grass and shrub species and the high cost of clearance preventing the extension of cultivation on forest tracts. Often attaining a height of 30–35 feet by creeping up over the forest canopy to reach sunlight, it was noted that *Lantana* stifles the growth of the forest. In the Berar forest tract, *Lantana* threatened the most remote forest tracts allotted for grazing and the extension of cultivation by the Berar tribal communities. In the Chikalda and Ellichpur area in Berar, it was noticed that *Lantana* growth started in the hedges along roadsides. As early as 1900 in these areas, clearing of *Lantana* along roadsides and hedges was initiated. The forest departments in several parts of the country follow this practice today.

#### Local level invasion of *Lantana*

##### *Lantana* in Coorg: 1878

The invasion, naturalization and control or management of *Lantana* in Coorg exemplifies the early issues related to *Lantana*, which is strikingly very similar to the current preoccupations with the species. *Lantana* was brought to Coorg by a missionary in a flowerpot and used as a hedge plant. But it soon escaped from the hedges to the fields and hillsides and spread extensively. Mr. Poviet, Conservator of Forest, wrote that *Lantana* was a major problem and hundreds of coffee

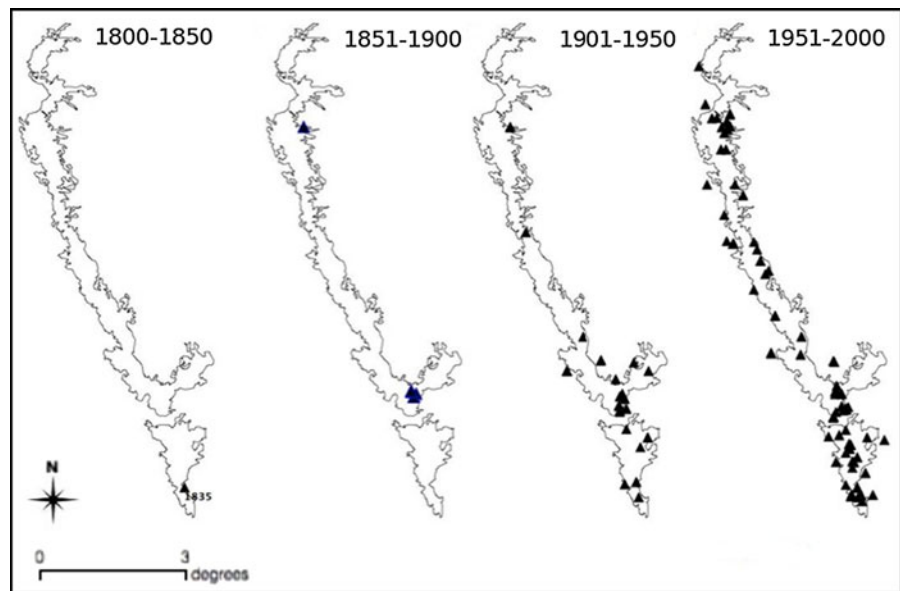
estates were abandoned due to *Lantana* invasion in Coorg. He wrote in 1893 that the cost for *Lantana* eradication was Rs. 7,413/km<sup>2</sup> in the first year, Rs. 2,471/km<sup>2</sup> in the second year and Rs. 1,235/km<sup>2</sup> in the third year. A. E. Lawrie, Deputy Conservator of Forests in Coorg, found that sandalwood sown along with *Lantana* was completely smothered by the latter in less than 3 years. It appears that this species was *L. aculeate* (*Gazetteer of Coorg*). He further observed that *Lantana* in the dry deciduous forest landscape never allowed the native vegetation to regenerate.

