INVASION OF *LANTANA* INTO INDIA: ANALYZING INTRODUCTION, SPREAD, HUMAN ADAPTATIONS AND MANAGEMENT

Thesis submitted in fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

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Abstract

Objectives and Research Questions

1. To reconstruct the history of invasion of *Lantana* in India
   - from where, by who, and when was *Lantana* species introduced into India?
   - given its long history in the country, is it still spreading or has it become more or less stable?

2. To study the human adaptation to *Lantana* invasion: socioeconomic causes and consequences of the use of *Lantana* as an alternative source of livelihood for forest dependent communities in southern India.
   - how have local communities adapted to the invasion ?
   - what are the key determinants that may have driven communities to use *Lantana* ?
   - what are the economic consequences of the use of *Lantana* by local communities ?

3. To critically review local practices and forest policy for the management of *Lantana* in southern India.
   - how has the use of *Lantana* by local communities impacted its local regeneration ?
   - does the use of *Lantana* in local context have implications for its management ?
   - what has been the role of the Forest Department and its policies in managing *Lantana.*

Methodology

Objective 1: Spatial and temporal spread of *Lantana* in India was reconstructed using historical records since 1800's. The spread of *Lantana* from South America to Europe and then to India was traced by studying herbaria records from four major herbaria in India and the Royal Botanical Garden, Kew, UK. Using GIS tools the spread of

Lantana within India was traced. In particular the spread of *Lantana* was mapped for the Western Ghats regions, a biodiversity hotspot in South India. Using ecological niche modeling, the predicted spread of *Lantana* was arrived at. Finally, personal interviews with retired forest officers and local communities were used to trace more recent patterns in the invasion of *Lantana*.

Objective 2: Human adaptation to *Lantana* was studied by identifying groups or communities that used *Lantana* as a "resource" in contrast to those that did not. Structured questionnaire was administered to people from 6 hamlets in three different districts in Southern India. Data was analysed using several socioeconomic parameters such as family size, land holdings, forest based income, wage labour, skill diversity etc. Multi-variate statistical tools were used to analysis the direct and indirect influences of these variables on the dependent variable (of using *Lantana*).

Objective 3: For this objective, I studied the response of *Lantana* towards harvesting. Plots were laid that were respectively harvested and unharvest as control and the growth dynamics/regeneration of the plant followed up. The plants were monitored for their coppicing ability as well. Besides, the policy and working plan documents of the different Forest Department were anlaysed to unravel the role of specific forest policy in managing the spread of Invasive alien species.

Key Results

Objective 1: The introduction and subsequent spread of *Lantana* in India can be traced to three distinct stages spanning nearly 200 years; first, its introduction from Latin America to Europe, second, from Europe to India and finally its spread within India. Within India, *Lantana* first moved into the British cantonments either by multiple introductions or by movement across cantonments. Thereafter the plant moved across other regions in the country, presumably due to natural succession. An ecological niche model prediction was made on the potential areas of invasion in the Western Ghats. Empirical data from herbaria records shows that the plant has nearly swamped most of the predicted habitats.

Objective 2: My study showed that several communities in southern India have been using *Lantana* for the past 25 to 30 years and thus seem to have adapted to the invasive species for their livelihoods. I analysed the possible drivers that may have shaped this adaptation. Among a number of socioeconomic parameters that distinguish people using *Lantana* as opposed to people not using are: a) lack of access to natural or financial capital, b) lack of tenure land, c) lack of initial investment capabilities and d) lack of alternative livelihoods. In summary, for communities/families that used *Lantana*, the latter provided a zero-investment resource that could be encashed. I discuss these results in the context of utilizing invasive species as a limited tool towards managing them.

Objective 3: Harvesting of *Lantana* significantly impacted the plants' regeneration and coppicing ability. Cutting of *Lantana* at primary stem level lead to high mortality of *Lantana*. However the seed bank and rootstock remains in the soil, which may induce the regrowth of *Lantana* in the future. Local practices have had reasonable affect on *Lantana* control. On the other hand that may contribute to local manage practices to control further spread. Forest practices and working plans have from time to time realized the need to control Invasive alien species (IAS), but have not been successful. Based on these results I discuss the need to develop a comprehensive plan of management of IAS, especially in the protected areas of the country.

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Acknowledgments

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Invasion of alien flora in native ecosystems is considered as one of the biggest threats to biodiversity and ecosystem services globally (Head and Muir 2004; Pimental 2005; de Lange and van Wilgen 2010). There are many factors which determine and define the invasibility (the properties of a community, habitat or ecosystem that determine its vulnerability to invasion (Richardson et al. 2011)) of a plant (Alpert et al. 2000), including, a) those resulting from the move to a new geographic region and b) those inherent to the growth characteristics of the species.

In terms of the transfer of alien plants to new geographic areas, the factors that influence invasibility include:

a) Political boundaries: a plant may be native to a continent but invasive to a particular country or region under certain conditions or land uses (Richardson et al. 2011).

b) Enemy release: free from their native habitats, invasive alien species (IAS) are no longer reined in by pathogens, pests and consumers that may have otherwise kept their population in check (Hornoy et al. 2011).

c) Climate suitability: the micro or macro climatic characteristics of their new geographical area may be similar to the plant's native habitat and thus supportive of their establishment and growth (Juan et al. 2010).

d) Residence time in the new area: many invasives take several decades or longer in a new location before becoming sufficiently established to then become problematic invasive species.

However, not all plants that are intentionally or unintentionally transferred from one region to another become invasive. For instance, Foxcroft et al. (2010) reported that there are 583 non-native plants found in tropical savannas in southern Africa but only 151 (26%) of them turned to be IAS. This is because invasive species often share several of a suite of characteristics that allow them to spread at the expense of native flora. Their characteristics include:

a) Rapid vegetative growth: In many instances the IAS outcompete native flora by their rapid growth rate. le Maitre et al. (2011) found that the Australian *Acacia* species outcompete native flora by their rapid growth rate in South Africa.

b) Strong interspecific competitive abilities: The disappearances of native barriers (away from predators) give advantage to IAS over functionally similar species in the ecosystem that use the resources in a same way as the IAS (Valéry et al. 2008).
c) Production of large numbers of seeds that are easily dispersed enable the IAS to quickly dominate over the native vegetation (Aravind et al. 2010; Richardson and Rejmanek 2011). Many also have long lived and large seed banks. For example, Love et al. (2009) showed that often the seeds of the invasive species, *Lantana camara* L. could account for nearly 50–70% to the total soil seed bank in the invaded area; these seeds remain in the soil for many years and sprout whenever the seeds are exposed to light.
d) Ability to alter ecosystem structure, functional properties (such as fire regimes or soil moisture) and species composition, all of which reduce the capacity of native flora (Gooden et al. 2009).

Prior to the European global explorations in the 1400s and after, plant introductions were over shorter distances; between regions, neighbouring countries and across small stretches of ocean. Movements of plants across the globe accelerated after 1492 when Christopher Columbus sailed across the Atlantic Ocean and explored the New World (Myers and Bazely 2003). The explorers carried their native flora and domesticated livestock to the new world to support their survival in the alien ecosystem and in return they brought flora and fauna from the New World and introduced them in their homeland (Crosby 2004). The introduction of alien flora influenced the agriculture and horticulture industry of the countries colonized by the political powers of Europe. The colonial powers introduced several species in their colonies, of which some went on to invade the native landscapes and became invasive (Kannan et al. *in press*). Consequently, through their path of invasion, IAS compete with, marginalize and frequently usurp native biological diversity (Mooney and Hobbs 2000; Essl et al. 2010), and in extreme cases, can lead to the extinction of native species (Atkinson et al. 2000).

Unraveling the history of plant invasion unfolds some interesting case studies on unintentional introduction of plant species, which ultimately escaped and became invasive. For instance, *Parthenium hysterophorus* L., which was inadvertently introduced with imported wheat by the USA PL 480 scheme, went on to become one of the most potent invasive weeds in the Indian sub-continent (Brahmam 2003). Similarly, the movement of cargo ships and release of ship ballast water unintentionally transported and introduced several plants and microorganisms to new geographical areas (Ruiz et al. 2000; Lavoie et al. 2003).

Against the well-communicated overarching negative effects of IAS on biodiversity and ecosystem services, the global agenda has been to prevent and contain IAS and thereby to mitigate their impacts on local biodiversity and the ecosystem function and human health (Convention on Biological Diversity 2001). Control programmes cost billions of dollars annually around the globe. This has led to some researchers questioning both the rationale and necessity for such controls, and indeed at times the very notion and definition of an IAS. For example, some researchers have questioned the use of the term invasive or invasive alien species (e.g. Brown and Sax 2004; Larson 2007; Shackleton et al. 2007a; Warren 2007; Kull et al. 2011). Their questioning is based on several ambiguities in defining a plant as invasive and the circumstances under which it is deemed an IAS and those under which it is not. For example, the term invasive is a relative one and has often been used in a specific socio-political context. Thus, a specific species that has crossed a political boundary may be termed invasive when in fact it might be well within the geographical limits of its ecological niche (Brown and Sax 2004). Additionally, some question the predominance of western scientific notions in defining and labeling species as IAS with little consideration of alternative and local views of the same species (O'Brien 2006). Another reason for ambiguity relates to the changing status of a specific introduced species. Often a plant introduced for some economic reason but later disused may turn out to be invasive – for no other reason than its adaptability to spread and since it is disused, the plant often can mimic the features of an invasive plant. For example, Carruthers et al. (2011) argued that several Australia *Acacia* species were introduced into South Africa and other parts of the globe for their desirable (at that time) biological characters such as vigorous growth, timber value, nitrogen fixing abilities, etc., but later became invasive due to changes in political, economic and social contexts that shifted the priorities on the use of the species. An important facet that these debates have in common is the recognition of the need to situate debates about and management of IAS in broader paradigms of socio-ecological systems, rather than simply biological ones (Brown and Sax 2004; Larson 2007; Shackleton et al. 2007a; Davis et al. 2011).

Although the need to define and control IAS may be debated in academic fora, there is less uncertainty among ecologists, conservationists and practitioners on the ground. Most countries subscribe to international treaties such as the Convention on Biological Diversity, which requires signatory countries to identify, control and eradicate IAS. The Global Invasive Species Programme (GISP) is a multinational agency set up specifically to promote awareness at national levels around the negative impacts of IAS and the need for countries to have strong and appropriate prevention and eradication programmes. Within country strategies and resources to address IAS vary considerably. For example, in USA the use of herbicide against IAS amounts to three billion USD annually (Pimentel et al. 2005) and the South African government spends R600 million Rands per year (US $ 1= R7.7 in January 2010) through its Working for Water programme to control IAS (de Lange and van Wilgen 2010). Love et al. (2009) suggested that in India the recent estimation for *Lantana* (one of the major IAS in India) removal was Rs.9000/hectare (US $ 1= Rs.45 in 2009).

Despite the considerable expenditures and energies devoted towards containment and eradication of IAS there are not many examples of success, especially of total removal (Krug et al. 2010; Nunez and Pauchard 2010; Bhagwat et al. *in press*). Prominent examples include the control of IAS by the Working for Water Programme in South Africa, *Lantana* in Hawaii and *Opuntia monacantha* Haw. in the Cape region in South Africa and several species from the Galapagos Islands (Zimmermann et al. 2004; Zalucki et al. 2007; de Lange and van Wilgen 2010; Davis et al. 2011; Bhagwat et al. *in press*). However, this may be a reflection of awareness around IAS being insufficiently widespread until 2 – 3 decades ago, and hence most IAS control programmes have not been operating for sufficiently long periods. Trying to undo decades or centuries of invasion by one or more IAS in a specific country is bound to require considerable time. The limited success is further compounded by the fact that preventing and controlling the spread of IAS is often enormously expensive (Pimentel 2005; Shaanker et al. 2010). For example, the Working for Water (WfW) programme in South Africa (perhaps one of the longest running and researched control programmes in the world) has spent more than a billion dollars over the last 15 years and yet a recent evaluation shows that for the most aggressive IAS the area invaded has not declined (van Wilgen et al. 2012). In other words, the expensive WfW programme has simply prevented greater expansion, but not succeeded in reducing the area infested. To do so will require markedly more financial resources and improved efficiencies. Obviously, management of IAS in developing countries of the tropics, which incidentally also happen to have more biodiversity and some of the worst cases of IAS, is thus heavily constrained with limited budget, technology and awareness (Perrings 2005; Nunez and Pauchard 2010).

1.2 Management of IAS in tropical human-dominated landscapes

The management of IAS is especially challenging in tropical human-dominated landscapes. First, in these habitats, IAS can exacerbate biodiversity crises. This is because these areas are rich in native biodiversity and thus IAS impacts can have significant consequences in reducing the population densities of some indigenous species (Millennium Ecosystem Assessment 2005). Secondly, many of these regions are experiencing rapid land transformation pressures as a result of increasing human populations (Millennium Ecosystem Assessment 2005). The combination of these pressures and IAS simultaneously can be disastrous for selected native biota. Thirdly, in these regions, rural communities have a high dependence on plant resources collected from the immediate environment many of which fulfill subsistence needs of the rural poor (Shackleton et al. 2007b; Rist et al. 2010; Ticktin et al. 2012). In many of these regions, Non-Timber Forest Products (NTFPs) constitute an important source of livelihood for millions of people (Shaanker et al. 2004a; Saha and Sundriyal 2012). In India alone, it is estimated that over 50 million people are dependent on NTFPs for their subsistence and cash income (Rasul et al. 2008; Behera 2009; Mahapatra and Shackleton 2011). Recent studies in India have shown that traditional income sources from forest-based resources could be jeopardized by IAS, both directly due to the IAS impact on resources, and indirectly by rendering these resources less accessible for collection and harvest (Shaanker et al. 2004a; Sundaram and Hiremath 2012; Ticktin et al. 2012). Thus, under these circumstances, IAS could potentially lead to further marginalization of the already impoverished livelihoods of the people in the tropical human-dominated landscapes.

On the other hand, in these landscapes, some IAS has been incorporated into local livelihoods. For example, Australian *Acacia* species are highly valued by poor households in South Africa for fuel wood and charcoal and the value of this trade is about US $ 143 million per annum (Pejchar and Mooney 2009). Similarly, poor rural households in Kenya highly depend on *Prosopis juliflora* for their fuel wood needs (Mwangi and Swallow 2008). Many communities depend on IAS largely for subsistence and in some cases for important cash income. For example, *Piper aduncum,* native of Central and South America, is heavily used by local communities in Papua New Guinea for a variety of uses including agriculture (to control soil erosion, as fences, tool handles, etc.), household use (construction poles and fire wood) and for medicinal purposes (for diarrhea, cough, tooth ache) (Siges et al. 2005). In fact, the local communities in Papua New Guinea prefer *Piper* over native species for its salient features and now it has become part and parcel of their lifestyle.

It is thus not uncommon, although paradoxical, that the control of IAS in these situations may lead to a loss of rural livelihood options (Kull et al. 2011). Control is typically advocated on ecological and conservation grounds, but with limited consideration of the social or economic implications to local people (Shackleton et al. 2007a). While the resolution of this dilemma - to control or not - is admittedly a difficult one to address, it throws open serious challenges to the conventional wisdom regarding definition of and approaches to managing IAS, at least for human-dominated tropical landscapes. However, from the food crop literature there are serious concerns expressed with promoting the use of alien species. As Nunez et al. (2012) argue, there is an inherent danger in promoting IAS for food product (and by extension any useful product) as it may lead to introduction of IAS into areas where it is not yet present, and promote maintenance or even intensification in areas where they already occur, with the potential for broader impacts on ecosystem goods and services.

Unfortunately, mainstream research on management of IAS has scarcely addressed the management requirements of IAS in tropical human-dominated landscapes. In fact, as argued by Shackleton et al. (2007a), the impact of IAS on rural livelihoods has received little attention, despite the fact that it is their (rural) land and waters that are most affected by IAS. Consequently, it appears that solutions to the management of

IAS need to be re-examined or adapted in some situations, especially in the tropics where IAS can affect human livelihoods both negatively and positively (Shaanker et al. 2010). In other words, besides the existing strategies for the management of IAS, there is a need for alternative strategies in terms of the net benefits they may yield, taking of course all benefits and costs into account.

1.3 The case of *Lantana* as an alien invasive species

Lantana camara L. (Verbenaceae), (hereafter referred to as *Lantana)*, is one of the most notable IAS in more than 10 bioregions of the world (Ghisalberti 2000; Richardson and Rajmank 2011). Native to Central and South America, popularly known as wild or red sage, the species is now reportedly distributed and established in over 12 bioregions and more than 60 countries globally (Richardson and Rejmanek 2011). These numbers alone serve to illustrate its credentials as an aggressive IAS. The Dutch moved *Lantana* to Europe in the 1600s for its ornamental purpose (Ghisalberti 2000; Ray et al. 2012). It was subsequently introduced in other colonies of the European powers, such as South Africa, India and Australia (Bhagwat et al. *in press*). Currently *Lantana* has invaded more than four million ha in Australia (Taylor and Kumar *in press*), 13 million ha in India and two million ha in South Africa (Bhagwat et al. *in press*). The plant produces copious fruits and is mainly distributed by birds and mammals over long distances, which further aggravates its spread (Taylor et al. *in press*). Seed recruitment and species diversity are greatly reduced in *Lantana* invaded landscapes compared to non-invaded landscapes (Gooden 2009; Sundaram and Hiremath 2012).

Lantana invasion could be accelerated by climate change (Taylor et al. *in press*) and many regions in North Africa, Europe and Australia may become climatically suitable for *Lantana* and in South Africa and China its distribution would expand. While most studies demonstrate an adverse effect of *Lantana*, such as reduction in native species diversity, inducing and altering forest fire regimes, a few have shown some positive effects of the plant. For example, Ghisalberti (2000) evaluated the properties of *Lantana* and found that extracts from flowers and leafs contain insecticidal properties and in particular a repellent effect on *Aedes* mosquitoes.

1.4 *Lantana* as an IAS in India

Lantana was first introduced by the British into India, at the East India Company Botanical Garden, Calcutta, in 1807, as an ornamental plant (Kannan et al. *in press*). Since then the species has spread across the length and breadth of the country and has displaced several native species (Bhatt et al. 1994; Sahu and Singh 2008; Dogra et al. 2009). Attempts to control *Lantana* in India have not been successful (Bhagwat et al. *in press*). Innumerable studies have been conducted to assess the impacts of *Lantana* on ecosystem structure, function and services (Sundaram and Hiremath 2012; Sundaram et al. *in press*; Taylor et al. *in press*).

Several methods of controlling *Lantana*, including chemical, mechanical, fire and biological, have been tried, but with limited success (Love et al. 2009; Sundaram and Hiremath 2012; Bhagwat et al. *in press*). Early records of the forest working plans and reports show some concern with the invasion of *Lantana* into timber and coffee plantations in the 1920s, followed by isolated and small-scale efforts at control (Chapter 2). 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. *Lantana* patches prevented grazing and thereby prevented the regrowth of grass and shrub species. Often attaining a height of 8 – 12 m 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 even today. Tireman (1916) wrote in the Indian Forester that *Lantana* proliferation was intolerable in Coorg and that significant funds were infused by the state to control *Lantana*. He also reported that elephants were employed to remove *Lantana* in Madras and Wayanad. According to Tireman, in Coorg, *Lantana* was uprooted and burnt because fire was the cheapest method of removing *Lantana*. Fire is one of the cheapest methods even today and is the most commonly used method for controlling *Lantana* and is often used in grazing areas (Love et al. 2009). However, mature *Lantana* is fire tolerant and re-growth from seeds and basal shoots is common (Hiremath and Sundaram 2005).

1.5 Disturbance and protracted invasion of *Lantana* in the Western Ghats

In Biligiri Rangan Hills Wildlife Sanctuary in the Western Ghats, the indiscriminate extraction of bamboo and other native resources leading to disturbance in the forest could have played a major role in the protracted expansion of *Lantana*. Shaanker et al. (2004) showed that the indiscriminate extraction of bamboo by the pulp industry from 1935-1975 in the northern part of the Biligiri Rangan Wildlife Sanctuary reduced the bamboo cover in the region from 118 km^2 to 12 km^2 (accounting for 90% loss in area). They also found the supply of bamboo to Mysore Paper Mill in Bhadravathi decreased from 35 433 tonnes in 1991-92 to 13 973 tonnes in 1998-99. In the same region, Sundaram and Hiremath (2012) reported that the *Lantana* invasion has increased manifold (33%) from 1997 to 2007. It seems that the expansive spread of *Lantana* in this forest region could have been enabled by the sites opened up by bamboo loss (Figure 1.1.). le Maitre et al. (2011) indeed argued that disturbance (fire, clearing, slashing, etc.) to native ecosystems can lead to a protracted invasion by IAS.