In Coorg alone the estimated areas of different classes of land infested by *Lantana* in 1912 were: private land, 284 km<sup>2</sup>, of which 141 km<sup>2</sup> had been cleared; Government waste land, 161 km<sup>2</sup>; reserved forests, 299 km<sup>2</sup>. An extensive scheme for eradicating *Lantana* over an area of 255 km<sup>2</sup> in reserved forests and other Government lands in Coorg was drawn up in 1914, but owing to the outbreak of World War I in that year the scheme was held in abeyance. The scheme, extending over a period of 11 or 12 years, was estimated to cost Rs. 440,000. So serious was the *Lantana* invasion in Coorg that it led to the passing of the legislation called the Coorg Noxious Weeds Regulation (1914); however it is another matter that it was not implemented because of the outbreak of the World War I.

#### Invasion of *Lantana* in the Western Ghats

The interviews with the retired forest officials indicated that *Lantana* was widespread when most of them started their careers as junior officers in the forest service in the 1950s and 1960s. Approximately 90 % reported that *Lantana* was already present at that time. This proportion remained more or less consistent for the responses regarding the second and third decades of their working life, suggesting that *Lantana* had already invaded most of the suitable areas by the mid 1900s. Many respondents, especially those who had been stationed in the southern areas of the Western Ghats (such as Coorg, Wayanad and Nilgiris) reported that *Lantana* was regarded as a problematic plant even when they started their careers, although there were only limited attempts to address the problem in indigenous forests and protected areas. *Lantana* was removed only in the areas of land used for timber plantations. Ironically highly infested areas were in abandoned estates and plantations. However, a

**Fig. 4** Spatial spread of *Lantana* in the Western Ghats in last 200 years 1800–2000 (each triangle represents individual collections)



spatial analysis of their responses, in particular of the sites where they reported not having seen *Lantana* when they first arrived, suggests that *Lantana* was well established in the southern Western Ghats by 1950, but less so in the central and northern regions of the Western Ghats. Its occurrence in the central and northern regions is thus a later phenomenon, mostly in the last 50 years. However, of the 50 sites reported by the respondents as being free of *Lantana* in the first decade of their service, at almost half (24) of these sites *Lantana* was reported by the second or third decadal periods. Thus, it appears that *Lantana* invasion into new regions might still be continuing.

The results from the interviews with elders of local communities echoed those of the forest officers. In the northern area at Mahadeo Koli in Bimasankar Wildlife Sanctuary, many said that *Lantana* had not been there 25–30 years ago, or only sparsely so. All agreed that in the last 10–15 years it has proliferated. In contrast, the elderly respondents of Soligas, and Palliyars in the southern Western Ghats stated that *Lantana* had been there even when they were children. However, all were of the opinion that it was increasing in density in the forests. More than 80 % of the respondents mentioned that the fodder for cattle has been reduced by *Lantana*. The Soligas in the BR Hills reported that several grass species and wild yams were displaced by *Lantana*. Soligas attributed the proliferation of *Lantana* to the banning by forest officials in the 1970s of winter burning (tharagu bengi).

The spatial distribution of herbarium accessions for the Western Ghats corroborates the information provided by these two sets of informants. The first herbarium accession of *Lantana* in the Western Ghats was recorded in 1835 in Courtrallam in southern part of the Western Ghats. Prior to 1950 there were only three sites from the northern and central areas of the Western Ghats with *Lantana* accessions, compared to 27 sites in the southern region (Fig. 4). By the year 2000, there were 27 sites (a nine fold increase) in the central and northern areas, whilst the number of sites in the southern regions had increased to 80 (more than a three fold increase).