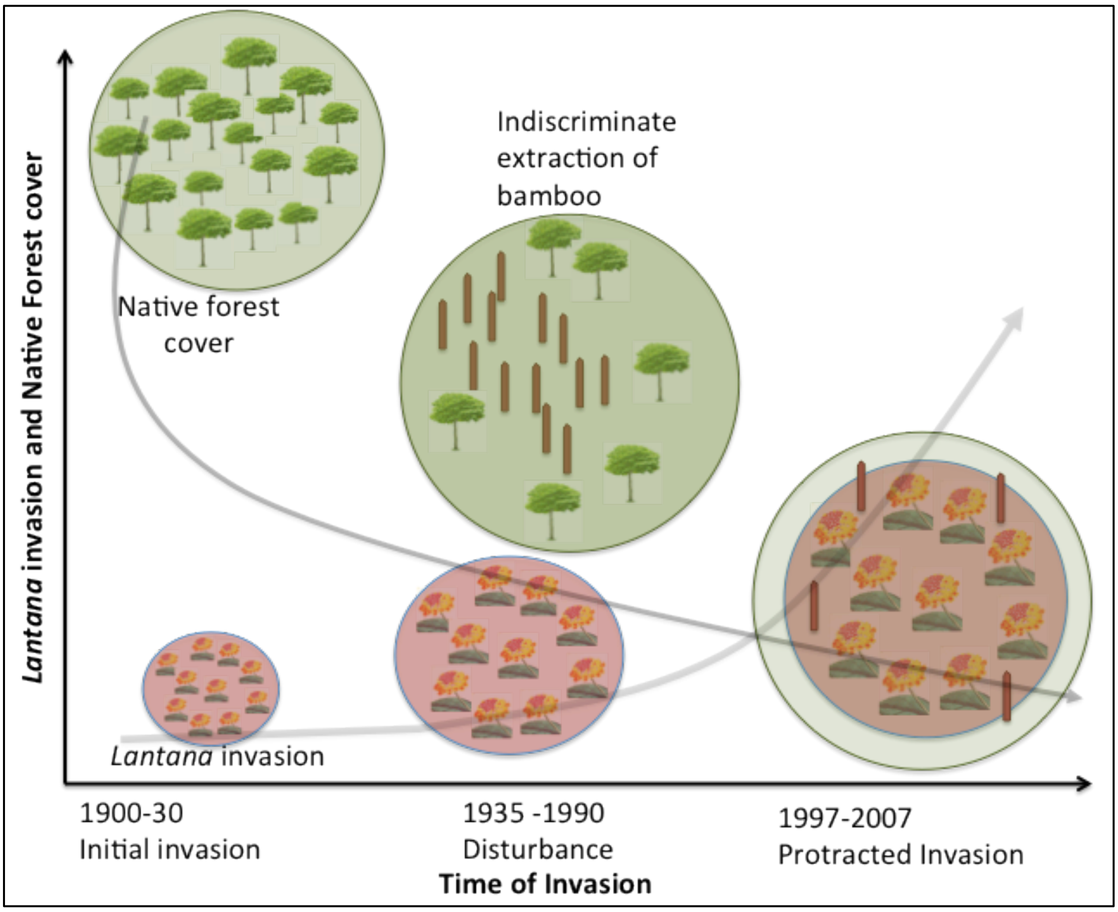


Figure 1.1. Disturbance and protracted invasion of Lantana in the Western Ghats

In India, a number of forest-dwelling communities depend almost exclusively on forest resources for their livelihood (Rasul et al. 2008; Saha and Sundriyal 2012). Among these communities are the Koravas, Madigas and tribal communities, such as the Soligas and Palliyars (Shaanker et al. 2010; Rist et al. 2011). These traditional weaving communities are often hereditarily dependent on bamboo and rattan resources, with most of them having no other means of livelihood (Shaanker et al. 2004b; Kannan et al. 2009). In recent years, indiscriminate extraction of bamboo and rattan (the two materials most preferred for weaving) has severely depleted the natural stocks and in many places has directly threatened the livelihoods and further marginalized these communities (Shaanker et al. 2004b). A lack of alternative sources of income and land tenure has further aggravated the challenges faced by these marginalized communities. Any effort that can offer an appropriate substitute for the declining wild bamboo and rattan resources could make a substantial difference to their livelihood. In this regard, Kannan et al. (2009) found that there are a number of communities using the locally abundant *Lantana* as a substitute for bamboo and rattan to make baskets and furniture in southern India. This provided an opportunity to undertake in-depth research into the use of an IAS, *Lantana*, and, as described by Shackleton et al. (2007a) investigate the conflicts of interest such use poses with respect to the control or not of this species. It also raises the question of whether this should be viewed as a conflict of interest. If the use of an IAS by local communities is sufficient to control its spread, then the negative ecological and conservation impacts can be reduced whilst simultaneously promoting socioeconomic livelihood benefits. However, there has been no such assessment in India, or to my knowledge internationally, in examining both the uses of an IAS and whether such use offers some prospect for control.

1.6 Seeking synergies: IAS control through use

The current views on managing IAS stem from the fact that these species typically result in ecological and economic decline over time. While the weight of evidence does justify this view, management or lack of it has often resulted in IAS occupying a predominant ecological space that is simply beyond any control measures (Bhagwat et al. *in press*). Under these circumstances, management worldviews and perspectives have often constrained the development of alternate management paradigms and regimes to address the issue of IAS, especially at more local scales.

One such alternate strategy is to identify approaches towards the utilization of IAS as one means of managing them. This approach, however, might not appear parallel to the entire purpose of eradicating IAS. However, as noted earlier, viewed from the point of minimizing the net cost of the invasive, exploitation of the invasive represents a potential approach towards this end. Thus, under certain boundary conditions when conventional management options were initiated too late to be cost effective and the IAS has been firmly entrenched, it might be worthwhile to consider alternate strategies, which include exploiting the species. In short, this calls for a shift in our view of managing IAS, from one of exclusion to that of inclusion.

Such a shift may not only be pragmatic but also realistic, especially in tropical human-dominated landscapes, where, as argued, low per capita incomes and preponderance of the IAS constrain effective control while the compulsions of rural livelihoods necessitate the invasive's utilization. In this context, IAS, especially those that have escaped effective control and eradication, could be viewed as a specific case of management.

1.7 Objectives

Against this background, this thesis reports on my research to a) explore the possible introductory pathways of *Lantana* from South America to India, b) understand the introduction history and spread of (time of invasion) *Lantana* in different parts of India, c) critically examine the management policies on IAS and management practices of *Lantana* and d) identify local adaptation practices such as the use of *Lantana* by local communities and ask if these responses by communities can indeed make a difference to the management of *Lantana*. Critical analysis of this question is potentially important to understand the drivers that allow communities to use IAS as bio-resources as well the socioeconomic consequences such use may have. I set forth to examine these issues by examining the following specific objectives as encapsulated in Figure 1.2.:

1. To reconstruct the history of invasion of *Lantana* in India.
2. To study the human adaptation to *Lantana* invasion: socioeconomic causes and consequences of the use of *Lantana* as an alternative source of livelihood for forest-dependent communities in southern India.
3. To critically review local practices and forest policy for the management of *Lantana* in southern India.

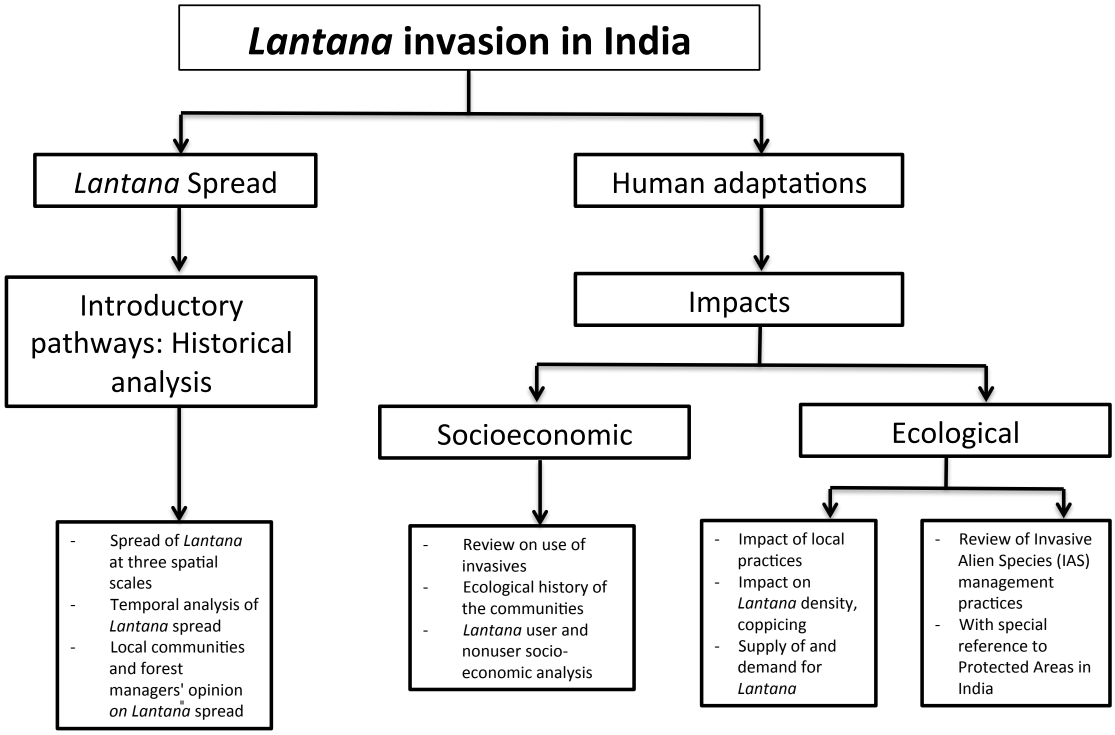


Figure 1.2. Conceptual flow of the study

Objective 1. To reconstruct the history of invasion of *Lantana* in India

In this section I have attempted to reconstruct the history of invasion of *Lantana* in India. Though it was generally known that *Lantana* was introduced by the British into India sometime in early 1800’s the exact route it took from South America to Europe and then on to India was not unraveled. Also not known were the specific circumstances under which species were mass introduced from South America to the European and British colonies. Understanding the temporal and spatial dynamics of the introduction and its subsequent spread in the Indian subcontinent would not only enrich our understanding of the process, but might also help in the possible containment or management programme at larger geographical scale. I reconstructed the history of introduction and spread by critically evaluating archival and historical and floristic records of plant imports for the last 200 years during the period before and after British colonization. I also analysed 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.

Objective 2. To study the human adaptation to *Lantana* invasion: socioeconomic causes and consequences of the use of *Lantana* as an alternative source of livelihood for forest-dependent communities in southern India

In this chapter I have analysed the use of *Lantana* by local communities in southern India and identify the possible causes and consequences of its use. In the study site, several communities have been using *Lantana* for fuelwood, in fencing their agricultural lands and as a substitute for scarce bamboo and rattans to make baskets and furniture. From the context of human adaptations to biodiversity change (Fabricius et al. 2007) and in this specific context, I asked a) what are the critical socioeconomic parameters that distinguish people or communities that use *Lantana* (the user group) compared to people that do not use (the nonuser group)? b) what are the key determinants that promote its use by communities? c) can such learning catalyze the use of *Lantana* in other communities and landscapes where the species is abundant?, and d) what are the tangible economic gains to communities that have gone on to using *Lantana*. The study was conducted in six different hamlets in three districts of southern India where *Lantana* is abundant and has invaded both forest and farmlands (Shaanker et al. 2010). The methods included both a questionnaire survey about the socioeconomic status of the user and nonuser households and an analysis of the ecological history of the communities in the region.

Objective 3. To critically review local practices and forest policy for the management of *Lantana* in southern India

In this chapter, I assessed the extent of utilization of *Lantana* by local communities in southern India and examine the impact thereof on the regeneration and coppicing of *Lantana*. Based on the study, I discuss whether the use of *Lantana* by local communities has significantly affected its local regeneration and if so, do such extraction practices have implications for the local management of IAS. I have employed several approaches including questionnaire and primary fieldwork to estimate the utilization of *Lantana* by the communities and its likely impact on the regeneration and coppicing of *Lantana*.

Finally, I also reviewed the existing policies on IAS and its implications on management of IAS in India with special reference to Protected Areas (PAs). I reviewed the Indian Forest Policy documents such as National Forest Commission Report, Indian Forest Act, Wildlife Protection Act, and others to understand the policy implications over the last half-century towards management of IAS. Forest Department working plans for Tamil Nadu, Kerala, Maharashtra and Goa were reviewed and specific plans contributing to IAS management – in terms of budget allocation for IAS removal, manpower use and how long they have been doing this in each site were documented and analysed. I also interviewed the retired forest officials who worked across the Western Ghats in Tamil Nadu, Kerala, Karnataka, Maharashtra and Goa and also reviewed the management practices of major IAS to identify their contribution in IAS management.

CHAPTER 2

RECONSTRUCTING THE HISTORY OF INTRODUCTION AND SPREAD OF THE INVASIVE SPECIES, *LANTANA*, AT THREE SPATIAL SCALES IN INDIA[1]

[1] *Kannan R, Shackleton CM, Shaanker RU (in press) Reconstructing the history of introduction and spread of the invasive species, Lantana, at three spatial scales in India. Biological Invasions, DOI: 10.1007/s10530-012-0365-z*

2.1 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 15thand 19th centuries saw a quantum jump in transfers of alien 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 eight 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 accidently 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 chapter, I have reconstructed the introduction and spread of *Lantana* in India. *Lantana* is regarded as one of the ten worst invasive species in the world (Ghisalberti 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 17th century from Brazil and later to other countries (Ghisalberti 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 (Ghisalberti 2000; Zalucki 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 chapter I 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, I 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? I used 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. I 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*.

2.2 Methodology

To reconstruct the history of *Lantana* introduction and its spread in India I employed two broad 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 analysing 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, I restrict my discussion to the genus, *Lantana*.

2.2.1 International and national spread of *Lantana*

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

2.2.1.1 Archival and historical information

I 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 and http://www.biodiversitylibrary.org which provide access to literature published prior to 1947. Based on the analysis of these different sources I inferred the probable path of introduction and spread of *Lantana* in India.

2.2.1.2 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. I 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 2003), which allowed mapping of the spread of *Lantana.*

2.2.2 Local scale case study

As a specific local case study, I 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, I 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, I 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 (n= 61). Within each community I 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 (±10.4).

Lastly, based on the occurrence data from the surveys and herbaria sheets for the Western Ghats I 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 programme uses the following variables such as mean of diurnal range (mean of monthly × (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, I analysed the pattern of spread of *Lantana* over the 150 years from 1850 to 2000 in the Western Ghats. Finally, based on these data, I projected the possible potential distribution of *Lantana* in the Western Ghats.

2.3 Results

2.3.1 Historical Introduction and Spread at the International and National scales

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 2.1.).

Table 2.1. 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	*L. involucrate* L.	1690	Native of West Indies and cultivated in the Royal Garden at Hampton Court, London[1,2,3]
2	*L. camara* L.	1691	Native of the West Indies. Cultivated in the Royal Garden at Hampton court, London[1,2,3]
3	*L. aculeate* L.	1692	Native of the West Indies. Cultivated in the Royal Garden at Hampton court, London[1,2,3]
4	*L. africana* L.	1731	Native of the Cape of Good Hope and cultivated by Mr.Philip Miller[1,2]
5	*L. melissifolia* Sol.	1732	Native of West Indies and cultivated by James Sherard[1,3]
6	*L. trifolia* L.	1733	Native of the West Indies and introduced before 1733 by Willam Houstoun, M.D[1,3,4]
7	*L. annua* L.	1733	Native of South America and introduced before 1733 by Willam Houstoun, M.D[1,3]
8	*L. recta* Cham.	1758	Native of Jamaica and cultivated by Mr. Philip Miller[1]
9	*L. odorata* L.	1758	Native of the West Indies and cultivated by Mr. Philip Miller[1,2,3]
10	*L. scabrida* Sol.	1774	Native of the West Indies and introduced by Mr. Gilbert Alexander[1,3]

Source: [1]*William A(1789)Hortus Kewensis. 2. pp 352*; [2]*Donn J (1796) Hortus Cantabrigiensis. Pp 72;* [3]*Loudon (1830). Loundon's Hortus Britannicus (1). pp. 245;* [4]*Sims J (1812)Curtis's Botanical Magazine or Flower Garden Displayed. 35. pp. 1449)*

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 17th century and it was exported as an exotic plant to the European colonies between 1800 and 1900 (Figure 2.1.).

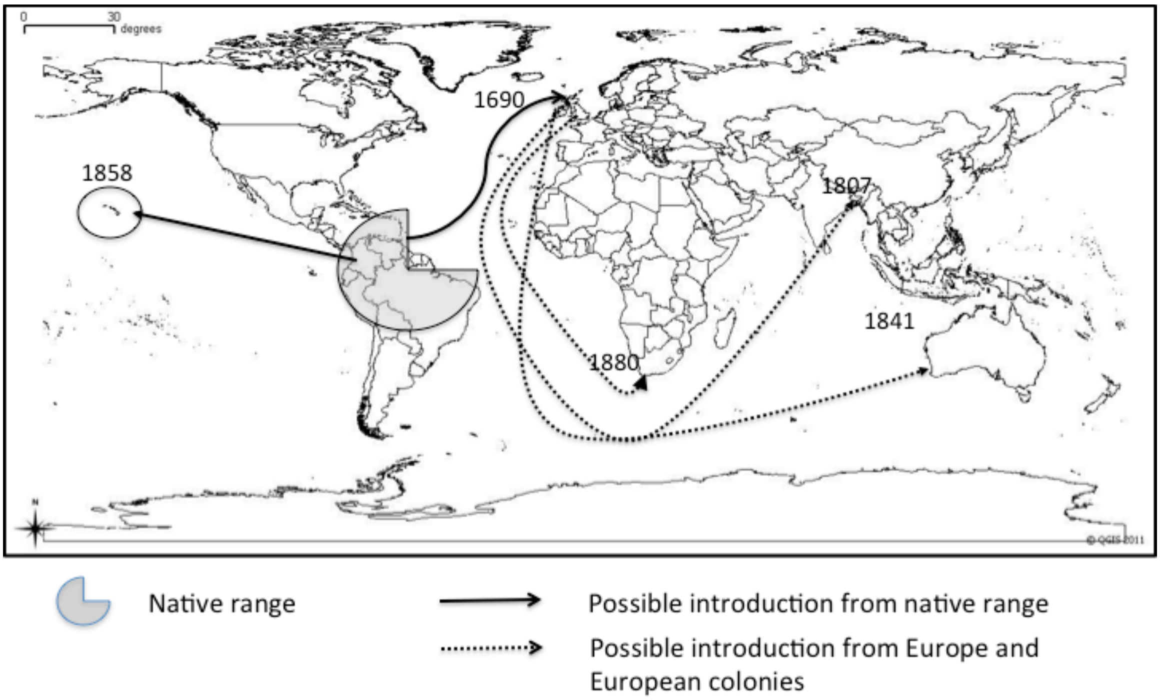


Figure 2.1. Probable routes of Lantana introductions from Latin America to the rest of the world (updated from Cronk and Fuller (1995)). (*Note that our study suggest that Lantana moved from Latin America to Europe as early as 1690*).

(Source: William A (1789) Hortus Kewensis, p.352 Roxburgh W (1814) Hortus Bengalenesis. p46, 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 (1913). Flora of Capensis: being a systematic description of the plants of the Cape colony, Caferaria and Port Natal.5.pp 189-192)

2.3.2 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 various botanical gardens in the country. Mughal Kings, who ruled India from 1526-1700, 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 Roxbourgh, and 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).

Table 2.2. 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 anthelmintiea, Xanthochymus, Egle Marmelos, Anacardium orientale, Calotropis gigantean, Sapindus emarginata, Zyziphus Jujuba seem to me to comprise most of those peculiar to this part of India and which might be worth the trouble of naturalization in a foreign colony. (Dr. Alex

		Gibson)
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)

2.3.3 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 Bengalenesis* (Table 2.3.). 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, Dapooree 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 2.3.). Based on the floristic records published between 1800-1900, 12 species of *Lantana* find mention, 11 of which are of American origin.

The first citation that I 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*.

Table 2.3. Lantana species introduced into India *(based on archival and Herbaria records from 1814; ordered by earliest to most recent)*

Sl. No	***Lantana* Species**	**Year**	**Record**	**Location**
1	*L. trifolia*	1807	Archival	Introduced in the East India Company's Botanical Garden, Calcutta[1, 2]
2	*L. aculeata*	1809	Archival	Introduced in East India Company's Botanical Garden, Calcutta[1, 2]
3	*L. camara*	1814	Herbaria	Found wild in Pachmarhi
4	*L. gogchana* Buch.	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[2]
5	*L. nivea* Vent.	1845	Archival	Cultivated in the East India Company's Botanical Garden, Calcutta[2]
6	*L. odorata*	1845	Archival	Cultivated in East India Company's Botanical Garden, Calcutta[2]
7	*L. sellowiana* Link &Otto.	1845	Archival	Cultivated in the East India Company's Botanical Garden, Calcutta[2]
8	*L. canescens* Kunth.	1845	Archival	Cultivated in the East India Company's Botanical Garden, Calcutta[2]
9	*L. alba* Mill.	1847	Herbaria	Found in the Herbaria of Nicol Alexander Dalzell, Bombay
10	*L. aculeata*	1857	Herbaria	Found wild in the Bombay presidency
11	*L. dubia* Wall.	1871	Herbaria	Found in the upper Himalyan area of Kumoun
12	*L. alba* Mill.	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[3]
13	*L. trifolia*	1878	Herbaria	Found wild in Conoor, Ooty
14	*L. odorata*	1880	Herbaria	Found cultivated in the Serampore Botanical Garden, Howrah
15	*L. crenulata* Otto & A.Dietr	1885	Archival	North Western India. Royle Falconer; Moradabad (cultivated) [5]

16	*L. wightiana* Wall.	1885	Archival	Found wild in South Madras in or near hills. Palani Mountains and Courtallum in the Western Ghats [5]
17	*L. camara*	1891	Archival	Extensively used as a hedge plant in Bangalore [4]
18	*L. nivea*	1894	Herbaria	Found wild in the Mussorrie hill
19	*L. crenulata*	1898	Herbaria	Kotdwara, Kheri, Oudh
20	*L. wightiana*	1901	Herbaria	Found wild in the River Aliyar, Pollachi
21	*L. mista*	1909	Herbaria	Found wild in Rangpoo, Sikkim
22	*L. involucrate* L.	1914	Herbaria	Cultivated in the Botanical Garden, Saharanpur
23	*L. montevidensis* (Spreng.) Briq.	1956	Herbaria	Found wild in Kothagiri, Nilgiris around 4, 500 ft
24	*L. urticifolia* Mill.	1956	Herbaria	Found wild in Dehradun
25	*L. sellowiana*	1957	Herbaria	Found wild in Kothagiri, leaves were very small and no prickles

(Source: [1] *Roxburgh W (1814) Hortus Bengalenesis. pp46;* [2] *Voigt J.O (1845) Hortus Suburbanus Calcuttensis. pp 472;* [3] *Brandis D (1874) The forest flora of North West and Central India. pp 369;* [4] *Cameron J (1894). The forest Trees of Mysore and Coorg (Third Edition). pp 214-15;*[5] *Hooker J.D (1885). Flora of British India. pp. 562-63)*

2.3.4 Herbaria records of *Lantana* collection in India

I 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 (Figure 2.2.). 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 2.3.).

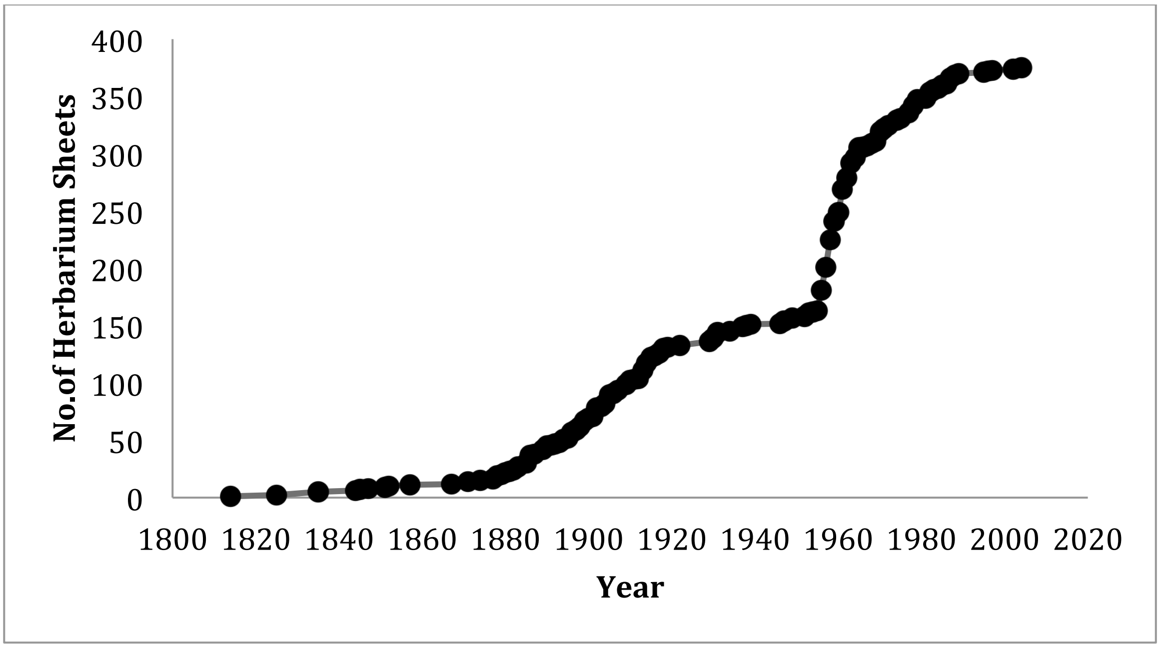


Figure 2.2. Herbarium records of Lantana species in India

It is noteworthy that the majority (86%) of herbaria records between 1800-1900 were from areas of concentrated British presence, such as British Cantonments (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 (Figure 2.3.). As mentioned earlier, the Court of Directors of the EIC supplied economically valuable and ornamental 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, Mussorrie, Chamba, Kouduru, Delhi, Quilon, and botanical gardens such as Darjeeling, Pune, Serampore, Saharanpure, Bangalore and Udhagamandalam (Ooty).

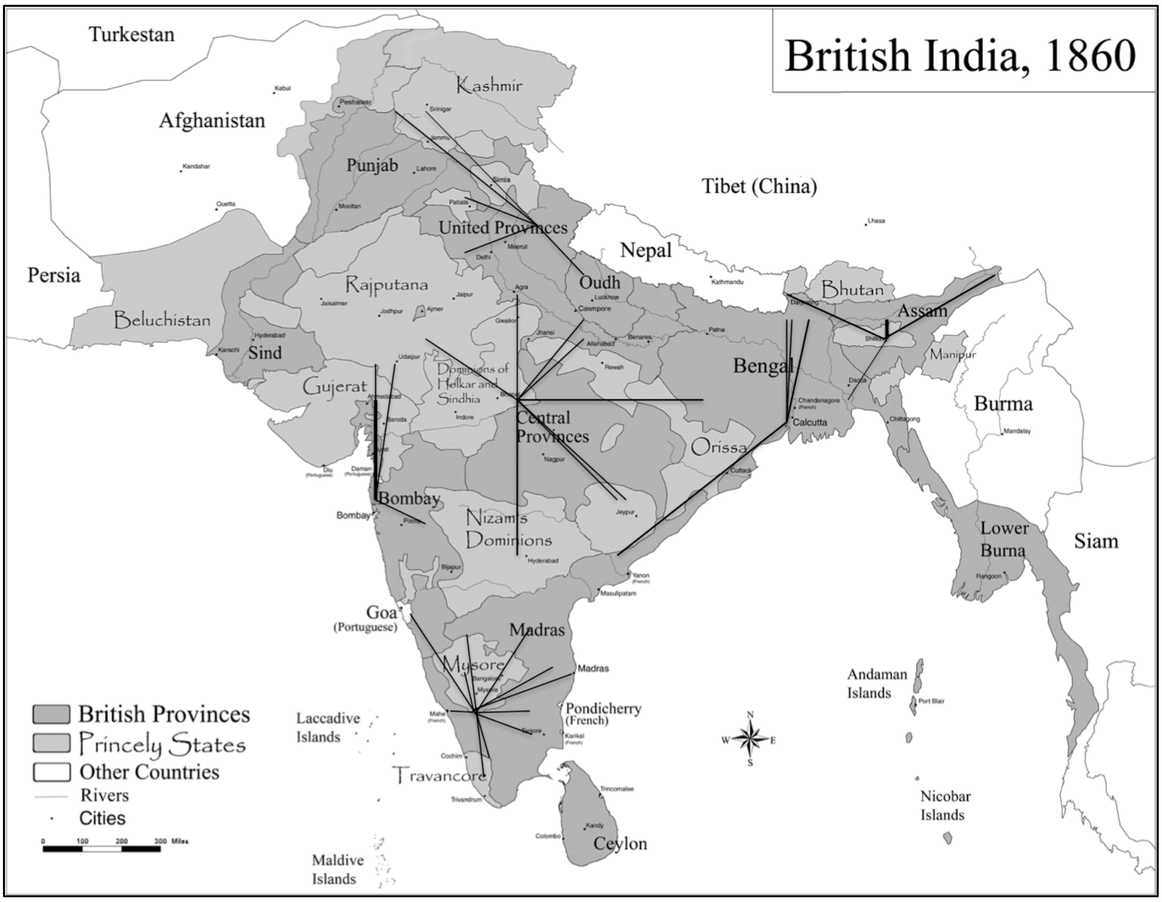


Figure 2.3. Probable Lantana introduction and spread pathways from the British cantonments and botanical gardens. *(British India Map Source: Wikimedia commons)*

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

I 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.

2.3.5 Spread into the wild in India

A number of references to *Lantana* were found as early as 1894 in the *Indian Foresters*. 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 cutting, burning, and uprooting. Often these programmes were coupled with planting of bamboo to replace *Lantana*, as was done in Savanthavadi, Maharahstra for four years (1911-1914) (Pereira 1920). Between 1900 and 1965 I found 15 articles that dealt with control measures such as manual and bio-control.

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 3-10 m 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.

2.3.6 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 Forests, 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^2 in the first year, Rs. 2 471/ km^2 in the second year and Rs.12 35/ km^2 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 three years. It appears that this species was *Lantana 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^2, of which 141 km^2 had been cleared; Government waste land, 161 km^2; reserved forests, 299 km^2. An extensive scheme for eradicating *Lantana* over an area of 255 km^2 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 eleven or twelve 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.

2.3.7 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 Nilgiries), 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 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 fifty 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 is appears that *Lantana* invasion into new regions is still 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 (Figure 2.4.) 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 (Figure 2.4.). 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).

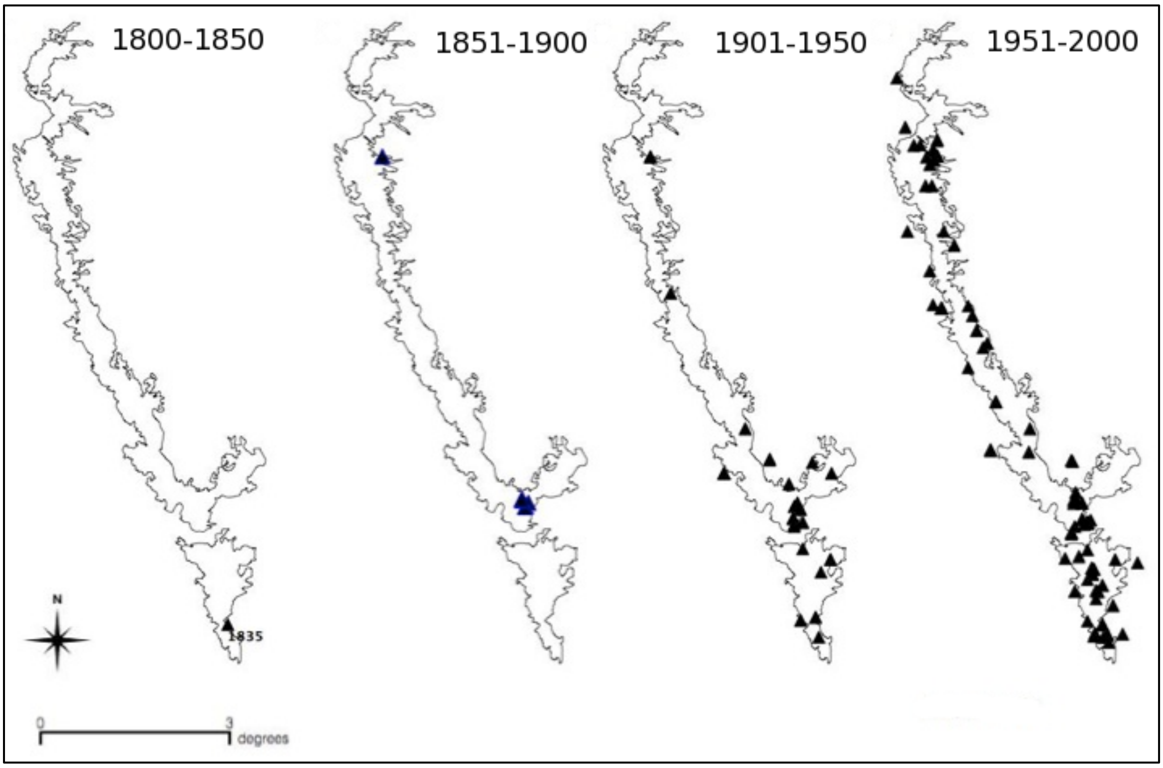


Figure 2.4. Spatial spread of Lantana in the Western Ghats in last 200 years 1800-2000
(each triangle represents individual collections)

2.3.8 Ecological niche model (ENM) predictions

Based on herbaria accessions, an ecological niche model (ENM) map for *Lantana* spread in the Western Ghats was generated (Figure 2.5.). 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.

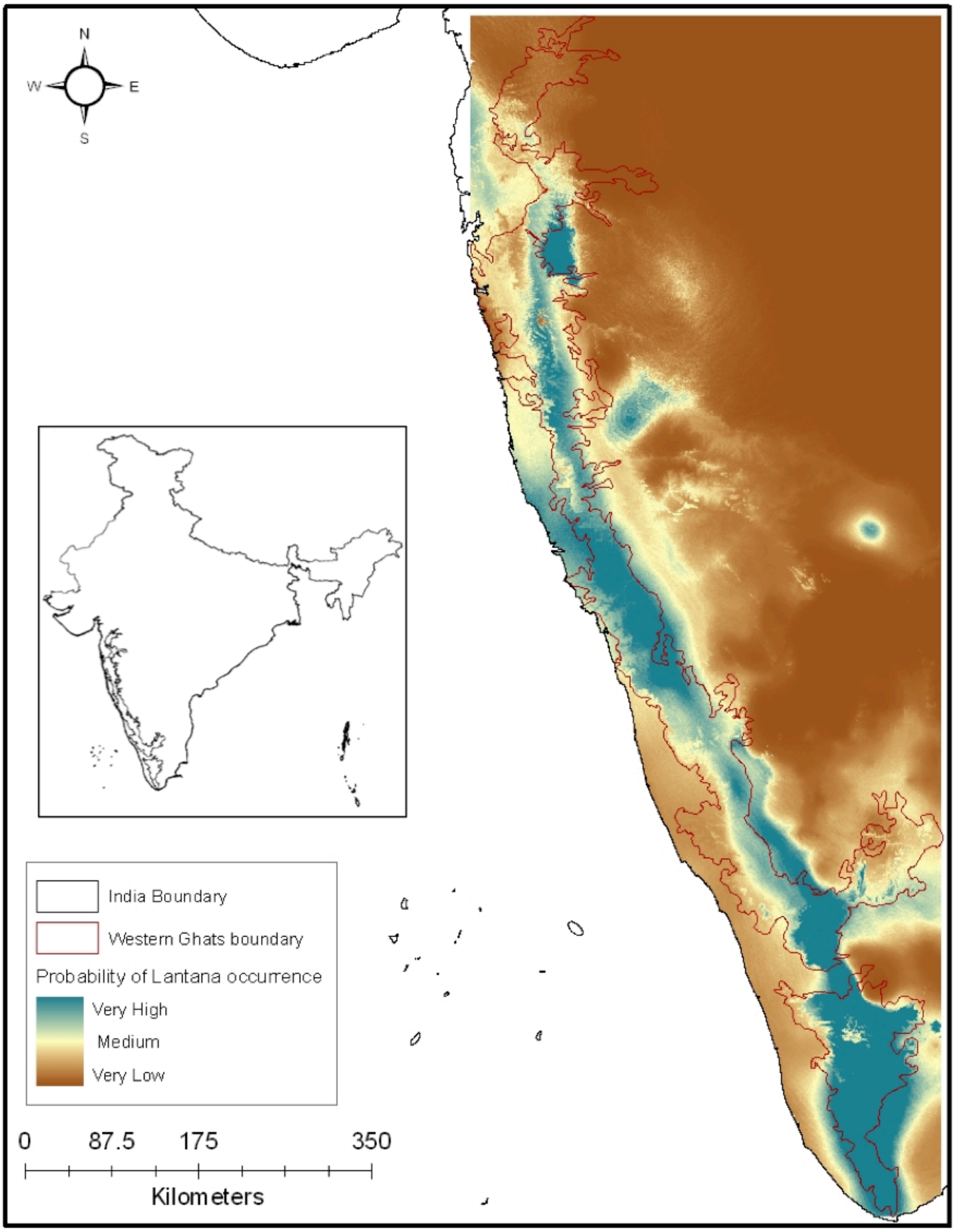


Figure 2.5. Ecological Niche Modeling (ENM) map for Lantana spread in the Western Ghats, India

2.4 Discussion

In this chapter I have provided a detailed historical analysis of the spread of *Lantana* species at three 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 an 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. *in press*).

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* 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. 2005b; 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 1911-14, efforts were made in Savanthvadi (Maharastra), 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. *in press*).

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 (ENM and CLIMEX) have been increasingly applied to forecast or predict the spread of invasive species (Shaanker et al. 2010; Bhagwat et al. *in press*; Taylor et al. *in press*). 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 in to 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. (*in press*) report that general management policy around control of *Lantana* in India shifted towards minimizing impacts on wildlife rather than removal. However, as shown by this chapter 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 programme 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. 2007a; 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.

CHAPTER 3

IDENTIFYING THE SOCIOECONOMIC CAUSES AND CONSEQUENCES OF USING *LANTANA CAMARA*, AN INVASIVE ALIEN SPECIES, BY LOCAL COMMUNITIES IN SOUTHERN INDIA[2]

[2] *Kannan R, Shackleton CM, Shaanker RU (submitted). Identifying the socioeconomic causes and consequences of using Lantana camara, an alien invasive species, by local communities in southern India. Ecology and Society.*

3.1 Introduction

3.1.1 IAS and its impacts

Invasive alien species (IAS) are one of the largest threats, second only to climate change, to biodiversity and ecosystem services across the world (Convention on Biological Diversity 2001; Kohli et al. 2006; Pimentel et al. 2005). It is estimated that losses of ecosystem services resulting from the spread of IAS may amount to US$ 120 billion per year in the USA and about ZAR 6.5 billion in South Africa (Pimentel et al. 2005; de Lange and van Wilgen 2010). Many plant IAS have eluded management, both because of their sheer spread as well as the exorbitant cost that control would incur (van Wilgen et al. 2012). Globally, there are very few examples of successful eradication of IAS, especially once it spans an area of tens of square kilometers or more (Mack and Lonsdale 2002; Moore et al. 2011). Some successful examples include the biological control of *Opuntia monacantha* in Cape region in South Africa in 1913, *Lantana* in Hawaii and Fiji Islands in the 1900s (Perkins 1925; Broughton 2000; Zimmermann et al. 2004) and physical removal of *Eupatorim serotinum* in Australia (Mack and Lonsdale 2002). In South Africa, the Working for Water (WfW) programme is a classic example of a physical management approach, wherein through local community employment, plants are removed and even eradicated (Moore et al. 2011; van Wilgen et al. 2012). Thus, for a large part, most invasive species have remained largely unchecked and hence have gone on to usurp native flora and fauna and disrupt the natural flow of ecosystem services (le Maitre et al. 2002; Richardson and van Wilgen 2004).

3.1.2 Ecological Social and cultural impacts

In the absence of sustained control, many invasive species have escaped and become naturalized in the sites of their invasion (Essl et al. 2010). For example, the Silver wattle (*Acacia dealbata*), introduced into Madagascar by the French in 1904 to support the railway and tannery industries, has now become naturalized in many parts of the country (Kull et al. 2007), as have multiple Australian *Acacia* species internationally (Kull et al. 2011). The naturalization of invasive plants could have several implications ranging from ecological to sociological/cultural. On the ecological front, the naturalization of an invasive species may lead to reshuffling of the structural, compositional and functional elements of biodiversity and in extreme cases to usurpation of native biota (Prasad 2012; Sousa et al. 2011; Sundaram and Hiremath 2012; Sundaram et al. *in press*). As a specific case, Denslow (2007) argued that the expansion of IAS inside protected areas could potentially affect and alter the protection status of the PAs as often these are beyond management.

From a sociological and cultural perspective, the naturalization of an IAS might lead to a number of consequences, most frequently identified as a loss of income or a loss of quality of life (Richardson and van Wilgen 2004; Pimentel 2005). However, there are increasing case examples of IAS providing positive elements to local livelihoods in providing provisioning services, income or aesthetic benefits (Shackleton et al. 2007a; Table 3.1.). This may include local adaptations and cultural integration of the species. Many local communities have devised and developed ingenious adaptations to and use of invasive species across the world. For example, Australian *Acacia (Acacia* subgenus *Phyllodineae*) is an IAS that has been successfully used as fuelwood, timber and food in different parts of the globe (Shackleton et al. 2007a; Kull et al. 2007; 2011). *Prosopis juliflora,* a South American invasive plant, is used as both fodder and food in Kenya and Niger (Geesing et al. 2004; Mwangi and Swallow 2005) and fuelwood in India (Patel 1985). In South Africa, the Prickly Pear (*Opuntia ficus-indica*), an invasive from Central America, is used to supplement the diet of people, provide fodder whilst also being adopted into local cultures and beliefs (Shackleton et al. 2007; 2011). *Eichhornia crassipes* (Water hyacinth), yet another IAS from South America, is used as a weaving material in several Southeast Asian countries, particularly in Bangladesh, Cambodia, Philippines, and Thailand (Malik 2007; Jafari 2010).

Table 3.1. Examples of Invasive alien species use across the world

Invasive alien species (IAS)	Native range	Invasive in	Use	Reference
Australian *Acacia (A. dealbata* Link; *A. mearnsii* De Wild)	Australia	Africa, Asia and Southeast Asia	Charcoal, timber, fuel wood in Africa, Madagascar and India	Kull et al. 2011
Chromolaena odorata (L.) R.M.King & H.Robinson	South and Central America	India	Natural dye in India	Earthcraft
Eichhornia crassipes (Mart.) Solms-Laub.	South America	Africa and Asia	Rope and furniture weaving in Lake Victoria in Kenya and Southeast Asian countries.	Jafari 2010
Imperata cylindrica	Asia	Africa	In Nigeria and Ivory Coast local communities are using this as important roofing material and medicine	Global Invasive Species database
Lantana camara L.	South America	Africa, Asia and Australia	Baskets, furniture in India	Shaanker et al. 2010
Mikania micrantha	South America	India, Sri Lanka, Malaysia, Fiji	Medicinal plant and animal feed	CABi 2011a
Mimosa pigra L.	Mexico and Central America	Australia	Fuel wood	Shaanker et al. 2010
Opuntia ficus-indica (L.) Mill.	Central America	Africa and India	Food	Shackleton et al. 2011
Pinus radiate D. Don	Central America	Africa, Australia and Chile	Timber	Randall 2002; CABi 2011b
Prosopis juliflora	South America	Africa and India	Timber, fuel wood and fodder in Kenya and Niger	Geesing 2002; Mwangi and Swallow 2005

Though these uses and adaptations are far from replacing conventional approaches and eradication programmes, they raise intriguing conceptual and policy questions regarding what is the very meaning of the term ‘invasive alien species’ (Warren 2007), what defines a weed, alien or an unwanted species (Subramaniam 2001), how local people come to terms with IAS (Shackleton et al. 2007a), and subsequently what processes catalyse or hinder how they incorporate them into their livelihoods, and, at a practical level whether such use serves to decrease the rate of spread and the negative impacts of IAS on ecosystem services. For example, it would be illustrative to analyse the factors that predispose local communities' adaptation to IAS around their homes and farmsteads and how this changes depending on the dominant land use or primary management objectives. Identifying the factors that drive such use might hold lessons for understanding the responses of local communities to IAS. For example, Shackleton et al. (2007a) hypothesized that the use of an invasive species will be a function of time since invasion, the competitive ability of the IAS and whether or not it produces tangible products such as wood, fodder, fruits or dyes. Understanding the drivers would also throw light on factors that actually promote the management of the invasive and in extending similar use with less resistance in places where IAS are not yet used.