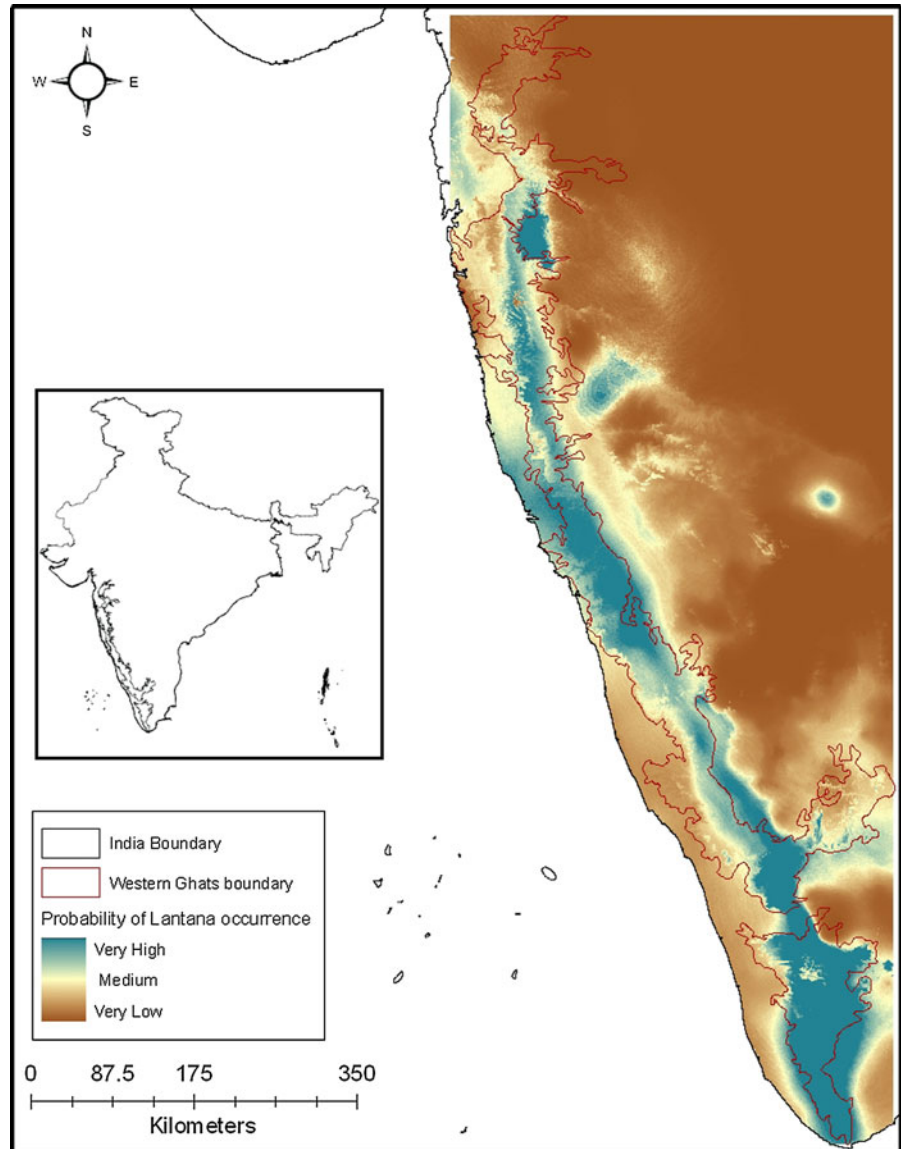
#### Ecological niche model predictions

Based on herbaria accessions, ecological niche model (ENM) maps for *Lantana* spread in the Western Ghats was generated (Fig. 5). The map shows that the predicted habitat suitability for *Lantana* in the Western Ghats is very varied from very poor to excellent. Most of the predicted excellent sites were restricted to the Southern and Northern parts of the Western Ghats. On the other hand, many parts of the Western Ghats such as Central Western Ghats were not suitable for the species.

#### Discussion

In this paper we have provided a detailed historical analysis of the spread of *Lantana* species at three

**Fig. 5** Ecological Niche Modeling (ENM) map for *Lantana* spread in the Western Ghats, India



spatial scales, and a period of over 300 years. At the international scale it is clear that the first species of *Lantana* were transported from the Americas and Caribbean to Europe in the late 1600s, with more following in the early 1700s. This is more than a century earlier than mapped by Cronk and Fullers (1995). It was cultivated in botanical gardens in Europe for almost a century (William 1789; Donn 1796; Sims 1812; Loudon 1830) before the first recorded introductions into India, to the Calcutta botanical garden, in 1807 (Roxburgh 1814). This was the first recorded transfer of plants from Europe to any of the colonies of that time. Among a large list of

plants that were introduced into India for a wide variety of economic uses (Spry 1841), *Lantana* was introduced as an ornamental plant, the same reason for its introduction elsewhere in the world (Petch 1921).