In this chapter I analyse the use of an IAS, *Lantana camara*, by local communities in southern India and identify the possible causes and consequences of its use. *Lantana camara* L. Verbenaceae (hereafter referred to as *Lantana*) is one of the most notable alien invasive plants with a pan-continental distribution (Ghisalberti 2000). Native to Central and South America, the plant is now reportedly distributed and established in over 12 bioregions and more than 60 countries around the world (Richardson and Rejmanek 2011). It is considered as one of the ten worst weeds recorded in human history (Cronk and Fuller 1995). *Lantana* was first introduced by the British, into India, at the East India Company Botanical Garden, Calcutta, in 1807, as an ornamental plant (Chapter 2; Kannan et al. *in press*). Since then the species has spread across the country and has displaced several native species (Bhatt et al. 1994; Sahu and Singh 2008; Dogra et al. 2009). Attempts to control *Lantana* in India have not been successful (Bhagwath et al. *in press*). Physical, chemical and biological methods to remove *Lantana* (such as uprooting by deploying elephants or by applying chlorine iodide or by introduction of insects from Mexico) has not been successful (Kannan et al. *in press*).

In its present expansive state, *Lantana* poses a serious threat to the native biological diversity in numerous reserve forests and protected areas in the country, whilst also disrupting critical ecosystem services (Bhatt et al. 1994; Love et al. 2009). Yet, several communities in southern India have been making use of *Lantana* as part of their livelihoods (Kannan et al. 2009). For example, communities have made use of *Lantana* for fuelwood, in fencing their agricultural lands and as a substitute for bamboo and rattans to make baskets and furniture (Figure 3.1.). From the context of human adaptations to biodiversity change (Fabricius et al. 2007) and in this specific context, to invasive species, this example offers an opportunity to ask a) what are the critical socioeconomic parameters that distinguish people or communities that use *Lantana* (the user group) compared to those who don't (the nonuser group)?, b) what are the key determinants that promote its use by communities?, c) can such learning catalyze the use of *Lantana* in other communities and landscapes where the species is abundant? and d) what are the tangible economic gains to communities in using *Lantana*? I discuss these questions in the larger context of how local communities have responded to biodiversity changes both spatially and temporally.

Figure 3.1. Lantana user groups *(1.Lantana stick collection by Madigas; 2.Lantana basket weaving by Irulas 3.Lantana basket ready for sale; 4.Lantana sticks boiling by Soligas 5. Lantana furniture making at MM hills 6.Lantana sofa)*

3.2 Methodology

3.2.1 Site profile

The study was conducted in six different hamlets in three districts of southern India where *Lantana* is abundant and has invaded both forest and farmlands (Shaanker et al. 2010). In these sites, Kannan et al. (2009) showed that several families and communities actively use *Lantana* for their livelihood requirements. Use of *Lantana* could be traced to at least 25 to 30 years ago for a few communities and more recently (<7 years) for others (Table 3.2.). While the latter were prompted to use *Lantana* by external agencies, it is not immediately clear how the early adopters took to *Lantana*. Personal interviews with respondents in this group indicated that elder members of their respective families passed on the skills of using *Lantana*.

The study was located in the following sites: Hannehola (12° 2`N, 77° 34`E) and Kommudikki (11°59`N, 77° 33`E) in Malai Mahadeshwara (MM) Hills Reserve Forest in Chamrajanagar District, Pudhupatti (10° 19`N, 78° 8`E), Anjukullipatti (10°14`N, 78° 4`E) near Sirumalai Reserve Forest and Vedasandur (10° 19`N, 78° 8`E) near Pachallur Reserve Forest in Dindigul District and Cheelampalle (13° 2`N, 78° 30`E) is close to Kaigal Reserve Forest, in Chittoor District in southern India. The *Lantana* collection permitted only in the Reserve Forest but not in Protected Areas (PAs) by the forest department because PAs are considered inviolate space (more detailed information on PAs is given in Chapter 5). MM Hills Reserve Forest is located in the southern part of Chamarajanagar district with a total forest area of 280 km^2. The reserve forest receives an average rainfall of about 400 to 600 mm from the northeast as well as the southwest monsoon (Misra 2002). Anjukulipatti and Pudhupatti are located in the southern part and Vedasandur in the northern part of the Dindigul district with an average rainfall of 900 mm. Cheelampalle is located in the southern part of Chittoor district and receives an average rainfall of 800-900 mm.

Table 3.2. Profile of nonuser and user households

Village	No. of Households	Sample size		No. of respondents by ethnic groups	Duration of *Lantana* use (yr.)
		Nonuser	User		
Hannehola	48	8	10	Soligas (18)	< 7
Kommudikki	21	12	0	Soligas (12)	< 7
Pudhupatti	35	5	12	Koravas (17)	>25
Anjukulipatti	30	5	6	Koravas (4); Pallar (7)	>25
Vedasandur	40	11	14	Koravas (25)	>25
Cheelampalle	57	5	24	Irulas (11) and Madigas (18)	>25
Total	231	46	66		

3.2.2 Community profile

The respondents of the study belong to several ethnic communities, namely Koravas (41%), Soligas (27%), Madigas (16%), Irulas (10%) and Pallar (6%). A brief description of these communities and their traditional occupation is presented below.

Soligas: The Soligas were hunter-gatherers and one of the early inhabitants of MM Hills and are a designated Scheduled Tribe (Ministry of Tribal Affairs 2009). Buchanan (1807) mentioned that Soligas lived in the hills where tigers were scarce, and practiced shifting cultivation. Thurston (1909) described the Soligas as those inhabiting the jungles between Dimbhum and Kollegal near Mysore. The degraded forests of the Gundal valley was attributed to the shifting cultivation practiced by the Soligas (Ranganathan 1934). Interaction with the elder members of this community reveled that until the 1930s, a barter market was in existence in Santhekan Boli (‘*Santhe*’: market ‘*Boli*’: hill). Foothill communities bought such forest products as honey, bamboo baskets, amla (*Phyllanthus emblica*), aralekai (*Terminalia chebula*), sigekai (*Acacia concinna*), makaliberu (*Decalepis hamiltonii*) and antowala (*Sapindus trifoliatus*) and in turn sold cloth, sugar, etc. Access to forestland and forest resources provided food security to Soligas. The Soligas were settled on revenue land (with title for agricultural land and house) in different hamlets in 1901-02. Kommudikki was surveyed and recorded as a revenue village (i.e. has demarcated boundaries and basic amenities are developed) in 1901. The Soligas practiced rain-fed agriculture and bamboo basket weaving was their traditional livelihood activity (Table 3.3.); incidentally, the term Soliga also refers to “people from bamboo thicket” (Sundaram et al. *in press*). They harvest and fabricate furniture made from *Lantana* and market them locally as well as in Mysore and Bangalore.

Koravas: The Koravas are traditional basket weavers and belong to the Scheduled Caste (SC) category under the bylaws of Indian system of classification of castes (Constitution (Scheduled Castes) Order 1950). The respondents were selected from three hamlets namely Pudhupatti, Anjukulipatti and Vedasandur. According to Thurston (1901). “*The Koravas traded merchandise namely salt, tamarinds, jaggery, leaves of the curry leaf plant from place to place on pack-bullocks or donkeys. The section of Koravas who carried salt inland from the coast became known as uppu (salt) Koravas. Another large class are the Dhabbai (split bamboo) Koravas, who restrict their wanderings to the foot of hill ranges, where bamboo are obtainable. With these they make baskets for the storage of grain, and various fancy articles”.*

The Koravas are basically bamboo basket weavers. However, when their access to bamboo was restricted and bamboo became unaffordable they shifted to other species. *Saccharum arundinaceum* and *Alingium salvifolium* found near streams and *Lantana* along the foothills, fallow land and fencing of the plantations were used (Shaanker et al. 2004b). However, because of its sheer abundance, *Lantana* was most preferred and predominantly used. Most of the Koravas are landless and live in colony houses (15 x 15 ft; approx. 5 x 5m) constructed by Government in the outskirts of the village. Dindigul is the nearby town and known for its mango production in Tamil Nadu. They weave baskets from *Lantana* and directly market them to the end customer or shopkeepers in Dindigul (Table 3.3.). *Lantana* flowers after the monsoon showers (June - July) and the peak seeding season is September to February. The Koravas move to other activities during summer (March - May) because during this season, *Lantana* dries up and is not suitable for basketry.

Irulas: The Irulas of Chittoor and North Arcot were jungle tribes until 1900 but later started practicing settled agriculture (The Imperial Gazetteer of India 1909). Buchanan (1807) wrote that the Irula houses were made by bamboo interwoven like basketwork and plastered on the inside with clay. He also claims that the Irulas traded timber and bamboo with the people from the plains. It seems that the knowledge on bamboo and basketry had remained with them for quite some time. Irulas belong to a Scheduled Tribe (Ministry of Tribal Affairs 2009) and are a highly marginalized forest dependent community. The Wildlife (Protection) Act (1972) restricted their access to forest resources, in particular, collecting bamboo, catching snakes and rats, which were their major livelihood activities. They practiced rain-fed agriculture and depended on labour (domestic/migration) and fuelwood collection for their livelihood (Table 3.3.). Madanapalle and Palmanare are the nearby towns. They harvest, weave and sell the *Lantana* baskets to middlemen in their village.

Madigas: According to Buchanan (1807) and Plowden (1883), the Madigas were cobblers and agriculture wage labour for the landlords and farmers. It is not clear when, where and from whom they learned basketry. Interaction with the village elders in Cheelampalle revealed that the Madigas (SC) (Constitution (Scheduled Castes) Order 1950) and Irulas were introduced to basketry some 25 years ago by the artisans in Mulbagal, Karnataka. In the past 20-25 years the agricultural activities in this region suffered due to a series of drought, crop failure and land use change (real estate). Consequently, the community was affected deeply because they were highly depended on agriculture as wage labour. About 25 years ago, a certain Mr. Billappa discovered a huge demand for baskets, in the nearby market in Madanapalle, for transporting tomatos to Bangalore and Chennai. He encouraged people to weave baskets whose marketing he coordinated in Madanapalle. Today, the Madigas, supply baskets for tomato and flower growers in Madanapalle, Kolar and Palmanare. The peak season for basket manufacture is during August to January.

Table 3.3. Occupation and products included in the respondents' income profile

Community	Agriculture	Forest resources	Trading	Labour	*Lantana*
Soliga	Finger millet (*Eleusine coracana*), jowar (*Sorghum vulgare*) and beans (*Dolichos lablab*)	NTFPs, bamboo, fuel wood, leafy vegetables	Petty shop	Local labour, migration, mason	Furniture
Korava	Cow pea *(Vigna sinensis)*	Fuel wood	Broom sticks, fruits, and vegetables	Local labour	Baskets
Irula	Sugarcane (*Saccharum officinarum)* and Groundnut *(Arachis hypogaea* L.*)*	Fuel wood	Petty shop	Local labour, migration	Baskets
Madiga	Groundnut *(Arachis hypogaea)*	Fuel wood	Coconut	Local labour and migration	Baskets
Pallar	Nil	Fuel wood	Nil	Local labour	Baskets

3.3 Data collection and analysis

3.3.1 Ecological history of communities

To address if the ecological history of communities might have predisposed them into adapting *Lantana* as an alternative raw material for bamboo, I traced the ecological history of these communities and bamboo resources. I analysed archival records of the gazetteers, working plans, administrative reports of the forest department across southern India with specific reference to the availability and access to bamboo by these communities. Based on these findings, I developed a perspective over the use of *Lantana* by the community.

3.3.2 Households surveys of nonuser and user groups

Population details of each village were collected from the village headman (Table 3.2.) and user and nonuser households were identified from the list. Simple random sampling (lottery method) was used to draw the user and nonuser sample from the list.

A questionnaire survey was carried out to assess the socioeconomic status of the user and nonuser households in the six study villages. The questionnaire focused on demographic and socioeconomic parameters such as family size, age, occupation, literacy and land holding details. It also solicited information on cash and noncash income parameters such as that from agriculture, livestock, forest income (non-timber forest products (NTFPs), bamboo basketry, fuel wood, etc.), trading (broom sticks, garlic and fruit retailing, etc.), and wage labour (Table 3.3.). The percentage of labour days spent by each household on different occupations was calculated to understand the per person/day income from important occupations. Per capita value for all the income sources were derived and the means and standard deviations were calculated. The Chi-square (χ^2) test was used to identify whether the usage of *Lantana* is specific to any particular household profile such as land holding, forest access and so on. The income parameters between user and nonuser groups were compared using Student t–test and ANOVA. All the statistics were performed by using R-(cmdr) version 2.14.2 software.

Cash as well as noncash income was taken for calculation of all income variables. Noncash income included crops cultivated for subsistence, fuel wood consumption, and forest produce consumed (leafy vegetables, fruits, bamboo, timber collected from the forest). The unit price for agricultural and forest products was collected from the local markets. Family labour cost (Purushothaman 2006) was used to identify the cost of family labour in agriculture, forest resource collection, trading and *Lantana* craft. Per capita net income was calculated for all the income variables by dividing the income by family size.

3.4 Results

3.4.1 Livelihood profile of nonuser and user groups

The livelihood profile of the respondents (59% being *Lantana* users and 41% nonusers) was examined with respect to their land holding, income profiles and other occupations that may contribute to their livelihoods (Table 3.5.). About 64% of the respondents were landless. Among those that had land (36%), none had access to irrigation and thus practiced largely rain-fed farming. Natural resource collection and their products (including NTFPs, bamboo basketry, fuel wood, etc.) contributed the most to the cash income. Labour (both domestic and migrant) and trading (broom sticks, garlic, fruits, etc.) constituted a reasonable proportion of the total income. Dependence on agriculture was mostly on a subsistence scale.

3.4.2 Socioeconomic profile of nonuser and user groups

Several socioeconomic traits were examined for the *Lantana* user (n= 66) and nonuser (n= 46) groups. The percentage of landlessness was higher among users (70%) than nonusers (53%) (χ^2= 3.84, *df* = 1, p< 0.05). However, the mean land holding size was not significantly different between the users (1 552 ± 3 247 m^2) and nonusers (2 706 ± 3 915 m^2) (Table 3.4.). Mean literacy (average number of people educated in the hh) was significantly higher for users (1.40 ± 1.31) compared to the nonusers (0.84 ± 1.11; p<0.0165). On an average the users had a significantly higher occupational diversity (skill sets) than the nonuser group. There were no significant differences between the user and nonuser with respect to age, assets held, family size, and gender (Table 3.4.).

Table 3.4. Socioeconomic profile of nonuser and user households

Attribute	Nonuser (n= 46)	User (n= 66)		
	Mean ± SD	**Mean ± SD**	**t- value**	**p- value**
Age (years)	43.2 ± 11.0	43.1 ± 11.8	0.0165	p> 0.98 ns
Assets (no.)	2.65 ± 2.54	2.66 ± 1.73	-0.0336	p> 0.97 ns
Family Size (no.of people/hh)	4.19 ± 2.21	4.42 ± 1.53	-0.6049	p> 0.54 ns
No.of Male/hh	1.43 ± 0.74	1.66 ± 0.79	-1.574	p>0.11 ns
No.of Female/hh	1.5 ± 0.69	1.45 ± 0.68	0.344	p>0.73 ns
Literacy rate (no.of people)	0.84 ± 1.11	1.40 ± 1.31	-2.4353	p<0.01*
Occupation (no.)	1.76 ± 0.89	2.07 ± 0.75	-1.9489	p< 0.05*
Land holding (m^2)	2 706 ± 3915	1 552 ± 3247	1.6433	p>0.10 ns

*(Significance. codes: 0 '***' 0.0001 '**' 0.001 '*' 0.05 '.' 0.1 'ns') ns- not significant*

3.4.3 Income profile of the nonuser and user groups

The respondents (user and nonuser) depended primarily on three major livelihood options besides *Lantana*, namely a) forest resource based income (NTFPs, fuel wood, bamboo basketry, etc.), b) trading (retail trading, broom sticks sales, etc.) and c) wage labour (local and migrant). Income from agriculture and livestock for both groups was negligible (Table 3.5.). There was a significant difference between the groups with respect to the income obtained from collection of forest resources. The nonuser group obtained nearly three-fold more income from forest resources, excluding *Lantana*, compared to the user group (p<0.001) (Table 3.5.). Income from forest resources includes that obtained from fuel wood, bamboo, NTFPs, leafy vegetables, fruits, and tubers. This pattern was also upheld further on normalizing for differences in individual family size; the per capita person daily income from forest for the nonuser group was (Rs. 9.16 ± 10.48) compared to that for the user (Rs. 5.45 ± 5.67) ($p<0.0328$) (Table 3.6.). Similarly, the nonuser group drew more income from trading than the user group. On an obvious note, the user group obtained income from *Lantana* use while the nonuser group relied mostly on either forest resources or from trading. However, the total income derived by the two groups was nearly the same (Table 3.5.). The income deficit in the user group due to forest resources and trading was made good by the income from *Lantana*; this was reflected in the differences in the percent of income contributed by the different sources between the two groups (Table 3.5. and Figure 3.2.). In this context, the use of *Lantana* by the user group and forest resources by the nonuser group appear to be mutually substitutable activities. Indeed, they are similar in that *Lantana* is also collected mostly from the forest. Therefore, the concentrated use of a single NTFP, i.e. *Lantana* represents significant specialization.

Table 3.5. Annual per capita income profile of the nonuser and user households

	Nonuser		**User**			
Income	**Mean ± SD Rs. (n= 46)**	**(%)**	**Mean ± SD Rs. (n= 66)**	**(%)**	**t- value**	**p- value**
Agriculture	133 ± 317	1	2 72 ± 878	1	-1.1801	$p>0.2412^{ns}$
Forest	4 209 ± 5 658	23	1 334 ± 1 572	7	3.3579	$p<0.001^{**}$
Labour	5 961 ± 7 122	32	4 958 ± 7 435	27	0.7196	$p>0.4735^{ns}$
Livestock	53 ± 256	0	92 ± 549	1	-0.4952	$p>0.6215^{ns}$
Trading	8 139 ± 15 673	44	3 278 ± 6 210	18	1.9971	$p<0.0507^{*}$
Lantana	0	0	8 536 ± 7 710	46		
Total	18 497 ± 13 725	100	18 472 ± 8 352	100	0.0109	$p>0.9913^{ns}$

The F values mentioned here are from an ANOVA of nonuser and user income measure as a response variable. Income level varied significantly between nonuser and user groups ($F_{(1, 550)}$= 10.3740, p $<0.001^{**}$) and within the group income vary significantly ($F_{(4, 550)}$ = 19.5848, p< 0.0001^{***}).
*(Significance. codes: 0 '***' 0.0001 '**' 0.001 '*' 0.05 '.' 0.1 'ns) ns- not significant*

Table 3.6. Per capita daily income from major income sources

Per capita man day income	**Nonuser (Rs.)**	**User (Rs.)**	**t- value**	**p-value**
Forest	9.16 ± 10.48	5.45 ± 5.67	2.181	$p<0.0328^{*}$
Trading	8.93 ± 26.55	6.88 ± 13.74	0.479	$p> 0.6333^{ns}$
Lantana	0	16.00 ± 15.54		

*(Significance. codes: 0 '***' 0.0001 '**' 0.001 '*' 0.05 '.' 0.1 'ns) ns- not significant*

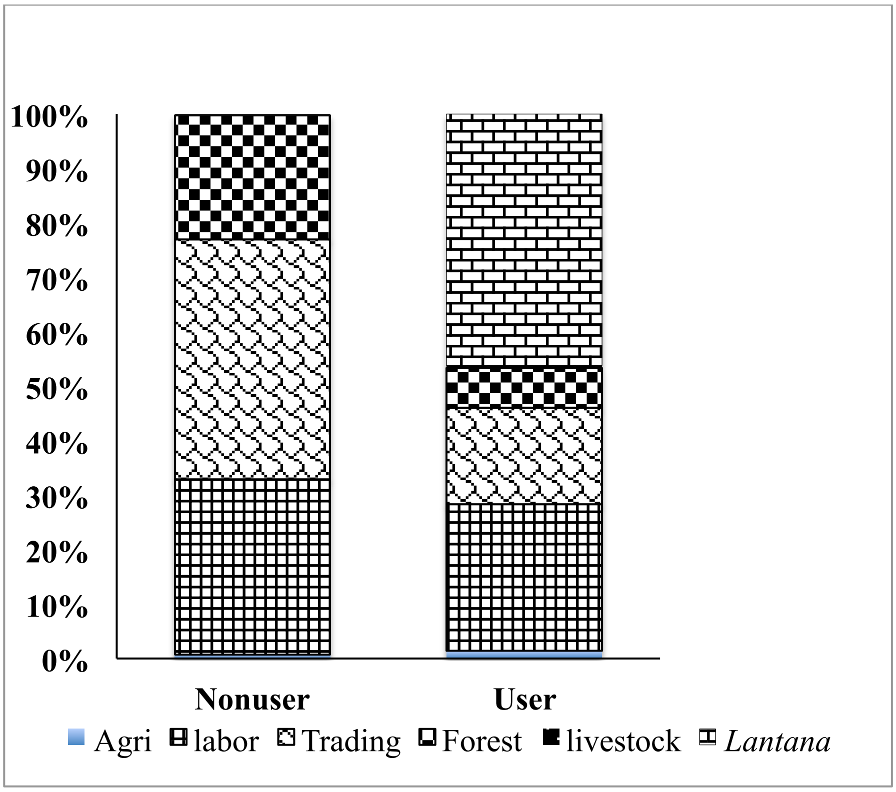


Figure 3.2. Relative income sources (%)the nonuser and user groups

Respondents in the user group were further divided into their age class a) >20-30 yrs, b) 31-40 yrs, c) 41-50 yrs and d) above 51 yrs. A significant proportion of the respondents belonged to 25-40yrs age group. The user group stratified by the age classes differed significantly on the sources of income such as income from forest ($p<0.016$) and *Lantana* ($p<0.011$) but the income from trading across the age class is not significant ($p>0.060$) (Table 3.7.). It seems the younger age class (20-30 yrs) earn more income from forest and *Lantana* and the elder age class (above 51 yrs) earn more from trading, as they are not able to frequently go to forest to procure the raw materials.

Table 3.7. Age classification of annual per capita income for the user groups

	Age group (yrs.)					
Income sector	21-30	31-40	41-50	Above 51		
	Mean ± SD *(n=14)*	Mean ± SD *(n= 17)*	Mean ± SD *(n= 18)*	Mean ± SD *(n= 17)*	F value	Pr (> F)
	27.2± 2.35	36.9 ± 3.38	46.8 ± 3.00	58.6 ± 3.37	297.4	0.0001***
Forest (Rs.)	2 487 ± 2 225	1 064 ± 1 925	867 ± 560	1 147 ± 680	3.689	0.0165*
Lantana (Rs.)	14 417 ± 12 023	6 385 ± 5 933	7 116 ± 3 800	7 349 ± 5 879	3.973	0.0118*
Trading (Rs.)	1 142 ± 4 276	1 236 ± 3 135	4 299 ± 6 990	5 998 ± 7 913	2.591	0.0607ns

*(Significance. codes: 0 '***' 0.0001 '**' 0.001 '*' 0.05 '.' 0.1 'ns') ns- not significant*

3.4.4 Ecological history of bamboo resources

I traced the history of availability of, and access to, bamboo in the study area in the last 100 years. The archives of the Kollegal Forest Department (encompassing MM hills range) dating to the last 70 years (1932-2002) showed that local communities extensively used bamboo for basketry and Chandrika (silk worm rearing plates) (Ranganathan 1934; Shanmuganathan 1956; Setty 1973). However, post-1970, triggered by the huge bamboo resources, several commercial interests sprung up. In 1973, a certain K.R.V. Setty wrote to the Kollegal forest division strongly recommending the potential exploitation of bamboo resources in Kollegal forest division. At the about the same time, the Mysore Paper Mills at Bhadravathi indiscriminately began to harvest bamboo in Kollegal and Chamrajanagar divisions; this led to decrease in supply of bamboo from 35 433 tonnes in 1991-92 to 13 973 tonnes in 1998-99 (Shaanker et al. 2004b). Such was the indiscriminate extraction that in the 2002-04 working plan of Kollegal division, Misra (2002) wrote that the guidelines for sustainable extraction of bamboo had not been followed in the region and consequently there could be an acute shortage of resources from the area. Compounded by this, flowering of bamboo and poor regeneration after flowering led to a severe decline of bamboo in the region. The forest ranges of Edayarahalli, Chikkailur, and parts of MM hills range which were major sources of bamboo for basketry and Chandrika were removed from the bamboo felling areas; bamboo extraction by local and state agencies in these areas were banned (Misra 2002). The final straw was the fact that those areas that were excluded from the above bamboo felling area, were subsequently notified to come under the jurisdiction of the Cauvery Wildlife Sanctuary in 1994 (Misra 2002). A Supreme Court order in 1996 prohibiting the removal of any living organism from inside the protected areas effectively prevented communities from collecting bamboo from the Cauvery Wildlife Sanctuary.

Thus, the Koravas and the Soligas living in this area and who were once thriving on the bamboo resources in the forests were no longer free to do. If any, they had to pay for the bamboo they obtained from the forest department. Under these circumstances, it appears that they took to *Lantana*, which was increasingly abundant., the use of an invasive alien species by local communities seems to have been driven by several factors (loss of bamboo, increase of *Lantana*, traditional occupational skill) that came into play at about the same time.

3.5 Discussion

3.5.1 Invasive alien species: Landscapes transformers

Invasive alien plants, with their rapid growth rates and wide adaptability, bring dramatic changes to landscapes, be it forests, agricultural lands, water catchment areas or wastelands (le Maitre et al. 2002). Their invasion into forest vegetation can totally reshuffle local species-abundance relationships that have been shaped by evolutionary interactions (Simberloff 2011; Sundaram and Hiremath 2012). Most IAS are uncontrollable, especially those that have reached a log or saturation growth phase. Ironically, most often, it is only at this phase that they attract most attention and concern from stakeholders ranging from governments and forest managers to local communities (Shackleton et al. 2007a). Governments and forest managers attempt to manage the invasion in the traditional or conventional manner, that of exclusion. This can take the form of physical approaches such as burning, rootstock cutting, uprooting and the like (Love et al. 2009). The history of control of invasive species the world over, bears testimony to the utter failure of these programmes with a few exceptions such as the case of Working for Water programme in South Africa.

3.5.2 Adaptation towards IAS

In recent years, alternative approaches to coming to term with IAS have been posited. Shaanker et al. (2010) showed that in much of the human dominated landscapes in the tropics, classical approaches to management of IAS might not be tenable or even desirable. They suggested that it is time to move from a classical mindset of eradication to that of adaptation. This theory is nested in the fact that in human dominated landscapes, a large proportion of people depend upon scores of NTFPs for their livelihoods (Rist et al. 2010; Mahapatra and Shackleton 2011; Saha and Sundriyal 2012). Thus, any IAS control or management initiatives need to consider the impact not only the IAS but also the livelihoods of local people. Unfortunately, this dilemma has failed to be addressed sufficiently in the world literature on invasive species. The response of the local communities to IAS can range all the way from exclusion (where, like the forest managers, communities might want to eradicate the weed and thus prevent their biological resources from being impacted by IAS) to inclusion (where the IAS might be actually used as one of the bio-resource elements). The first option is rarely encountered at a local level usually because of the spatial scale of invasion as well as the logistics. On the other hand, it is very conceivable that communities could actually explore and innovate the use of the new resource, especially if in some way the IAS can make good their loss.

Several studies have addressed how communities may have come to terms with IAS. For example the use of *Opuntia ficus-indica*, *Prosopis juliflora*, and *Acacia phyllodineae* are well recorded; each of these initiatives seems to have come from within the local community (Geesing et al. 2004; Shackleton et al. 2007a). The success of these indigenous initiatives has often been replicated elsewhere (Jafari 2010). For example the use of *Prosopis juliflora* in Lake Baringo in Kenya was well demonstrated where in fact after the initial use, *Prosopis* become popular elsewhere in the world wherever it invaded (Mwangi and Swallow 2005). Kull et al. (2007) and Shackleton et al. (2007a) have attempted to unravel the social, cultural, political and economic factors, which may have driven local communities to use the IAS. A key finding of both these studies was that specific IAS were frequently an important resource for the rural poor, especially in the context of the limited livelihood opportunities available to them. Under these conditions they went on to argue, that removal of IAS could actually be detrimental to those livelihoods (de Wit et al. 2001; Shackleton and Gambiza 2008). Thus, they argued that management planning or control of IAS should look beyond the traditional perspectives of IAS control and should be comprehensive and weigh the relative costs and benefits of control, including the benefit to local communities' from use of IAS. It may potentially fill the gap between conventional IAS management practices and local adaptations. So long as the ecological cost of such use is less than that due to invasion and management of IAS, use of IAS by local communities could be a pragmatic approach in improving livelihoods of the poor. Shaanker et al. (2010) mirrored similar arguments for the use of *Lantana* by the local communities in southern India.

In this study, the adaptation of local communities to an invasive species can be decomposed as a trade-off between the losses of income from forest resources that have been usurped by the invasive against the gain that might make good the loss by using the invasive as a resource. For example, in a study in southern India, Ticktin et al. (2012) showed that over a 10 year period, the populations of an important non-timber forest product species, *Phyllanthus emblica* decreased by 16 per cent in areas infested by *Lantana*. While data do not exist, it could be assumed that such loss may have translated in to loss of income for people dependent on these forest resources. Under this scenario, the communities may for want of alternative livelihood opportunities be forced to consider using the invasive as a resource. While there is no unequivocal evidence to support this conjecture, two important data sets from the study site reinforce this possibility. First, over the last few decades, the study area has witnessed a nearly monotonic loss of bamboo resources due to a host of factors including extraction by paper mills as well as mast flowering (Misra 2002; Shaanker et al. 2004b). Second, during this period, the area saw a steep increase in the density of *Lantana* with clear effects on the native biological resources (Bharat and Hiremath 2012, Aravind et al. 2010). Under this complex mix of local drivers it is tempting to suggest that the abundant biomass of the invasive species opened the possibility for its use to make good the loss due to the lost forest resources.

The above hypothesis is supported by several respondents, especially those belonging to the Korava community. According to them, when bamboo became scarce and later it became too expensive to procure from the forest department, their major source of livelihood was threatened. Under these circumstances, families were forced to seek alternative resources, such as *Saccharum arundinaceum, Alingium salvifolium*, and *Lantana, which* offered a suitable substitute for bamboo. The latter was abundantly available and was a zero-investment biomass that only had to be extracted from the forests and wastelands.

3.5.3 Local contingencies, local solutions

The results suggest that often local contingencies might have shaped local solutions and adaptations to an invasive species. After its introduction to India in 1807, *Lantana* spread to almost all parts of the country (Chapter 2). Of particular interest here is the spread of the IAS into forested landscapes that are home to a number of forest dwelling and forest fringe communities. These communities have been and still are heavily dependent upon forest resources for their livelihood (Shaanker et al. 2010). Among other non-timber forest products, bamboo has been a central resource for the communities. All of these communities are known for their dexterity in working with bamboo in the scrub and moist deciduous forests of southern India (Kannan et al. 2009; Shaanker et al. 2010) and a major livelihood strategy, besides others, have been weaving baskets and other articles from bamboo. Many families of these communities have been using *Lantana* for the past 25 to 30 years. In numerous situations, the communities have evolved simple processes and technology to work on *Lantana* as a substitute for bamboo. So why and under what conditions have these communities switched over to *Lantana* in place for bamboo? As mentioned elsewhere in this chapter the restricted access to a forest resource such as bamboo and NTFPs have seemingly predisposed the communities to choose other abundant alternatives in the region. This matches the trajectory illustrated by Shackleton et al. (2007a). Thus, under situations where an IAS (*Lantana*) is perceived to be a substitute for a locally available, but less abundant and difficult to access resource (bamboo) then the communities would be predisposed to use IAS as a substitute.

Within the communities, families that used (user group) and those that did not (nonuser group) differed with respect to the income that they drew from forest resources (other than *Lantana*). The nonuser group earned significantly greater than the user group from collection of forest resources. They spent a significantly greater number of person days collecting forest resources. Could such difference in some way have led the user group to consider using *Lantana* to make good their loss? While it is tempting to suggest this indeed could be the immediate economic driver, it is fraught with a certain degree of circularity – in that the socioeconomic data ideally should have come from people before their dependence on *Lantana*. Unfortunately this is impossible in such time-static studies. However, interviews with the user group indicated that either because of an opportunity cost (living well outside the forest boundaries or culturally incompatible), these families had traditionally been dependent more on bamboo related occupations than say, forest resource collections. Consequently, upon realizing the substitutability of *Lantana* for bamboo, the families switched to using *Lantana*.

Both the user and nonuser group made use of forest resources. However, the user group was now largely specialising in the use of one forest resource, namely *Lantana*. Belcher et al. (2005) demonstrated from an analysis of 61 case studies globally that household income from commercial sale of NTFPs was greatest with increasing specialization. In this case study, the total income was very similar between the user and nonuser group and so the income cash benefits of specialization were not apparent. However, there were other benefits of specializing on *Lantana*, which include it being an abundant resource, available all year round, markets were increasingly available in larger urban centres, and diminished conservation concerns associated with harvesting it because it is an IAS.

CHAPTER 4

UTILIZATION AND IMPACT OF USE OF *LANTANA CAMARA* BY LOCAL COMMUNITIES IN SOUTH INDIA[3]

[3] *Kannan R, Shackleton CM, Shaanker RU (submitted) Utilization and impact of use of Lantana camara by local communities in South India. Journal of Tropical Ecology*

4.1 Introduction

Lantana camara. L (hereafter *Lantana*) was introduced as an ornamental plant into India in the early 1807 in the East India Company Botanical Garden in Calcutta (Chapter 2; Kannan et al. *in press*). Since then the plant has spread through most part of the country, making it one of the most widespread invasive alien species (IAS) in India (Shaanker et al. 2010; Dobhal et al. 2011; Khuroo et al. 2011), and still expanding (Chapter 2; Kannan et al. *in press*). In a comparative analysis of stem density of plants between 2000 and 2010 in the BRT Sanctuary, Sundaram et al. (*in press*) found a significant net increase (33%) of *Lantana* stems over the ten year period. Ecological niche modeling studies in the recent past indicated that the plant is likely to spread and invade most parts of the country and specifically to habitats such as the Western Ghats and northeastern Himalayas, including protected areas (Kannan et al. *in press*; Taylor et al. *in press*).

Attempts to control *Lantana* in India have been uncoordinated and largely futile. Physical, chemical and biological approaches to control the spread have been evaluated in the past and have been shown to ineffective (Love et al. 2009; Shaanker et al. 2010; Bhagwat et al. *in press*; Sundaram et al. *in press*). Due to both its extensive geographical spread as well as the tremendous cost involved in controlling it, *Lantana* has escaped all management devices. Thus, like many IAS, *Lantana* is currently deemed uncontrollable in India and is expected to overwhelm many Indian landscapes, including forests, agricultural land and wasteland (Ramaswami and Sukumar 2011; Prasad 2012).

In tropical human dominated landscapes, including India, *Lantana* has usurped native biota, many of which have been and still are crucial in providing livelihoods and safety nets to the rural poor (Chapter 3; Ticktin et al. 2012). For example, several communities in southern India still derive more than half their annual cash income from sourcing Non-Timber Forest Products (NTFPs) including, bamboo and rattans (Shaanker et al. 2004a). The spread of *Lantana* has either completely usurped some of these resources or thinned them substantially (Rist et al. 2010). Consequently, in many sites, the spread of *Lantana* has adversely affected the livelihoods of communities by either depriving them of the traditional sources of non-timber forest products or by impeding easy access to the resources (Rist et al. 2011).

Under this scenario, some communities in south India have evolved local solutions to mitigate their loss by actually attempting to use *Lantana* as a resource (Chapter 3; Kannan et al. 2009). Thus, several communities have been using *Lantana* as a substitute for scarce bamboo and rattans. Recently Kannan et al. (*submitted*) showed that several forest dependent communities in the states of Karnataka and Tamil Nadu in India have been using *Lantana* for as long as 25 to 30 years. Though the exact circumstances under which the communities began to use *Lantana* are not clear, Kannan et al. (*submitted*) argued that the ecological history of the area indicated the role of several interplaying factors, namely: a) all the communities adopting *Lantana* were already adept at weaving baskets and other craft from bamboo and rattans. These communities earned substantial cash income from the bamboo products besides depending upon several non-timber forest products (Shaanker et al. 2004a, b) during the past 25-30 years there had been intense extraction of bamboo for a paper and pulp factory from the area (Shaanker et al. 2004b) leading to scarcity of bamboo. This had an adverse effect on the livelihoods of the communities' dependent upon bamboo weaving. Being untenured and lacking formal skills in other livelihood occupations, the communities either chose to serve as wage labourers in local or more distant plantations or granite quarries and, c) at about this time (25 to 30 years ago), *Lantana* became visible as an abundant invading biomass. Independent reports confirm that the area began to be rapidly swamped by *Lantana* (Aravind et al. 2010; Sundaram and Hiremath 2012; Sundaram et al. *in press*). This scenario corresponds well with the conceptual model of Shackleton et al. (2007) where uptake of a potentially useful IAS is dependent on the amount of time it has been in the area and its increasing rates of abundance following a logistic curve. Shackleton et al. (2007a) labeled this as Phase 2. Kannan et al. (*submitted*) argued that under these conditions, people in the region responded to the changing biodiversity status (bamboo loss and *Lantana* gain) and ingeniously adopted *Lantana* as a substitute for bamboo. The use of *Lantana* by the people was further reinforced in recent years by external agencies such as HESCO (Dehradun) and ATREE (Bangalore) that promoted the use of *Lantana* by rural communities, both as a means to provide a gainful source of cash income and to manage *Lantana*. Under this programme, ATREE extended the scope of use of

Lantana by designing and diversifying the product range as well as identifying and deepening the market reach of these products. Consequent to these initiatives, today a large number of families spread over the three southern Indian states are actively using *Lantana* as a substitute for bamboo and rattans and earning more than 60 per cent of the their cash income from this resource.

Thus, despite being one of the worst IAS, and in the absence of any control measures, *Lantana* is being used by a sizable section of the people in southern India to enhance their livelihood portfolio. Other work internationally has similarly shown widespread use of various IAS species for both household provisioning and also for income generation. (Table 3.1. in Chapter 3). However, Shaanker et al. (2010) pointed the need to link the use of IAS along with debates and policies around control options and management strategies. An absence of any control measures, which potentially has negative outcomes for multiple ecosystem services and biodiversity. Yet, on the other hand, top-down and externally driven control mechanisms potentially have negative outcomes for local communities through removal of a resource that has become integral in local livelihoods (de Wit et al. 2001; Shackleton et al. 2007a). However, there are no instances internationally, of which I am aware of, where the impacts of local use have been assessed in terms of the ability to check or reduce the extent or rate of spread of an IAS. The IAS use studies have focused on benefits to local households and communities through providing subsistence goods or resources for income generation. The same applies to use of *Lantana* in India, as there has been no appraisal of the impacts of local use of *Lantana* on the ecological viability of invading populations and the rate of spread. In other words, does extensive use of an IAS by local communities serve to diminish its abundance and vigour and hence its ecological impacts? If so, to what extent? Thus, in this chapter, I assess the extent of utilization of *Lantana* by local communities in southern India and examine the impact thereof on the regeneration and coppicing of *Lantana*. Based on the study, I discuss whether the use of *Lantana* by local communities has significantly affected its regeneration and if so, do such extraction practices have implications for the local management of *Lantana*.

4.2 Study site

The study was conducted in the Malai Mahadeshwara (MM) Hills Reserve Forest (11º 55' and 12º 13' N and 77º 30' to 77º 47' E), located in the Chamarajanagar district, Karnataka state, India (Aravind et al. 2010). About 64 percent of the 291 km^2 area is under the dry deciduous forest followed by scrub forest (21%) and moist deciduous and riparian forest (15%) (Shaanker et al. 2001). The reserve forest receives an average rainfall of about 400 to 600 mm from the northeast as well as the southwest monsoon. The temperature ranges from 10^0 C to 40^0 C. December, January and February are the coldest months and April, May and June are the hottest months of the year (Misra 2002).

The Indian Forest Act (1927) classified forests into three categories, namely Reserve Forest, Village Forest and Protected Forest. In the Reserve Forest all customary rights such as grazing, fuel wood collection and collection of NTFPs were prohibited unless due permission was issued by the forest officer (Indian Forest Act 1927, Section 26). The Village Forest category provided villagers access to forest produce and pasture, provided the community protected and improved the condition of these forests (Indian Forest Act 1927 Section 2). The Protected Forest was seen as a regulated revenue stream and the Forest Act allowed the state governments to make rules to regulate access to timber and other forest produce by issuing permits and passes (Indian Forest Act 1927 Section 32). In the study site, MM Hills Reserve Forest, people are allowed to collect NTFPs after obtaining due licenses from the forest department. In fact in 1987, the state government, through an order No. FFD-7-FDP-85 dated 17-11-1987, gave rights to LAMPS (Large Scale Adivasi Multipurpose Societies) to collect and sell NTFPs in Kollegal forest division. The Deputy Conservator of Forest has the authority to exclude areas from NTFP collection and also decide the list of NTFPs to be collected by issuing passes for the collection of certain species. Local contractors bid for different NTFPs and the highest bidder is awarded the contract. Village boundaries are demarcated and carved out from the forest boundary. Villages, which were surveyed by the Surveyor of India and for which land title was issued, were considered as revenue land and all other land occupation were considered as encroachment. Fuel wood collection and grazing are prohibited and offenders face a penalty from the forest officers but still large number of families depends on fuel wood collection. *Lantana* is listed as a weed and forest department currently allows harvesting of *Lantana* from the MM Hills Reserve Forest, although this is not the case in Protected Forests (Chapter 5).

4.3 Methodology

Three approaches were adopted to estimate the use of *Lantana* by the communities and its likely impact on the regeneration and coppicing of *Lantana*. Firstly, I used a questionnaire to solicit information from respondents on the extent and nature of use of *Lantana* and their perceptions about how such use may have affected the regeneration and coppicing of *Lantana*. Secondly, I estimated the extent of utilization by inventorying the nature and number of *Lantana* craft products produced over a given time period and used that to estimate the demand for *Lantana* relative to the standing stock in the forest. Lastly, I studied the impact of harvesting on *Lantana* by simulating the extraction from selected field sites and then evaluating the impact on the regeneration, coppicing ability and mortality of *Lantana* plants.

4.3.1 Participatory appraisal

A participatory appraisal of the impact of extraction of *Lantana* was conducted with *Lantana* user groups in MM Hills (10 hh), Chittoor (19 hh) and Dindigul district (32 hh). All the participants actively use *Lantana* for making a variety of products. In the appraisal, key issues pertaining to the access, availability, coppicing, regeneration, dispersal, etc. of *Lantana* were discussed. The perceptions of the people were noted and categorized. Particular attention was paid to indicators of the impact such as the distance travelled to procure *Lantana*, the relative ease or difficulty in procuring *Lantana* over the years, the relative access of stems of defined girth, the seasonal availability and regeneration of *Lantana*, etc. The respondents' perceptions about *Lantana* density, regeneration and coppicing were tabulated and the responses categorized as per cent response.

4.3.2 Standing stock of, and demand for, *Lantana* stems

An estimate of the supply of, and demand for, *Lantana* stems was made with specific reference to MM Hills, Karnataka. Specifically, to estimate the supply of *Lantana*, stems were harvested by local craftsmen from five plants and the girth (cm) and stem length (m) were measured for each plant to show the potential supply of useful stems per plant. Further to that, the stems were grouped into girth size: big, (> 6 cm), medium (3.1- 6 cm) and small (< 3 cm). The estimation was done for both moist deciduous and dry deciduous sites in MM Hills. This was scaled to understand supply per unit area of forest by counting the number of plants in six (180 m^2) plots in each of two different moist deciduous forests and one dry deciduous forest (i.e. 18 in total). Ganeshaiah and Shaanker (2001) estimated the percent of the area in MM Hills under different forest types infested with *Lantana*. Based on these estimates, a projection was made regarding the standing stock of *Lantana* for the entire MM Hills Reserve Forest (Table 4.1.).