Following its introduction into India, the spread of *Lantana* across the country, either through subsequent multiple introductions from Europe to different British cantonments in India, or through exchange and transfer of plants among the cantonments within the country, was reasonably rapid, only a few decades. *Lantana* began to be cultivated in most of the botanical gardens established by the colonial administrators (Voigt 1845). There is a clear pattern of early

accessions and records of *Lantana* being associated with cantonments, botanical gardens or plantations established by the British colonial authorities where it was used as ornamental or hedge plant. This parallels the pattern of introductions in other countries where *Lantana* was first associated with areas of colonial settlement, such as towns and cities (Bhagwat et al. 2012).

From these initial sites of introduction, *Lantana* spread into the wild to become an IAS throughout much of India. The first herbarium accession collected in the wild was 1814, and the frequency of accessions collected from the wild increased markedly after 1850. The first bibliometric mention of *Lantana* in the wild was 1874 and 1885 with the author describing it as already “widespread” and naturalized (Brandis 1874; Hooker 1885). It’s clear from the commentaries in the *India Gazetteers* and the *Indian Foresters Journal* that the spread of *Lantana* was facilitated by disturbances in forest (logging for railways and shipping and clearing for plantations) and open landscapes, including clearing for establishment of timber plantations in forest reserves and protected areas. Its affinity for disturbed sites is now well known (Duggin and Gentle 1998; Sharma et al. 2005; Prasad 2012). By the late 1800s, it was regarded as a noxious weed in India, and in May 1900, the Inspector General of Forest realizing the seriousness of this issue, instituted a study for the biological control of *Lantana*. In fact this period also saw a number of efforts from the Forest Department to actively manage *Lantana*. For example, during 1911–1914, efforts were made in Savanthvadi (Maharashtra), to replace *Lantana* by bamboo. However, due to lack of coordination and funding, the efforts were generally limited in spatial extent and impact (Bhagwat et al. 2012).

At a local scale the interviews with elderly officials and rural people indicated that *Lantana* invasion is still occurring in some areas. Herbaria records of the Western Ghats region suggest that *Lantana* was seemingly well established in the southern regions by the 1950s, but not so in the central and northern regions. But over the last few decades’ respondents reported that it has spread into these parts too, with negative impacts on local resources important to tribal communities as well as biodiversity generally. This includes protected areas and even priority threatened species (e.g. Krishna et al. 2008; Lahkar et al. 2011; Prasad 2012), mirroring negative impacts upon

biodiversity in most countries where it has been introduced (e.g. Turner and Downey 2010). In recent years ecological niche modeling tools have been increasingly applied to forecast or predict the spread of invasive species (Uma Shaanker et al. 2010; Bhagwat et al. 2012). These tools, if used judiciously, can be used as a cost effective tools to monitor and mitigate the spread of invasive species (Moore et al. 2011; Kaplan et al. 2012). For example, in this study, using herbaria records of occurrence of *Lantana*, the ecological niche models predicted a strong possibility of spread of *Lantana* across the entire Western Ghats. This prediction is in fact corroborated by historical occurrence and spread of *Lantana* through the last 100 years; the species has made inroads into most parts of the Western Ghats (Sundaram and Hiremath 2012). As is apparent the model could become a good management and early warning tool to direct prophylactic measures against the impending spread of the invasive into new areas as predicted by the model.