Table 4.1. Total area under Lantana in MM Hills

Total area of MM Hills infested with *Lantana* (km^2)	*Lantana* infested areas			Sample plot size (unharvest area)	
	Dry deciduous (km^2)	Moist deciduous (km^2)	Scrub forest (km^2)	Moist deciduous forest$ (km^2)	Dry deciduous forest # (km^2)
231	148	34	48	0.00216	0.00108

$ (Kommudikki 1080 m^2 + Marapala 1080 m^2) 2160 m^2 =0.00216 km^2

 # Palar 1080 m^2=0.00108 km^2

The demand for *Lantana* stems was extrapolated from an inventory of the total number and type of *Lantana* products (large furniture and small crafts products) made by the MM Hills artisans during 2011-2012. An inventory of the nature and volume of the products made by the group per month and year was made. The girth size and length of all the *Lantana* stems required per individual craft or furniture item were measured and recorded on site. By multiplying the number of sticks (and size) per product type by the number of units of each product produced per year, the total demand of *Lantana* stems to make all the products by the community was estimated.

4.3.3 Effect of harvesting on plant density

In 2010, I monitored the density and regeneration of *Lantana* in two forest types (moist deciduous and dry deciduous) in MM Hills that were used for *Lantana* extraction and compared it with a control site from where *Lantana* was not harvested. At the moist deciduous forest type, two sites (Kommudikki, Marapala) were chosen based on the years (2007 and 2009) in which they had been harvested by the local artisans. The density of mature plants and regeneration (small plants) of *Lantana* at these sites was compared with an unharvest site within the same forest type. A similar study was done in in dry deciduous forest, at Palar. At each of the three sites, and for each year, six transects (180 m^2/transect) were laid out and the number of all *Lantana* stems and their girth were determined.

The total number of stems found in the three sites was further grouped by stem girth < 3 cm (saplings), 3.1-6 cm and > 6 cm (plants). The mean and standard deviation were computed for all the data sets. The mean density and regeneration of stems in the harvested plots was compared with those in the control using a student t-test.

4.3.4 Effect of harvesting on plant coppicing ability

The impact of harvesting (cutting stems) on the ability of *Lantana* to coppice was evaluated. This was done at two sites, namely Kommudikki (in the moist deciduous forest) and Palar (in the dry deciduous forest). One hundred and fifty plants at each of these sites were tagged during the dry season in April 2010. To simulate the natural process of harvesting practiced by the local artisans, the primary, secondary and tertiary stems (Figure 4.1.) were cut from each of 50 plants. The number of coppice stems emerging from the cut ends were enumerated at two periods, first six months later during the following wet months (October 2010) and then again, after 12 months during the dry months (April 2011). Seasonal effects were considered by repeating the experiment with the initial cutting in the wet season (October 2010) at both sites (Kommudikki and Palar), and the emergence of coppice stems enumerated six months later during the dry season (April 2011) and again 12 months later in the wet season (October 2011).

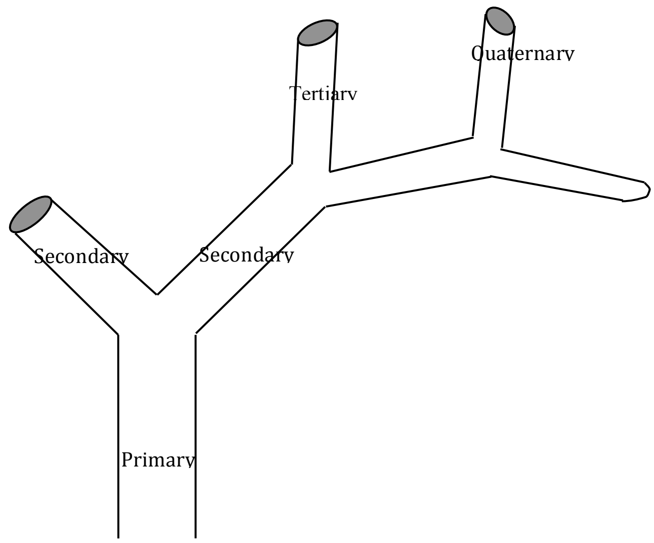


Figure 4.1. Lantana stem cutting experiment stem selection

The statistical significance of the treatment results, regeneration and coppicing ability (different harvesting treatments, site differences) were evaluated using a one-way ANOVA.

4.4 Results

4.4.1 Local perceptions of *Lantana* abundance and change

Most of the *Lantana* users (79%) collected *Lantana* from the local forest. About 20% of the artisans collected *Lantana* from nearby fallow or wasteland. The artisans were not allowed to harvest *Lantana* from the coffee plantations and garden hedges. Most of the artisans preferred to extract the stems either during or after the rains when the stems had either grown or regenerated. These stems were found to be ideal for basket making. However, for *Lantana* furniture sturdier sticks are required and the artisans collected sticks all year round. Over 80% of the artisans mentioned that the distance travelled to collect *Lantana* has increased in recent years, perhaps reflecting the shrinking of *Lantana* resources nearer their homesteads. Many also mentioned that it was harder to find large stems, which are necessary for certain furniture items. The Korava craftsmen who used to collect *Lantana* from wastelands in Dindigul district in

Tamil Nadu explained that they could no longer do so because the area had been taken over by either real estate or mango cultivation. They now are forced to go into the nearby dry deciduous forest to access *Lantana*.

Nearly 85% of the craftsmen mentioned that *Lantana* coppices profusely after harvest and is promoted by monsoon rain in June-September (Table 4.2.). The 84% of the craftsmen (basket weavers) said that they revisit the harvested sites in 2-3 years time but 16% of the craftsmen (furniture makers) mentioned that it takes more than 5-6 years to revisit the harvested sites to get sticks of similar size. This difference is probably due to the need for thicker stems for furniture making because larger plants are targeted, which take longer to regrow to the required size. Both groups of users agreed that they never uproot the plants, but rather harvest the sticks, which are suitable for their craftwork and leave the plant to regenerate. However, both users mentioned that fire (man made/natural) and land use change (mango cultivation/ real estate) reduces the availability and regeneration of *Lantana*. Most of the artisans believe that birds are the major seed dispersal agents of *Lantana*.

Table 4.2. Local ecological knowledge amongst the user groups

	Strongly agreed	Moderately agreed	Weakly agreed
Primary harvesting season	August –January	February-April	May-July
Strongest coppicing rate	After rain	Winter	Summer
Highest density of stems	Moist deciduous forest (high altitude)	Dry deciduous and shrub forest and fallow land	Fence and farm land
Ease of access to *Lantana*	Farm/fallow land/fence	Dry deciduous	Moist deciduous forest
Seed dispersal agent	Birds (bulbul, crow, myna, etc.)	Animals (deer, bear, goat, etc.)	Wind

The Koravas and Madigas are well aware about the availability of *Lantana* stems for basketry in the forest. More than 90% of them said the peak season for harvesting *Lantana* is August –January. The demand for *Lantana* baskets to transport flower, tomatos and vegetables increase during the wet season (July- December).

4.4.2 Supply of and demand for *Lantana* stems

Based on the existing use of *Lantana* it is estimated that a total length of about 7 840 m of big stems, 45 238 m of medium stems and 16 633 m of small stems are required by the community of 10 artisans in MM Hills per year (Table 4.3.) This translates to about 1 040, 2 144 and 3 610 plants of the respective girth categories in the moist deciduous forest. Similar figures for dry deciduous forest are 2 091 big, 14 962 medium and 34 295 small plants of the respective girth categories (Table 4.4.). Clearly the number of plants required to meet the demand is more from the dry deciduous forest compared to the moist deciduous forest. This is due to the significantly lower stem length of plants in the dry deciduous forest compared to the moist deciduous forest ($t= 3.87$; $p<0.0001$).

Table 4.3. Lantana stems stock per plant in moist deciduous and dry deciduous forest

Length of the stick for furniture per plant in (m)			
Place	**Big (>6 cm)**	**Medium (3.1-6 cm)**	**Small (<3 cm)**
Moist Deciduous	7.5 (23%)	21.1 (63%)	4.6 (14%)
Dry Deciduous	3.7 (51%)	3.0 (42%)	0.5 (7%)
Annual requirement of Stems length (in m)	7 840	45 288	16 633

Nearly 80% (231 km^2) of the MM Hills Reserve Forest is under *Lantana* cover (Ganeshaiah and Shaanker 2001), equating to approximately 148 km^2 of dry deciduous forest, 34 km^2 of moist deciduous and 48.5 km^2 of scrub forest. Based on this estimate, the moist deciduous forest is expected to have 94 440, 2.66 million and 37.87 million stems of big, medium and small girth, respectively, from 34 km^2. Similarly, in the dry deciduous forest, 822 222, 26.31 million and 50. 29 million (big, medium and small) stems are expected from 148 km^2 (Table 4.4.). Thus, there is a higher availability of stems from the dry deciduous forest than from the moist deciduous forest because of its larger extent. However, the availability of stems in the largest girth class is much lower than the smaller or medium size classes, which was also substantiated by local perceptions. It means that harvesters have to travel longer distances (5-10 km) to procure bigger stems

Table 4.4. Supply and demand of Lantana in MM Hills

Place	Forest	Big (>6 cm)	Medium (3.1-6 cm)	Small (0-3 cm)
Standing stock (No. of plants)	Moist Deciduous*	94 440	2 660 060	37 870 440
	Dry Deciduous*	822 222	26 311 104	50 292 579
Annual demand (No. of plants)	Moist Deciduous	1 040	2 144	3 610
	Dry Deciduous	2 091	14 962	34 295

*(*No. of Lantana plants available in unharvest transects (180 m^2 * 12=2 160 m^2) was multiplied to the size of the MD (34 km^2) and (180 m^2 * 6 = 1 080 m^2) to DD (148 km^2) forest possibly infested with Lantana in MM Hills)*

4.4.3 Effect of extraction on regeneration

In the two moist deciduous forest (MD) sites, Kommudikki and Marapala, regeneration of *Lantana* was significantly lower in the harvested plots compared to the control plots. The harvested sites had only about 40% - 50% density of stems compared to the unharvest plots. However, in the dry deciduous (DD) plot in Palar, there was little difference in the total density of regenerative stems between the harvested and unharvest plots (Table 4.5.). These patterns were also mirrored when the data were grouped and analysed separately for stems < 3 cm, 3.1- 6 cm and > 6 cm girth (Table 4.5.)

Table 4.5. Total number of stems per 180 m² plot in MM Hills (n=6 per site)

Girth	Place	2007 (Harvested)	2009 (Harvested)	2010 (Control)
All stems	Kommudikki	781	1 096	1 447
	Marapala	705	340	1 134
	Palar	464	421	565
	Mean ± SD	650 ± 165	619 ± 415	1 048 ± 447
Small (< 3 cm)	Kommudikki	727	967	1424
	Marapala	616	225	982
	Palar	338	274	367
	Mean ± SD	560 ± 200	488 ± 414	924 ± 530
Medium (>3.1-6 cm)	Kommudikki	53	110	21
	Marapala	84	103	148
	Palar	116	133	192
	Mean ± SD	84 ± 31	115 ± 15	120 ± 88
Large (> 6 cm)	Kommudikki	1	19	2
	Marapala	5	12	4
	Palar	10	14	6
	Mean ± SD	5 ± 4	15 ± 3	4 ± 2

Differences in the average girth in harvested plots in the moist deciduous forest were variable. At the Kommudikki site stems were significantly thicker in the harvested plots for small stems, but at the Marapala and Palar site they were significantly thinner (saplings) in the harvested plots. However, there was no difference in the mean girth of stems (plants) between extracted and control plots from Palar, the dry deciduous site (Table 4.6.).

Table 4.6. Mean girth of stems (< 3cm, 3.1-6cm, and >6cm) in MM hills

Girth size	Place	Year	Harvested *Mean ± SD*	2010 (Control) *Mean ± SD*	t-value	p-value
Small	Kommudikki		1.04 ± 0.69	0.65 ± 0.30	14.68	<0.0001***
(<3cm)	Marapala	2007	0.93 ± 0.60	1.53 ± 0.72	-17.78	<0.0001***
	Palar		1.38 ± 0.83	1.60 ± 0.85	-3.44	<0.0006***
Medium	Kommudikki		3.93 ± 0.71	4.33 ± 0.72	-2.16	0.0371*
(3.1-6cm)	Marapala	2007	4.10 ± 0.81	3.80 ± 0.67	2.869	0.0047**
	Palar		4.16 ± 0.74	4.12 ± 0.75	0.507	0.6121 ns
Big	Kommudikki		6.5	8.4 ± 1.55	NA	NA
(>6cm)	Marapala	2007	6.56 ± 0.81	6.6 ± 0.63	-0.082	0.9363 ns
	Palar		7.53 ± 0.89	7.16 ± 0.76	0.862	0.405 ns
Small	Kommudikki		0.94 ± 0.62	0.65 ± 0.30	13.75	<0.0001
(<3cm)	Marapala	2009	1.02 ± 0.86	1.53 ± 0.72	-8.11	<0.0001
	Palar		1.57 ± 0.85	1.60 ± 0.85	-0.44	0.6575 ns
Medium	Kommudikki		4.10 ± 0.75	4.33 ± 0.72	-1.35	0.1850 ns
(>3.1-6cm)	Marapala	2009	4.31 ± 0.82	3.80 ± 0.67	5.12	<0.0001
	Palar		4.14 ± 0.82	4.12 ± 0.75	0.23	0.8141 ns
Big	Kommudikki		7.24 ± 1.22	8.4 ± 1.55	-1.02	0.4772 ns
(>6cm)	Marapala	2009	6.50 ± 0.41	6.6 ± 0.63	-0.26	0.8013 ns
	Palar		6.76 ± 0.57	7.16 ± 0.76	-1.16	0.2803 ns

*** Highly significant; ** Significant; ns not significant

4.4.4 Effect of extraction on coppicing

The result of the first experiment in which cutting was applied in the dry season (April 2010) and measured in wet (0-6 months) (October 2010) shows that the number of coppice shoots ranged from 1.48 ± 1.50 to 4.66 ± 2.78 across all treatments, i.e. primary, secondary and tertiary) (Table 4.7.). On average, the number of coppicing shoots were higher in the dry deciduous (Palar) site compared to the moist deciduous (Kommudikki) site. This pattern persisted when the estimates were redone 12 months later in the following summer (April 2011). However, there was a decline in the number of coppice shoots in the dry season (12 months) compared to that in the wet season (six months) in the moist deciduous for the cuts on secondary and tertiary stems. This is possibly owing to the effects of shoot competition and the re-establishment of apical dominance, or to loss of coppice through either fire or browsing. In the dry deciduous site however, there was no significant difference in the number of coppice shoots from the wet to the dry season (Table 4.7.).

Table 4.7. Number of coppice shoots per cut stem for stems cut in dry and wet seasons

Season cut	**Forest type**	**Stem cut**	**6 months**	**12 months**	**F-value**	**Pr(>F)**
Dry	Moist forest (Kommudikki)	Primary	1.48 ± 1.50	3.80 ± 4.86	10.36	0.001**
		Secondary	2.38 ± 2.13	1.10 ± 1.61	11.39	0.001**
		Tertiary	2.14 ± 1.91	1.32 ± 1.49	5.702	0.018*
	Dry forest (Palar)	Primary	3.90 ± 1.96	3.76 ± 2.00	0.125	0.725ns
		Secondary	4.44 ± 1.80	4.48 ± 2.98	0.007	0.936ns
		Tertiary	4.66 ± 2.78	4.68 ± 2.66	0.001	0.971ns
Wet	Moist forest (Kommudikki)	Primary	7.40 ± 4.42	0	140.00	<0.0001***
		Secondary	6.58 ± 5.62	1.66 ± 2.23	32.99	<0.0001***
		Tertiary	5.74 ± 5.49	2.76 ± 4.34	9.04	0.0033**
	Dry forest (Palar)	Primary	5.28 ± 3.79	3.46 ± 2.67	7.681	0.0066**
		Secondary	7.94 ± 4.14	6.26 ± 4.28	3.973	0.0490*
		Tertiary	10.0 ± 5.98	7.20 ± 6.05	5.487	0.0212*

*** Highly significant; ** Significant; ns not significant

The effect of cutting in autumn (October) on the ability of the plants to coppice in the following dry (six months) and wet (12 mo) seasons at the two sites (Table 4.7.) showed, that between the sites, the number of coppice shoots was higher in the dry deciduous than the moist deciduous forest. Second, across the wet to the dry season (a difference of six months) there was significant decline in the coppice at both the forest sites with time (Table 4.7.).

The decline in coppice shoots was computed as mortality of stems between the two seasons. While the initial cutting during the dry season (April) had little or no perceptible decline or mortality of stems between the wet and dry season census at both sites. However, there was a significant mortality of coppice stems at both sites when the harvesting was done in the wet season (October) (Table 4.8.). In particular, none of the coppice from primary stems survived for 12 months, indicating stems mortality.

Table 4.8. Percentage of coppice stem mortality after the cutting in moist deciduous and dry deciduous forest *(n=50 plants per treatment)*

Forest	Cut stem	Cut in dry season (April 2010-April 2011)		Cut in wet season (Oct 2010-Oct 2011)		Chi-square	p-value
		6 months	12 months	6 months	12 months		
Moist	Primary	36	34	14	100	33.5	<0.0001
	Secondary	34	60	12	60	7.74	0.0054
	Tertiary	32	46	16	62	7.70	0.0055
Dry	Primary	6	8	10	28	1.314	0.2516
	Secondary	0	8	4	16	1.867	0.1718
	Tertiary	8	12	2	28	8.333	0.0038

4.5 Discussion

Invasive alien species like *Lantana* examined in this study, is one of the most uncontrollable species given their sheer expansive spread as well as the attendant cost that might be involved in controlling them (Love et al. 2009; Nautiyal and Nidamanuri 2012). Consequently *Lantana* has posed a serious challenge to conventional management schools, which prescribe the complete control or eradication of *Lantana*. But attempts to control or eradicate *Lantana* (either physical or otherwise) have more often than not met with failure and have done little to mitigate the impacts of *Lantana* on ecosystems and the services thereof (Bhagwat et al. *in press*; Sundaram et al. *in press*). In the absence of any action, *Lantana* has continued to spread and in many places of the world, often has also become naturalized among the native vegetation (Richardson and Rajmanek 2011; Taylor et al. *in press*). Furthermore and of central interest to this study and others (Geesing 2004; Shaanker et al. 2010; Shackleton et al. 2011; Kull et al. 2011), in human dominated landscapes such as that in India, Africa and other regions, the IAS have also become assimilated into the livelihoods of local communities, as are other native plant species. For example, the use of other IAS such as *Opuntia ficus-indica*, *Prosopis juliflora*, and *Acacia phyllodineae* by local communities in different parts of Africa is well documented (Geesing 2004; Shackleton et al. 2011; Kull et al. 2011). In India, Kannan et al. (2009) have documented the use of *Lantana* by local communities. Indeed their studies show that many communities in southern India earn more than 60 per cent of their cash income from extracting *Lantana* stems and converting them to a slew of handicrafts (Kannan et al. 2009; Shaanker et al. 2010).

In the context of the existing challenge to control IAS, such use of IAS by local communities is intriguing (Jafari 2010). Hitherto there are no studies that have explicitly addressed the impact of harvesting *Lantana* on the further spread of this IAS. In this study, I have attempted to assess the extent of utilization of *Lantana* by local communities in southern India and examine the impact thereof, on the regeneration and coppicing of *Lantana*. Specifically I attempt to ask if such impacts could have any implications for the local management of *Lantana*.

4.5.1 Demand for, and supply of, *Lantana*

Based on current estimates of demand, I found that there is abundant availability of stems (both big and small). However, the availability of bigger stem classes is less than the small stems. Big stems (> 6 cm) used for scaffolds in furniture are derived from plants that are old (5-6 yrs.), perhaps representing the pioneer plants. On the other hand, small stems (< 3 cm girth) are derived from almost all plants including younger plants. The big stemmed (older plants) are mostly restricted to a small patch of moist deciduous forest. The size class structure of *Lantana* in the study sites followed a “Reverse J” shape curve, characteristic of stable populations (Figure 4.2.), (Shankar et al. 1998; Shackleton et al. 2005). In such a demographic pattern, obviously there is a premium on older age class and therefore on “big” stems. In this context, it is easy to realize that the demand for big stems might be relatively difficult to procure at least in the local area; the artisans may have to travel larger distances to procure them. Thus under the present extraction demands, older and larger plants might reduce in frequency though they still would be available on a larger landscape level. This could potentially influence the current range of products made by the artisans and might cause a shift to products that rely more on smaller stems. This is also supported by the interviews with several artisans who expressed difficulty in procuring big stemmed plants from the forest.