Local knowledge of the rural inhabitants implicate formal management approaches by the Forest Department, namely banning of winter burning, in the spread and densification of *Lantana* and suppressing or displacing the growth of native grass species (Prasad 2012). Russell and Roberts (1996) report that relatively frequent, low intensity burns keep *Lantana* at low and manageable heights, although the density is unaffected. But if keeping plants in a low regrowth stage diminishes flowering, seed production will be reduced and overall invasion rates may be slowed. However, Hiremath and Sundaram (2005) argue that different ecosystems respond differently towards forest fire. Clearly these observations indicate the need for the participation of local community and an adaptive management approach towards the management of *Lantana*. Bhagwat et al. (2012) report that general management policy around control of *Lantana* in India shifted towards minimizing impacts on wildlife rather than removal. However, as shown by our study and Sundaram and Hiremath (2012) there has been an unabated increase in distribution and density of *Lantana* in many parts of the Western Ghats. Under this scenario, it is imperative that while removal might not be a practical proposition, there is a need for an adaptive or integrated management program that can arrest the spread of *Lantana*.

In summary the introduction and subsequent spread of *Lantana* in India can be divided into three distinct

stages; first, the introduction of *Lantana* from Europe and Latin America, second, the colonization or rapid build up in the country and finally, graduating to be an invasive alien species characterized by its super-abundance. Typically this process is similar to the temporal patterns describing the spread of most invasive species (Shackleton et al. 2007; Uma Shaanker et al. 2010; Richardson et al. 2011) and to the spread of *Lantana* in other regions, e.g. South Africa (Vardien et al. 2012). Following its introduction in the 1800s and the lack of attention paid to the management of *Lantana* in the following 200 years, the species has exploded to its current status of being one of the 10 most invasive species in the world. Today in its super-abundant state, the ecological and management costs of the species have spiraled up, making the management of the species cost ineffective in many areas. Nevertheless tracing such historical patterns is useful in understanding the processes and the drivers involved in contributing to the invasiveness of such species. In fact careful analysis might also unravel critical “tipping” points that might be responsible for

a species to become invasive. Understanding such tipping points could have potential application in preventing the invasiveness of species and perhaps in managing them.

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## Appendix

See Table 3.

**Table 3** Inputs and key comments from the British community in India as a response Dr. Spry’s questionnaire about introduction and naturalization of plants from other parts of the world

Province	Point of contacts for the court of Directors, EIC	Key remarks
The Western India (encompass Bombay and Gujarath)	Dr. Browne Private secretary to the Honorable Governor of Bombay Dr. Alex Gibson, Superintendent of the Botanic Garden at Dapoore, Gujarath	The tract along the Ghats between Dhurrumpore and the Taptee, as being well adapted for the cultivation of timber trees; the valley of candeish for fruit trees, exotic; the banks of the Nerbuddah, the Vindhyan range, and the country between Ahmedabad and Ahmednuggur, northward for timbers, fruit trees, and medicinal plants from the temperate parts of the globe. (written by Mr. Nimmo to Dr. Browne who forwarded these remarks to Dr. Spry)  As regards ornamental trees and shrubs, the number of these introduced at various times by amateurs and practical horticulturists is considerable and yearly increasing (Dr. Alex Gibson)  The number of medicinal plants which could be supplied by us from this quarter of India for naturalization in the West Indies and some other of the colonies of England is not large. Some of Polygonums, Solanums, Crotons, Cannabis sativa, Vernonia anthelmintia, Xanthochymus, Egle Marmelos, Anacardium orientale, Calotropis gigantean, Sapindus emarginata, Zyziphus jujuba seem to me comprise most of the those peculiar to this part of India and which might be worth the trouble of naturalization in a foreign colony. (Dr. Alex Gibson)