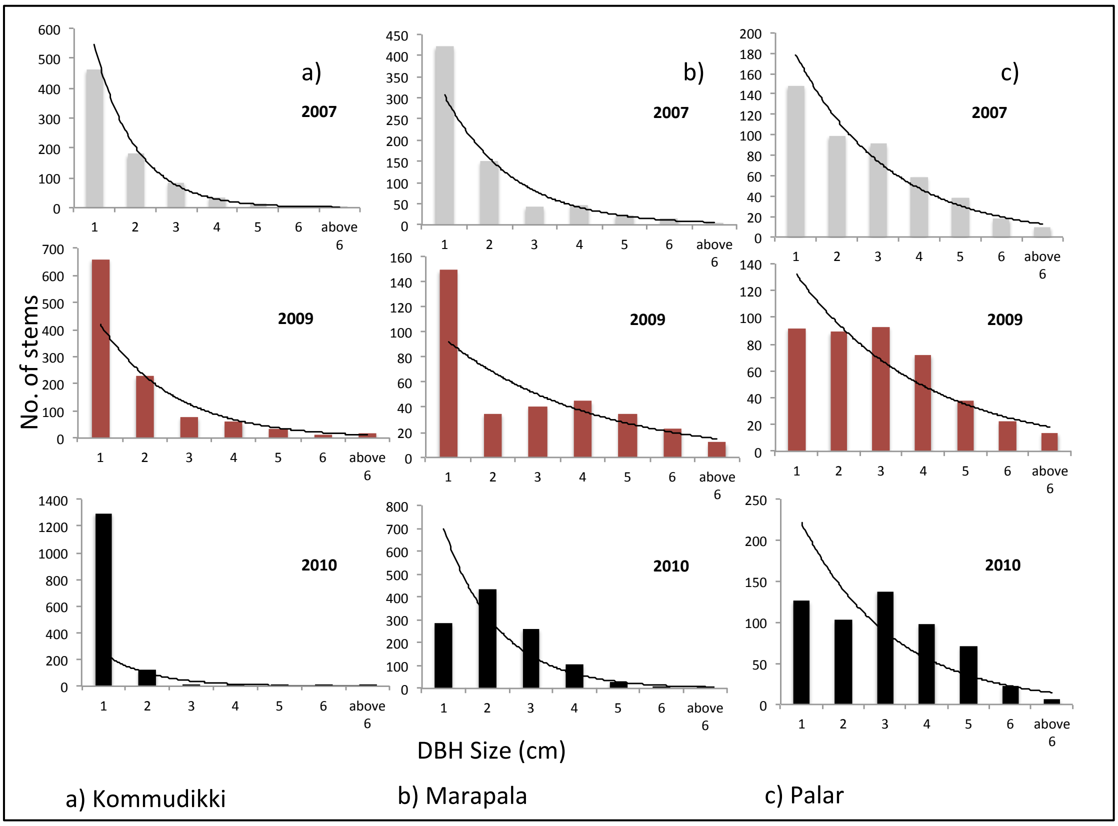


Figure 4.2. Lantana stem density in three different sites in MM hills

4.5.2 Impact of *Lantana* extraction on regeneration and coppicing

I assessed the impact of extraction of *Lantana* on the regeneration and coppicing at two forest sites, the moist deciduous and dry deciduous forests in MM Hills. Sites that were harvested at two periods (2007 and 2009) were followed up and the regeneration in terms of *Lantana* density enumerated in 2010 and compared with unharvested sites in the same area in 2010. In the moist deciduous forest, *Lantana* density reduced by 40% to 50% in the harvested sites compared to the unharvested sites. However, there was a little difference between the harvested and unharvested sites in the dry deciduous forest. These results are intriguing and could perhaps have been influenced by the both the age class distribution at the two sites and by local ecological correlates. First, at the moist deciduous forest, compared with the dry deciduous forest, there are a larger proportion of bigger size class stems (the former sites have relatively larger proportion of older plants, *personal observation*). Harvesting such bigger stems for making furniture would presumably lead to their truncation from the population distribution (and hence lowering the density); this could open up the space for native species recruitment (Sundaram and Hiremath 2012). Further, since big stems mean removal of primary stems, the total seed pool contributed by such extraction would be reduced (once again leading to reduction in density); also under this situation, since the soil is not disturbed, the buried seeds are not exposed to sunlight for further germination (Love et al. 2009). On the other hand, harvesting of predominantly small stems (the secondary and tertiary) in the dry deciduous forest is unlikely to have impacted the density due to both the basic distribution of such stems in these forests and the fact that harvesting them may not lead to the total removal (and death) of the plant. In summary, my results indicate that harvesting of *Lantana* can lead to substantial reduction in the local regeneration of the plant compared to sites that are unharvested.

The number of coppice shoots following cutting and their survival was recorded for a period of one year thereafter. The number of coppice was forest-type sensitive. The average number of coppice shoots was higher in the dry deciduous site compared to the moist deciduous site. At the moist deciduous forest, the mean number of coppice shoots was higher when stems were cut in the wet season compared to that in the dry season. While it is not immediately clear, the observed results could be due to shoot competition and the re-establishment of apical dominance (Shackleton 2001), or to loss of coppice through either fire or browsing when the cutting was done in the dry season compared to the wet season. For example, browsing of *Ocotea bullata* coppice shoots retarded elongation by 66% and increased mortality relative to protected shoots during the first two years after harvesting (Lubbe 1990). In the dry deciduous site however, there was no significant difference in the number of coppice shoots between wet and dry season.

Finally, I also monitored the mortality of stems between the two seasons at the two sites. Cutting during the dry season had no effect on mortality of stems, while it did when done in the wet season. Overall, a year after cutting, there was 60% and 75% mortality of the coppiced stems in the moist and dry deciduous forest respectively. This shows that timing of cutting is crucial if the objective is to decrease *Lantana* populations. Height of cutting has also been shown to effect mortality and regrowth rate in other species (lower cutting heights increases mortality) (e.g. Bowersox et al. 1990; Johansson 1992) and should be examined for *Lantana* as well.

4.5.3 Implications for management of *Lantana*

My study indicates that extraction of *Lantana* by local communities can substantially impact the regeneration. The results themselves are not completely unobvious given the fact that a number of earlier studies have demonstrated similar effects for other non-timber forest products harvested by local communities (Shankar et al. 1998; Shackleton et al. 2005; Rasul 2008). However, while in the latter scenario, the interest and concern arise from the need to sustainably harvest the NTFPs, in the case of *Lantana*, the interest is to ask if the harvest can actually be unsustainable so as to lead to a reduction in the population of *Lantana*. As a matter of fact, this contrasting perspective on NTFPs (to ensure that harvest is sustainable) and on IAS (to ensure that harvests are unsustainable) is an interesting axis to debate if use (harvesting) of IAS can become a viable strategy for their control (Shaanker et al. 2010; Shackleton et al. 2011). As mentioned elsewhere (Chapter 1), the prevailing mainstream school for control of IAS is unipolar, with the major mandate being eradicating the IAS via top-down interventions (Jafari 2010). Thus, to this school, use of IAS, is an idea antithetical to their core philosophy. But in recent years several researchers (Shackleton et al. 2007a; Shaanker et al. 2010; Kull et al. 2011; Shackleton et al. 2011) have questioned this paradigm especially in the context of the role IAS play in local livelihoods (Chapter 3).

In this study, I show that in the process of using *Lantana* as a bio-resource for enhancing local livelihoods, the communities might actually be promoting its control, for the reason that such extraction lead to reduction in regeneration and mortality of the plants. Admittedly however, the magnitude of such impacts would be scale dependent with respect to number of families/communities in a local area that adopt the use of *Lantana*, spatial scale of their operations, market demand, etc. As shown in my study, given the existing scale of use, the following is clear: a) there is an imminent difficulty in procuring big stemmed plants for making larger products such as furniture, b) due to continuous harvesting of *Lantana* over the last few years (2007-2010), there is a significant reduction in *Lantana* density in areas harvested compared to those not harvested, c) while coppicing is evident, there is often a substantial mortality of coppiced stems either due to restoration of apical dominance or herbivory (*personal observation*), and d) there is death of the entire plant if the primary stem is cut in the wet season. Clearly therefore, harvesting of *Lantana* in MM Hills can be regarded as unsustainable and if continued to be harvested by more number of families, can lead to reduction in the density of *Lantana*.

In summary, promoting the use of *Lantana* (as well as other IAS) by local communities can actually be viewed as one of the means to manage the species. I argue that conventional management programmes can enfold this strategy as one of several approaches towards dealing with IAS. The advantage of this approach lies in the fact that a) it is inexpensive, b) it can be sustained over years, unlike, top-down control or eradication programmes that are typically once-off and which in the long term may not be effective in preventing the recurrence of the species, c) it involves the local communities and thereby State or Forest department can leverage a greater human resource force to deal with the issue than otherwise, and finally, d) it empowers and enhance the livelihoods of local communities. In fact if the potential of this approach can be realized, the State can actively promote the use of IAS, such as *Lantana* by local communities.

CHAPTER 5

PLAYING WITH THE FOREST: INVASIVE ALIEN SPECIES, POLICY AND PROTECTED AREAS IN INDIA[4]

[4] *Kannan R, Shackleton CM, Shaanker RU (under review) Playing with the forest: invasive alien species, policy and protected areas in India, Current Science*

5.1 Introduction

Colonization of Africa and Asia by the European powers between the 15thand 19th centuries lead to a quantum jump in the introduction of alien species into the colonized territories for food, fodder, energy and ornamental purposes (Pyšek and Richardson 2008; Khuroo et al. 2012). The Indian sub-continent was one such region in which colonial invasions brought in a number of invasive alien species (IAS) that greatly transformed the native landscapes. For a major part the introductions and subsequent naturalization of plant species native to other countries into India was guided by the colonial government polices (Kannan et al. *in press*). However over the years, many of these introductions went on to become IAS. For example, Sankaran et al. (2009) listed *Chromolaena odorata*, *Lantana camara*, *Mikania micrantha* and *Mimosa diplotrichaas* as the major IAS in India. In the recent past *Prosopis juliflora* was introduced as an alternative fuelwood tree in southern India. *Lantana* was introduced into India at the East India Botanical Gardens, Calcutta in 1807 as an ornamental plant by the British (Chapter 2). Since then *Lantana* has spread to most parts of the country, in farmlands and forestlands, and has posed a formidable challenge to farmers and foresters alike. Conventional management efforts to control *Lantana* have not been successful. To date there is no robust management or monitoring mechanism against IAS in India. Large numbers of forest dependent communities still depend on forest resources and their livelihood is in stake due to pervasive landscape alteration by major IAS in different parts of India. It is important to review the existing policies and their implication on IAS management in India with special reference to Protected Areas (PAs) in India.

In this regard, I reviewed the Indian Forest Policy documents such as the National Forest Commission Report, Indian Forest Act, Wildlife Protection Act, and others to understand the policy implications over the last half a century towards management of invasive alien species. I interviewed 73 retired forest officials who worked across the Western Ghats in Tamil Nadu, Kerala, Karnataka, Maharashtra and Goa and also reviewed the management practices of major IAS to identify their contribution in IAS management.

5.2 The protected area network in India

In 1970, the Indian wildlife board drafted the national wildlife policy which highlighted the major threats to wildlife species and habitats in the country such as hunting, poaching, habitat alteration or destruction, forest fire, introduction of exotic species, and commercial exploitation of forest resources (Mandal 2003). This catalyzed the enactment of the Wildlife (Protection) Act in 1972 which emphasized the need for creating protected areas devoid of anthropogenic pressures such as livestock grazing, anthropogenic fires, land holdings and so on. This act classified the protection status into three categories, namely National Parks, Wildlife Sanctuaries and Closed Areas. Prior to 1972 there were only five National Parks and 64 Wildlife Sanctuaries in India, but within the next three decades these numbers increased almost ten times to 668 (Comprising 102 National Parks and 515 Wildlife Sanctuaries, 47 Conservation Reserves and 4 Community Reserves) with an additional 39 Tiger Reserves and 28 Elephant Reserves for species specific management (Table 5.1.).

Table 5.1. Number and extent of designated protected areas in India

Type	Status	Number	Area (km^2)
National Parks	Declared	102	36 579
Wildlife Sanctuaries	Declared	515	119 929
Conservation Reserve	Declared	47	1 382
Community Reserve	Declared	4	20

Sources: Protected Area Network (MoEF) http://envfor.nic.in/downloads/public-information/protected-area-network.pdf

5.3 Protected areas as undisturbed land

In India, as well as internationally, the guiding philosophy in declaring protected areas (PAs) is that they are parcels of land in which human disturbance is minimal or absent, so as to promote *in-situ* conservation of representative or essential ecosystem services and processes, or habitats and species, with a special emphasis on endangered, threatened and rare species. Thus, they are expected to be largely devoid of anthropogenic pressures such as land clearing, agriculture, logging, hunting, human-induced fires and grazing by livestock (Bruner et al. 2001). In India this objective is supported by a number of policies and management plans which restrict or deny most anthropogenic impacts in protected areas (Table 5.2.). However, the reality in India of high human population pressures and historical land rights results in many protected areas having villagers living within them (Karanth and DeFries 2010), although expropriations continue in flagship protected areas (DeFries et al. 2010). These residents have legally recognized rights of access and use, although with prescriptions and with significantly more restrictions than is the case outside protected areas (National Forest Policy 1988).

Table 5.2. Commonly encountered pressures on protected areas in India

Pressure	Prevalence of the pressure in PAs	Origin of the pressure	Prevalence of management responses to the pressure	Strength of on-the-ground management response
Fire [1,2]	Very common	Internal	Common	Strong
Fuelwood collection [3]	Very common	External	Common	Strong
Grazing by livestock [3]	Very common	External	Common	Medium
NTFPs harvest [4]	Very common	External	Common	Strong
Invasive plants [5,6]	Very common	Internal	Absent	Absent
Animal poaching [7]	Common	External	Common	Very strong
Land encroachment [4]	Common	External	Common	Very strong
Shifting agriculture [8]	Common	Internal	Common	Very strong
Dam construction[8, 9]	Rare	Internal	Case specific	Very strong
Mining activities[8]	Rare	Internal	Case specific	Very strong

[1]Lahkar et al. 2011; [2]Sundaram et al. in press; [3]Kannan et al. in press; [4]Marothia 2009; [5]Krishna et al. 2008; [6]Dutt 2000; [7]Reddy and Chakravarthy 1999; [8]Balooni 2002; [9]Bhargav and Dattatri 2011

National Parks are afforded the highest protection status, such that livestock grazing is totally prohibited, as is cultivation and private land holdings, along with the control of fire (Wildlife Protection Act 1972). On the other hand, in Wildlife Sanctuaries a degree of local flexibility is usually afforded, such that the Chief Wildlife Warden can control, regulate or prohibit grazing or movement of livestock, NTFP collection and so on. However, most PA managers in India view forest fires, grazing, fuelwood and NTFP collection as a major threat to conservation outcomes and therefore seek to eliminate them (Ambinakudige 2011). Fire control programmes and anti-poaching are an integral part of every PA management system, consuming a significant portion of the budget.

5.4 Invasive alien species as a threat to biodiversity

The Millennium Ecosystem Assessment (2005) lists invasive alien species (IAS) as one of the five primary drivers of change in ecosystem composition, structure and function. Moreover, global climate change may well accelerate the rate of introduction and spread of IAS into areas where they were previously absent, or increase their performance relative to indigenous species (Raizada et al. 2009). Invasive alien species can have large detrimental economic impacts on human enterprises such as fisheries, agriculture, grazing and forestry. Globally the costs associated with the negative impacts of IAS have been put at US$ 1.4 trillion per year, close to 5% of global GDP at that time (Pimentel 2005). A review by Clavero and García-Berthou (2005) concluded that IAS were the main cause of avifaunal extinctions worldwide, and the second highest cause for the extinction of freshwater fish and mammals. Overall, examination of the IUCN database on species extinctions implicated a negative role of IAS in 50% of those extinctions where a cause could be identified or inferred, second only to habitat transformation (Ervin 2003). At a national level**,** Pimentel et al. (2005) estimated the environmental costs associated with IAS in the United States to be approximately US$ 120 billion per year, and that IAS were the primary threat to about 42% of the indigenous species already on the threatened and endangered species inventories. At a sub-national level, Turpie et al. (2003) estimated at the turn of the millennium that the negative economic impact of IAS on ecosystem services in the Fynbos biome in South Africa (the world's most florally biodiverse area), was in the vicinity of US$ 110 million per annum and that IAS threaten 55% of South Africa's red data plants and up to 60% of endemic freshwater fish species in the country. Born et al. (2005), however, caution that most studies calculating the economic impacts of IAS are underestimates and most require more robust methodologies.

India also suffers the impacts of IAS, many of which are highly invasive. Khuroo et al. (2012) recently reported that 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 found in India. The negative impacts have been felt through losses to grazing, agricultural production and for some species, human health (Kohli et al. 2006).

5.5 Invasive alien species and protected areas in India

Given the significance of IAS in imperiling biodiversity throughout the world there has been a steady development of international conservation policies and agendas to create awareness and support national agencies to develop national policies and strategies. For example, Article 8 (h) of the Convention on Biological Diversity, to which India is a signatory, behooves countries to eradicate IAS, which threaten local ecosystems, habitats and species. The Global Invasives Species Programme was set up to create awareness and provide advice and support in combating IAS.

However, these developments do not seem to have filtered into PA policies and management plans within India, even though IAS can jeopardize the protection status of PAs (Denslow 2007). Table 5.3. shows that explicit policies and management responses on the control of IAS are absent from most Indian PA plans, whereas in many other countries (e.g. South Africa, USA) IAS control plans are an integral component of individual PA management plans. This absence of a policy and management response is in spite of growing number of reports and research articles on IAS and their impacts in Indian PAs (Love et al. 2009; Ramaswami and Sukumar 2011; Prasad 2012; Sundaram and Hiremath 2012)

For example, Kerala Forest Research Institute and CAB International (2009) collaboratively compiled a manual on *Chromolaena odorata*, *Lantana camara*, *Mikania micrantha*, *Mimosa diplotricha* and *Parthenium hysterophorus* as major IAS in India (Sankaran et al. 2009). Most of the PAs in the Western Ghats and Eastern Himalayas are highly infested by at least one of these five IAS, and the spread and negative impacts are increasing. For example, Sundaram and Hiremath (2012) monitored 134 plots across 540 km^2 in the Biligiri Rangaswamy Tiger Reserve between 1997 and 2008, and found that the percentage of *Lantana camara* (hereafter *Lantana*) stems per unit area increased from 5.5% in 1997 to 57.2% by 2008. Sharma et al. (2005a) and Love et al. (2009) have previously drawn attention to the rapid spread of *Lantana* throughout India, including in PAs. Recently, Prasad (2012) noted how *Lantana* was rapidly spreading in Bandipur Tiger Reserve in southern India and that it suppressed grass cover and indigenous tree sapling density, which mirrors the results of Ramaswami and Sukumar (2011) for selected species in Mudumalai Wildlife Sanctuary. Sharma and Raghubanshi (2011) reported negative impacts of *Lantana* cover on herbaceous species diversity and cover in several areas of central India. Such negative impacts of IAS are not limited to plant species, but also other taxa such as insectivorous and canopy birds in MM Hills forest reserve (Aravind et al. 2010), certain antelope species (Krishna et al. 2008) and rhino (Lahkar et al. 2011), which are amongst the national priority species for conservation in India. IAS also negatively impact the livelihoods of local communities, with respondents at BR Hills and MM Hills reporting that *Lantana* invasion was reducing the grazing in the forest and NTFP harvests (Prashanth 2009).

Ironically however, some PA managers suggest that *Lantana* might be positive in that it provides cover for carnivores and some other game species (Bhagwat et al. *in press)*, seemingly forgetting that such a role was played by indigenous understory species prior to being replaced by vast swathes of *Lantana* now dominant in many protected areas, and increasing.

Table 5.3. Examples of policies and Acts relating to IAS in India

No.	Policy on invasive species/weeds	Year promulgated
1	The Livestock Importation Act	1898
2	The Destructive Insects and Pests Act	1914
3	The Madras Agricultural Pests and Diseases Act	1919
4	The Travancore Plant Pests & Plant Diseases Regulation	1919
5	The Coorg Agricultural Pests & Diseases Act#	1933
6	The Patiala Destructive Insects and Pests Act	1943
7	The Bombay Agricultural Pests and Diseases Act	1947
8	The Rewa State Agricultural Pests and Diseases Act	1947
9	The East Punjab Agricultural Pests, Diseases and Noxious Weeds Act,	1949
10	The East Punjab Agricultural Pests, Diseases and Noxious Weeds Act, as extended to Himachal Pradesh	1949
11	The Assam Agricultural Pests and Diseases Act	1950
12	Plant Quarantine (Regulation of Import into India) Order	2003

Coorg Noxious weed Act 1914 was proposed due to *Lantana* invasion in the coffee plantations and followed by heavy forest fire. However, the act was not implemented until 1933 due to World War 1 and its heavy expenses for the British. *Source: Agricultural legislation in India (1952)*

5.6 Playing with the forest: inaction against invasive alien species in Indian protected areas

Despite the clear negative trends and impacts, very few PAs in India have active and vigorous programmes to stem the tide against IAS. Love et al. (2009) demonstrated the cut rootstock method as an effective physical removal technique of Lantana in Corbett Tiger Reserve in northern part India. It is cost effective in smaller scale (Rs.4000-5000/ ha) but expensive in larger scale. Typically, the only limited action to control IAS is to clear some areas as a component of fire control practices, not for their biodiversity impacts per se. Common practices are to cut and burn IAS that occur within a few metres of roadsides within the PA, which provides a firebreak against wild fires as well as some improved short-range visibility in the forest for viewing of game species. My experience is that there are very few efforts to seriously control or remove IAS deeper in the forest, a feature also noted by Bhagwat et al. (*in* *press*). Indeed, Bhagwat et al. (*in press*) go so far as to suggest that PA managers in India have given up trying to eradicate IAS, but simply seek to control them. But it would be fair to mention that the fact that managers have given up on controlling *Lantana*, rests on the belief that it is uncontrollable. However, the same is not the norm with other intractable management issues such as controlling wild fires, illegal poaching and fuel wood collection. On the other hand, much scientific evidence in the country, shows that IAS are continuing to spread into new areas and densification in areas already invaded; a stark testament that the said control efforts along roadsides are having no effect.

From the survey among the retired forest officers of Karnataka Forest Department more than 85% reported that there were hardly any management programmes to control IAS, and relatively little scientific research on the issue providing practical guidelines to PA managers. The only method that they knew for control was to manually cut and burn. This is labour intensive and offers only a short-term solution because the seed bank of the major IAS remain and hence reinvasion occurs very rapidly. Some IAS, such as *Lantana*, may even be stimulated by the burning (Hiremath and Sundaram 2005). Thus, the clearing and burning of a few meters along roadsides has no impact whatsoever on the spread of IAS in Indian PAs.