**Table 3** continued

Province	Point of contacts for the court of Directors, EIC	Key remarks
Northern India	Mr. Henry Cope, Secretary of the Horticulture Society at Meerut Mr. Alexander Ronald Esq, Planter at Dunbaree on the eastern side of the Goruckpore District R. Montgomery Esq, Magistrate at Azimghur	It would also be highly desirable if we could introduce and raise some of the valuable trees growing on the continent of Central America, the West Indies and other parts of the globe, assimilating climate with ours (Mr. Henry Cope). The only return we can make you for the services we hope to receive at your hands, is a proffer of procuring for you a collection of Hill seeds from our gigantic neighbours of Himalayas which we think would in many instances prove acceptable addenda to your gardens in England (Mr. Alexander Ronald).
Central India	Major J. W. Ousely, Political Officer in charge of the Hoshungabad and Principal assistant to the commissioner Mr. R. H Mathews, Esq, Indigo Planter	The logwood is very extensively cultivated as an ornamental shrub. (Dr. Spry)
Bengal	Mr. T. A. Dearman, Deputy collector at Dacca Mr. Robert Ince, Secretary to the Barrisaul Agricultural and Horticultural Society Mr. Andrew Mills, Esq, Commissioner at Cuttack Rev. Mr. Williamson Missionary on the district of Beerbhoom	It has accordingly been recommended that the gradual introduction, from every part of the world, into India, of every variety of tree and plant adapted to its climate, should be an object steadily kept in view. (From Professor Royle, Court of Directors, EIC, to James Cosmo Melville, Esq. Secretary at the India House)

## References

- Bhagwat SA, Breman E, Thekaekara T, Thornton TF, Willis KJ (2012) A battle lost? Report on two centuries of invasion and management of *Lantana camara* L. in Australia, India and South Africa. PLoS ONE 7(3):e32407. doi:10.1371/journal.pone.0032407
- Bhatt YD, Rawat YS, Singh SP (1994) Changes in ecosystem functioning after replacement of forest by *Lantana* shrubland in Kumaun Himalaya. J Veg Sci 5:67–70
- Brahmam M (2003) Congress grass (*Parthenium hysterophorus*): a fast spreading biological pollutant. Community For 2:22–24
- Brandis D (1874) The forest flora of north west and central India: a handbook of the indigenous trees and shrubs of those countries. Wm. H. Allen & Co., London. Also available in <http://archive.org/stream/forestfloraofnor00stewuoft#page/n5/mode/2up>
- Broughton S (2000) Review and evaluation of lantana biocontrol programs. Biol Control 17(3):272–286
- Cameron J (1894) The forest trees of Mysore and Coorg. The Mysore Government Central Press. Also available in <http://archive.org/stream/cu31924001712169#page/n3/mode/2up>
- Cronk QCB, Fuller JL (1995) Plant invaders. Chapman and Hall, London
- Dawson W, Mndolwa AS, Burslem DFRP, Hulme PE (2008) Assessing the risks of plant invasions arising from collections in tropical botanical gardens. Biodivers Conserv 17:1979–1995
- Day MD, Wiley CJ, Playford J, Zalucki MP (2003) *Lantana*: current management status and future prospects
- Deena MJ, Thoppil JE (2000) Antimicrobial activity of the essential oil of *Lantana camara*. Filoterapia 71:453–455
- Delisle F, Lavoie C, Jean M, Lachance D (2003) Reconstructing the spread of invasive plants: taking into account biases associated with herbarium specimens. J Biogeogr 30:1033–1042
- Dobhal PK, Kohli RK, Batish DR (2011) Impact of *Lantana camara* L. invasion on riparian vegetation of Nayar region in Garhwal Himalayas. J Ecol Nat Environ 3:11–22
- Dogra KS, Kohli RK, Sood SK (2009) An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India. Int J Biodivers Conserv 1(1):004–010
- Donn J (1796) *Hortus Cantabrigiensis*: a catalogue of plants, indigenous and foreign cultivated in the walkerian botanical garden. John Burges Printer, Cambridge. Also available in <http://archive.org/stream/hortuscantabrig00gardgoog#page/n7/mode/2up>
- Duggin JA, Gentle CB (1998) Experimental evidence on the importance of disturbance intensity for invasion of *Lantana camara* L. in dry rainforest-open forest ecotones in north-eastern NSW, Australia. For Ecol Manage 109:279–292
- Foxcroft LC, Rouget M, Richardson DM, Fadyen SM (2004) Reconstructing 50 years of *Opuntia stricta* invasion in the

- Kruger National Park, South Africa: environmental determinants and propagule pressure. *Divers Distrib* 10:427–437
- Ghisalberti EL (2000) Review *Lantana camara*. *Fitoterapia* 71:467–486
- Grover JK, Yadav S, Vats V (2002) Medicinal plants of India with anti-diabetic potential. *J Ethnopharmacol* 81:81–100
- Hiremath AJ, Sundaram B (2005) The fire-lantana cycle hypothesis in Indian forests. *Conserv Soc* 3:26–42
- Hooker JD (1885) *Flora of British India. Asclepiadea to amarantacea*. vol 4, Published under the authority of the secretary of state for India in council, L. Reeve & Co, London
- Hornoy B, Tarayre M, Hervé M, Gigord L, Atlan A (2011) Invasive plants and enemy release: evolution of trait means and trait correlations in *Ulex europaeus*. *PLoS ONE* 6:10
- Juan S, Luo Y-Q, Zhou F, He P (2010) The relationship between invasive alien species and main climatic zones. *Biodivers Conserv* 19:2485–2500
- Kaplan H, Van Zyl HWF, Le Roux JJ, Richardson DM, Wilson JRU (2012) Distribution and management of *Acacia implexa* (Benth) in South Africa: a suitable target for eradication? *S Afr J Bot* 83:23–35
- Khuroo AA, Reshi ZA, Malik AH, Weber E, Rashid I, Dar GH (2012) Alien flora of India: taxonomic composition, invasion status and biogeographic affiliations. *Biol Invasions* 14:99–113
- Kohli KR, Daizy RB, Singh HP, Kuldip SD (2006) Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. *Biol Invasions* 8:1501–1510
- Krishna YC, Krishnaswamy J, Kumar NS (2008) Habitat factors affecting site occupancy and relative abundance of four-horned antelope. *J Zool* 276:63–70
- Lahkar BP, Talukdar BK, Sarma P (2011) Invasive species in grassland habitat: an ecological threat to the greater one-horned rhino (*Rhinoceros unicornis*). *Pachyderm* 49:33–39
- Loudon (1830) Loudon's *Hortus Britannicus*: a catalogue of all the plants indigenous, cultivated in or introduced to Britain. Also available in <http://archive.org/stream/loudonshortusbri00loudrich#page/n5/mode/2up>
- Moore JL, Runge MC, Webber BL, Wilson JRU (2011) Contain or eradicate? Optimizing the management goal for Australian acacia invasions in the face of uncertainty. *Divers Distrib* 17:1047–1059
- Paul TK (2010) The earliest record of *Parthenium hysterophorus* L. (Asteraceae) in India. *Curr Sci* 98:1272
- Pereira WE (1920) *Lantana* in the math-working circle of the Savantvadi State Forest. *Indian Forester*
- Petch T (1921) *Lantana* in Ceylon. *J Indian Bot* 2:302–306
- Prasad AE (2012) Landscape-scale relationships between the exotic invasive shrub *Lantana camara* and native plants in a tropical deciduous forest in southern India. *J Trop Ecol* 28:55–64
- Pyšek P, Prach K (1995) Invasion dynamics of *impatiens glandulifera*—a century of spreading reconstructed. *Biol Conserv* 74:40–48
- Pyšek P, Richardson DM (2008) Invasive plants. In: Jorgensen SE, Brian DF (eds) *Ecological engineering*. Vol. 3 of *Encyclopedia of Ecology*, vol 5, pp 2011–2020
- Richardson DM, Rejmanek M (2011) Trees and shrubs as invasive alien species—a global review. *Divers Distrib* 17:788–809
- Richardson DM, Pyšek P, Carlton JT (2011) A compendium of essential concepts and terminology in invasion ecology. In: Richardson DM (ed) *Fifty years of invasion ecology: the legacy of Charles Elton*. Blackwell Publishing Ltd., pp 409–420
- Roxburgh W (1814) *Hortus Bengalensis*: a catalogue of the plants growing in the Honourable East India Company's botanic garden at Calcutta
- Royle JF (1840) *Botanic garden established in Calcutta. Essay on the productive resources of India*. Wm. H. Allen and Co, London
- Russell MJ, Roberts BR (1996) Effects of four low-intensity burns over 14 years on the floristics of a blackbutt (*Eucalyptus pilularis*) forest in southern Queensland. *Aust J Bot* 44:315–329
- Sahu PK, Singh JS (2008) Structural attributes of *Lantana*-invaded forest plots in Achanakmar–Amarkantak Biosphere Reserve, Central India. *Curr Sci* 94:494–500
- Sankaran KV, Ellison CA, Suresh TA (2009) Major invasive alien weeds in India: Biology and Control. 1. Weeds-India-Control. Kerala Forest Research Institute. 632.5
- Shackleton CM, McGarry D, Fourie S, Gambiza J, Shackleton SE, Fabricius C (2007) Assessing the effects of Invasive alien species on rural livelihoods: case examples and a framework. *Hum Ecol* 35:113–127
- Sharma GP, Raghubanshi AS, Singh JS (2005) *Lantana* invasion: an overview. *Weed Biol Manage* 5:157–165
- Sims J (1812) Curtis's botanical magazine or flower garden displayed 35:1449
- Sousa R, Morais P, Dias E, Antunes C (2011) Biological invasions and ecosystem functioning: time to merge. *Biol Invasions* 13:1055–1058
- Spry HH (1841) Suggestions received by the Agricultural & Horticultural Society of India for extending the cultivation and introduction of useful and ornamental plants: with a view to the improvement of the agricultural and commercial resources of India
- Sundaram B, Hiremath AJ (2012) *Lantana camara* invasion in a heterogeneous landscape: patterns of spread and correlation with changes in native vegetation. *Biol Invasions* 14:1127–1141
- Tireman H (1916) *Lantana* in the forest of Coorg. *Indian For* 42(6):385–392
- Turner PJ, Downey PO (2010) Ensuring invasive alien plant management delivers biodiversity conservation: insights from an assessment of *Lantana camara* in Australia. *Plant Prot Q* 25:102–110
- Uma Shaanker R, Joseph G, Aravind NA, Kannan R, Ganeshiah KN (2010) Invasive plants in tropical human-dominated landscapes: need for an inclusive management strategy. In: Perrings C, Mooney H, Williamson M (eds) *Bioinvasions and globalization: ecology, economics, management and policy*. Oxford University Press, Oxford
- Vardien W, Richardson DM, Foxcroft LC, Thompson GD, Wilson JRU, Le Roux JJ (2012) The introduction history, spread, and current distribution of *Lantana camara* in South Africa. *S Afr J Bot* 81:81–94
- Voigt JO (1845) *Hortus Suburbanus Calcuttensis*: a catalogue of the plants which have been cultivated in the honorable east

- India company's Botanical Garden. Bishop's College Press, Calcutta. Also available in <http://archive.org/stream/hortussuburbanus00voig#page/n7/mode/2up>
- Wikimedia Commons (2012) Web link [http://en.wikipedia.org/wiki/File:British\\_india.png#filehistory](http://en.wikipedia.org/wiki/File:British_india.png#filehistory)
- William A (1789) *Hortus Kewensis* or catalogue of the plants cultivated in the Royal Botanical Garden at Kew. George Nicol Bookseller, Pall Mall
- Zalucki MP, Day MD, Playford J (2007) Will biological control of *Lantana camara* ever succeed? Patterns, processes & prospects. *Biol Control* 42:251–261