In instances where clearing of larger areas deeper in the forests have occurred, they are associated with development of plantations of valuable timber species for revenue, or restoration plantings (Sharma et al. 2005b). My interaction with some of the forest managers of the PAs in the Western Ghats indicates that their species selection for plantations is based on three criteria: (a) fast growth, (b) good timber value, and (c) un-palatability to game species. These criteria encourage the planting of exotic species, such as eucalyptus, silver oak (*Grevillea robusta*) and acacia (*Acacia auriculiformis*); in effect replacing one IAS with another alien species. Thus, the clearing of IAS for establishment of plantations is not linked to biodiversity conservation objectives and outcomes. These plantations in PAs have their own impacts on forest ecosystem processes and biodiversity. For example, eucalyptus plantations are well known for their high water use, ground water depletion, suppression of ground cover species and plant species richness generally (Calder et al. 1997; le Maitre et al. 2002; Milton and Dean 2010; Calvifio-Cancela et al. 2012).

Denslow (2007) emphasized in the management guidelines for PAs that forest managers need to be careful and evaluate exotic species used in rehabilitation and restoration projects to avoid introducing or facilitating the spread of IAS.

On the surface, this inaction against IAS in Indian PAs is slightly complex to understand. The case against IAS because of their negative impacts on biodiversity and ecosystem services has been well argued internationally. Thus, why the absence of any coherent and meaningful response? I pose two possible explanations, namely (a) lack of appropriate policy or awareness, and (b) perverse application of policy and regulations.

The suggestion that there is a lack of appropriate policy and awareness by conservation policy-makers and PA managers is undermined by India having a rich legacy of policies and regulations spanning almost a century relating to the control of IAS (Table 5.3.). Thus, at the policy and legislative level at least, there seems to be a suite of enabling policies, even if there is no exclusive national legislation or policy addressing the problem of IAS. Nevertheless, the recently introduced operational guidelines of the "Intensification of Forest Management Scheme" (2009) of the Ministry of Environment and Forest emphasizes the need for control and eradication of forest invasive species and providing assistance to state owned or supported research institutions to carry out research into management or eradication of IAS (IFMO 2009). Notably, the recent legislation of the scheduled tribes and other traditional forest dwellers (Recognition of Forest Rights Act 2006) provides an enabling policy space for the participation of local communities in protection as well as management of PAs, forests and biodiversity generally. It recognizes and vests rights to the local Gram Sabha (village committee) to protect the wildlife and biodiversity of the PAs. In the Act, chapter 5 (a) (b) and (d) strongly urges local communities to ensure the protection of ecologically sensitive areas, regulate the access to community NTFPs, and stop any activity which adversely affects wild animals, forests and biodiversity.

If these policies are not being acted upon at the management level, then there are either unseen barriers to implementation, or awareness at the management level is lacking. If the latter, it would suggest that training curricula at forestry and conservation institutions need to be revised to include sufficient materials and promote understanding of the threats to biodiversity and ecosystem services posed by IAS. Besides these, it is imperative that PA managers understand the need to manage IAS by developing active early detection programmes, prevent spread by active monitoring, develop corridors devoid of IAS for free movement of large mammals to maintain forest connectivity, which is otherwise threatened by forest fragmentation. Unfortunately, because of a single-track mission (of eradication), many of the above mentioned perceptions have hardly influenced, or entered, management portfolios of PA managers in India.

The notion of a blind application of legislation as an explanation for inactivity against the threats of IAS originated during discussions with individual PA managers in the Western Ghats area during 2008 to 2010. These dialogues revealed perhaps a more insidious reason for the lack of meaningful programmes to control IAS in PAs. The explanation was provided, on several occasions, that the Wildlife Act (1972), which was the foundation of the growth of PAs in India, prevents the harvesting and removal of plant and animal materials from PAs. This interpretation of the 1972 Act was reinforced by a ruling of the Supreme Court order (Writ Petition (Civil) No. 171 /1996) in December 12, 1996. Thus, a paradoxical situation exists that the very legislative Act used to conserve biodiversity in PAs can also be used to prevent the eradication of IAS, which actually threatens the same biodiversity. This is especially so for National Parks, where all harvesting is strictly prohibited. There is some leeway in Wildlife Sanctuaries. Management officials argue, therefore, that even with sufficient awareness and budget, they would be acting illegally.

However, the Supreme Court order also created a space for addressing the legal concerns through ordering the constituting of a Central Empowered Committee (CEC) to look into the issues related to environment and forests. The track record of the issues handled by the CEC is quite impressive. They have submitted numerous findings and recommendations to the Honorable Supreme Court on PA and forest policy and managements issues. For example, farming encroachment in the Western Ghats and Northeastern Himalayas, closure of mining activities to protect the flora and fauna in the Kudremukh National Park and protecting endangered species such as Olive Ridley sea turtles in Orissa (Sanctuary Mangazine 2003). So, although a strict reading of the Wildlife Protection Act (1972) does prohibit harvesting in PAs, the Supreme Court ruling provided a mechanism for this to be reviewed and for flexibility on a case by case basis. Thus, I see a compelling case for scientists or managers to approach the CEC for them to provide clear guidelines and exemptions regarding programmes for the vigorous control and removal of IAS from PAs.

5.7 Conclusion: protecting protected areas against IAS

The negative impacts of IAS on biodiversity and ecosystem services are well known and decried throughout the world. In this research I have argued that the presence and increasing spread of IAS is threatening biodiversity in PAs (and outside) in India, thereby undermining the very reason for their existence. Yet, in the face of this severe threat, there appears to be very little coherent and meaningful response to limiting the impacts in PAs by halting the spread into new areas and removing IAS from the millions of hectares already invaded (Shaanker et al. 2010). The precise reasons for this lack of a response need to be clearly understood, and then addressed. Once addressed, scientists and conservationists need to work together to address the scourge with vigor and urgency drawing on examples and best practices from around the world and adapting them to the Indian context. Researchers need to categorize alien species according to the level of threat and rate of spread in each of the bioclimatic zones (e.g. Robertson et al. 2003). After the classification, broad and replicable management strategies need to be developed based on a range of options (van Wilgen et al. 2011) related to (a) early detection, (b) control and removal, and (c) ecosystem management and monitoring of the IAS.

CHAPTER 6

CONCLUSION

6.1 Invasive Alien Species

Human movements across the globe, over land or sea, be it in the form of migrations, explorations or colonization, and in more recent times through trade, have often brought along manifold changes in culture, language, food, diseases and even in the natural history of the places or regions visited (Essl et al. 2011; Nunez and Pauchard 2010; Perrings et al. 2010a). The European colonization of Africa and Asia in the 18^{th} century was perhaps one of the largest such movements and brought profound changes to both continents (le Maitre et al. 2011; Bhagwat et al. *in press*). The colonization contributed to an unprecedented movement of plants into new habitats, often physically distant from their native habitats. The human colonizers engineered most of these movements for their own pleasure, welfare and survival in new countries and habitats (Kannan et al. *in press*). Many of these plant introductions went on to completely change the local cultural food habits of people; for example, the tomatoes, potatoes, green chillies, all from South America, brought into India by the British, forever changed the culinary preparations and farming practices in India (Beinart 2004; Sekar 2012). Similarly the Cucurbita spp., radish (*Raphanus sativus*), potato (*Solanum tuberosum*) and carrot (*Daucus carota*) and carnations, all from other parts of the world, distinctly changed the vegetable and ornamental industry in Asia (Convention on Biological Diversity 2001). However, a few of the species, though intended to be used by the colonizers, established so successfully that they rapidly spread over large areas, and became what are today referred to as "Invasive Alien Species" (IAS).

For example, *Impatiens glandulifera*, native to Himalayas, was introduced in England in the 19^{th} Century for its ornamental value, has invaded all most all the countries in the Europe and in particular the Czeck Republic (Pysek and Prach 1995; Williamson 2010). Similarly, different Australian *Acacia* species were transported from Australia and introduced into South Africa and Madagascar for its timber, tannery, fuelwood and ornamental values (Chapter 3; Carruthers et al. 2011). The British introduced *Lantana* into India in 1807 as an ornamental plant in the East India Botanical Garden in Calcutta, and several other British Cantonments (Chapter 2; Kannan et al. *in press*). Two hundred years later, the species has run amok and today is regarded as one of ten worst invasive species in terms of its spread, uncontrollability, and the losses incurred to agricultural productivity, native flora, and many tangible and intangible ecosystem services (Bhagwat et al. *in press*), which together have significant implications for local livelihoods.

From an historical perspective, the movement of *Lantana*, as with any other IAS, is worth understanding. Under whose directions and under what circumstances and through what route, did such introduction happen? From an ecological context, the movement and subsequent spread has raised questions on the effects on native species, and the associated ecosystem services. From a management perspective the movement has prompted methods of containing the spread. Besides these rather formal issues, a more recent interest raised in the IAS literature is the local human adaptation to such exotic species, such as the widespread use of *Piper aduncum* for multiple purposes by forest communities in Papua New Guinea (Siges et al. 2005); and multiple use of Australian *Acacia* species in South Africa and Madagascar(Kull et al. 2007; Kull et al. 2011), the stem of *Malvastrum coromande-lianum* and *Sida acuta* used for fibre in Indian Himalayan range (Sekar 2012).

In this thesis I chose to focus on three major issues related to the introduction and spread of *Lantana* in the Indian sub-continent. The first is an attempt to recreate the ecological history of the introduction and spread of *Lantana* in India. Using a variety of approaches, including archival research and spatial and temporal analysis of floristic records, I reconstructed the history of the circumstances under which the colonial powers decided to introduce *Lantana* into India. Through research based on the archival records I also reconstructed the plausible path taken by *Lantana* to reach India from South America. Fuentes et al. (*in press*) suggested that scientists and forest managers should use herbaria records to source baseline information of the invaders, as the cost of collecting this information in developing countries is expensive. Similarly within India, I traced the floristic records in major national herbaria and by accessing archival records of British administration, I have traced the possible path of spread of *Lantana*. Second, in the context of increasing spread of *Lantana* (and its uncontrollability), I addressed human adaptations to *Lantana*. In the tropics, especially where people still depend substantially upon forest or native vegetation based resources (bamboo, NTFPs etc.) (Mahapatra and Shackleton 2011; Saha and Sundriyal 2012), IAS could potentially undermine their livelihoods (Sundaram and

Hiremath 2012; Ticktin et al. 2012). In this study, I asked if local communities in *Lantana* dominated landscapes actually do use *Lantana*, and if so what are the drivers of such an adaptation. And under the situation that people do use *Lantana*, I also asked what are the specific consequences, from a socioeconomic perspective. In the final section, I have critically reviewed local practices and forest policy for the management of *Lantana* in southern India. Specifically, I analysed if peoples' adaptation and use of *Lantana* has any impact on the local management of *Lantana*, especially under the condition that the species is not amenable to classical forms of management (Bhagwat et al. *in press*).

In this chapter I first briefly summarize the salient findings and based on these, discuss the implications that these might have for the changing perspectives on the management of IAS and the possible role of local human adaptations in managing IAS. I also dwell on the larger context of IAS in human dominated landscapes and argue that an inclusive strategy needs to be developed in managing IAS. Finally, I also discuss the management of invasive alien species in the socio-ecological context in which the IAS is placed. I discuss several cross cutting themes and ideas that may have a bearing on the overall perspective and management of IAS.

6.2 Reconstruction of *Lantana* introduction and spread into India

I examined the movement of Lantana over a time span of roughly 200 years spread across three spatial scales, including global, national and regional, in the Western Ghats, a biodiversity hotspot. I found that *Lantana* species were transported and cultivated in the European botanical gardens in the 1690s, one hundred years before their introduction into European colonies in Africa, Asia and Australia (Chapter 2; Kannan et al. *in press*). Contrary to the general belief that *Lantana* species in India were introduced directly from South America, my study shows that the *Lantana* species in India came from European botanical gardens where they were being maintained. This is evident from the correspondence between the Secretaries of Horticulture and Agriculture Societies of India and Court of Directors of the East India Company in London in 1830s (Chapter 2; Kannan et al. *in press*). The movement of *Lantana* was only one among a score of plant species that were directed to be moved into the English colonies for agricultural and horticultural purposes.

Specifically, *Lantana* was chosen for its ornamental value (Pejchar and Mooney 2010). In India, *Lantana* was first introduced into British Cantonments, botanical gardens and plantations (Figure 6.1.). Soon after its introduction into India sometime in the early 1800s, the species began to spread from the introduction sites, a fact noted by the colonial government over 100 years ago.

However, it's spread into surrounding landscapes was not deemed as undesirable at the time and thus there were no policies or management practices to address the spread during it's early, and perhaps, controllable, stages (Chapter 2 and 5; Kannan et al. *in press*; Bhagwat et al. *in press*). This view was supported by interviews with retired forest officers and elders in local communities.

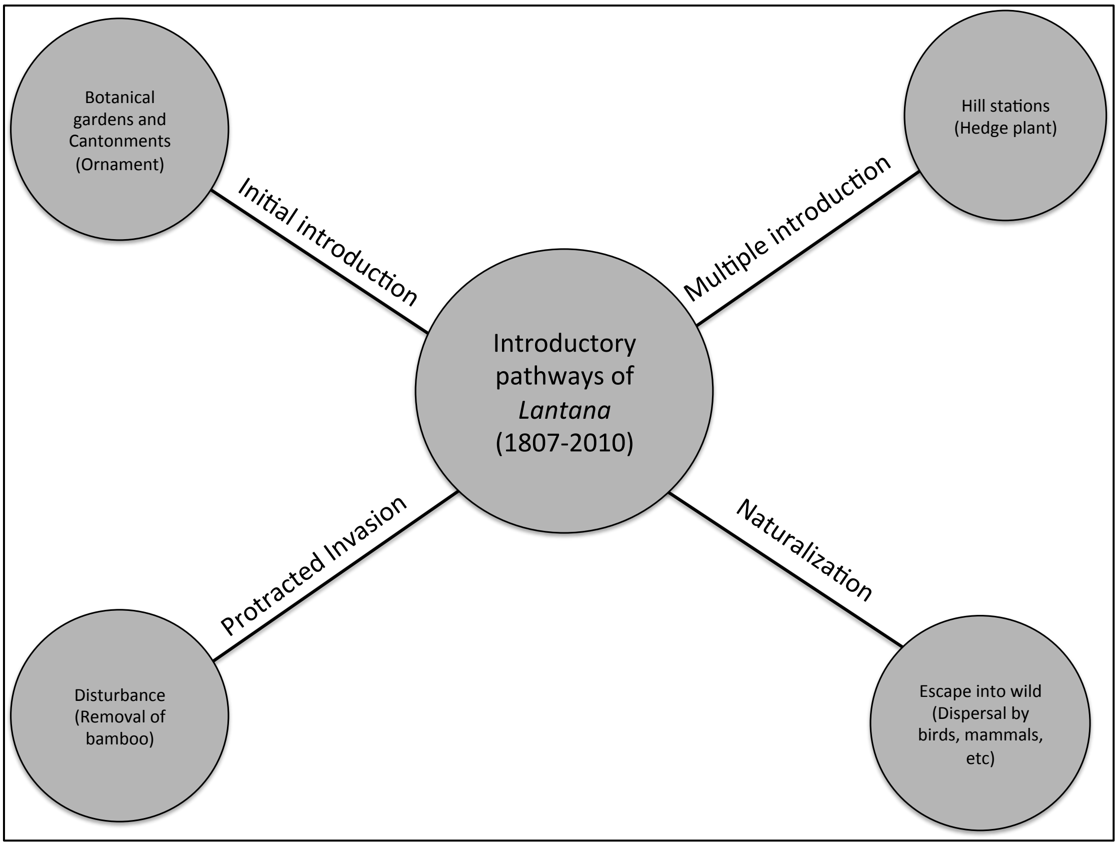


Figure 6.1. Synthesizing the introductory pathways of Lantana invasion in India

6.3 Human adaptation to *Lantana*: socioeconomic causes and consequences

To understand the socioeconomic and ecological impact of use of *Lantana* by different communities I asked a) what are the critical socioeconomic parameters that distinguish the *Lantana* user groups from nonuser groups? b) what are the key determinants that promote its use by communities? c) can we borrow these lessons to actually catalyse the use of *Lantana* (especially in the context where it cannot be controlled) in other communities where the species is abundant? d) can we identify what are the tangible economic gains to communities that have are using *Lantana*? and e) how has the use of *Lantana* by local communities impacted its local regeneration?

The results showed that communities in the study site have been using *Lantana* for over 25 to 30 years and apparently such use was endogenous (not prompted by external agencies) (Chapter 3). Communities or families that use *Lantana* did so to primarily compensate for their loss of income from forest based natural resources. Tracing the ecological history of the region revealed an interesting pattern that is suggestive of the possible driver of *Lantana* use by the communities. The study site was a thriving area for non-timber forest products collection by local communities. The site was also once known for its rich bamboo resources. Several of the communities that I studied derived a large proportion of their cash income by weaving bamboo handicrafts. The name of one of the communities, the Soligas, literally means "out of bamboo". Indiscriminate extraction of bamboo by commercial pulp industries, compounded by mast flowering of bamboo, drastically reduced the bamboo stocks. I presume this disturbance over native ecosystem contributed to the expansive spread (protracted invasion) of *Lantana* in the study site (Chapter 3; le Maitre et al. 2011). However, with the expansive spread, in many sites, *Lantana* also caused a suppression of the growth of other non-timber forest product species and in many places also hindered easy access into the forest (Sundaram and Hiremath 2012; Ticktin et al. 2012). It is under these ecological circumstances that families and communities of at least two of the four communities I studied, namely, the Soligas and Koravas, that hitherto were dependent on NTFPs and bamboo, probably switched to using of *Lantana* as an alternative bio-resource (Figure 6.2.).

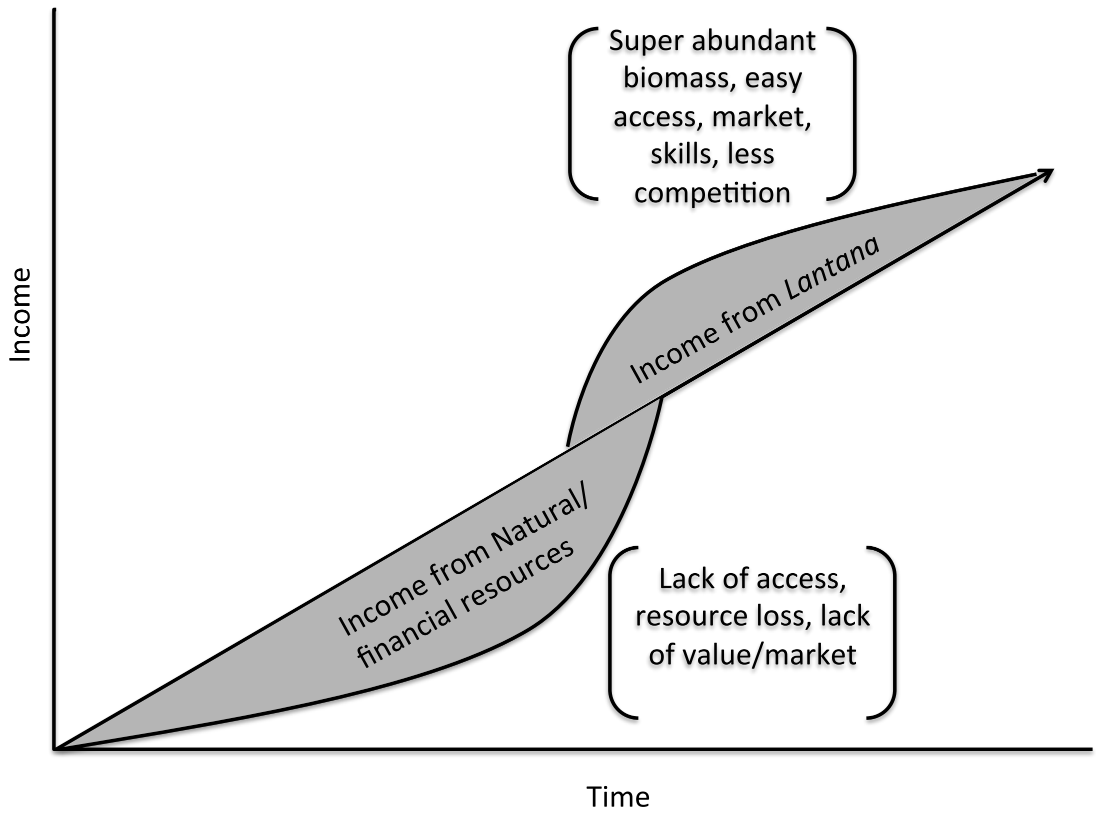


Figure 6.2. Compensating the income loss from natural resources by IAS

The immediate driver for two other communities, Madigas and Irulas, who unlike Soligas and Koravas, were much less dependent on bamboo or NTFPs, but dependent on local agricultural labour markets, seems to be motivated by the decline of the labour market due to series of droughts and land use changes. These communities turned to using *Lantana,* because it is zero investment raw material. Shackleton (2007b) argued that poor and marginalized communities make extensive use of natural resources because they are zero investment raw materials. I also found that the access to financial, as well as natural resources is crucial for poor and marginalized communities to take up the use of such IAS that are zero investment resource. The income from IAS is an important part of the household income of the rural poor. Shackleton et al. (2007) argued that since IAS is available all year round and often in proximity to households, they tend to reduce dependency on native species for such uses as fuel wood, fiber, timber, etc. Similarly, Kull et al. (2011) found in the central highlands of Madagascar that local communities actually prefer the IAS *Acacia dealbata* (native of Australia), because it provides valuable contribution for the subsistence economy of the rural poor. Most of the economic analyses of the IAS operate at an aggregate scale (e.g. de Wit et al. 2001; Pimentel et al. 2005), which can completely mask the different sets of costs and benefits that operate at the scale of individuals or households directly affected (Chapter 3). Thus, the local communities' adaptation of IAS needs to be acknowledged and addressed judiciously while forest managers plan the management of IAS.

Under these circumstances one of the strategies to address IAS could be a greater inclusion of local communities in local management programmes (e.g. South Africa's Working for Water programme) or foster increasing use of an IAS (Chapter 3 and 4). I argue that the latter may lead to an adaptive management of the IAS in a manner that would not only contribute to local management but also in alleviating poverty of the rural communities in developing countries where control or management of IAS is financially constrained (Perrings 2005; Nunez and Pauchard 2010).

6.4 Local practices and forest policy for the management of *Lantana* in southern India

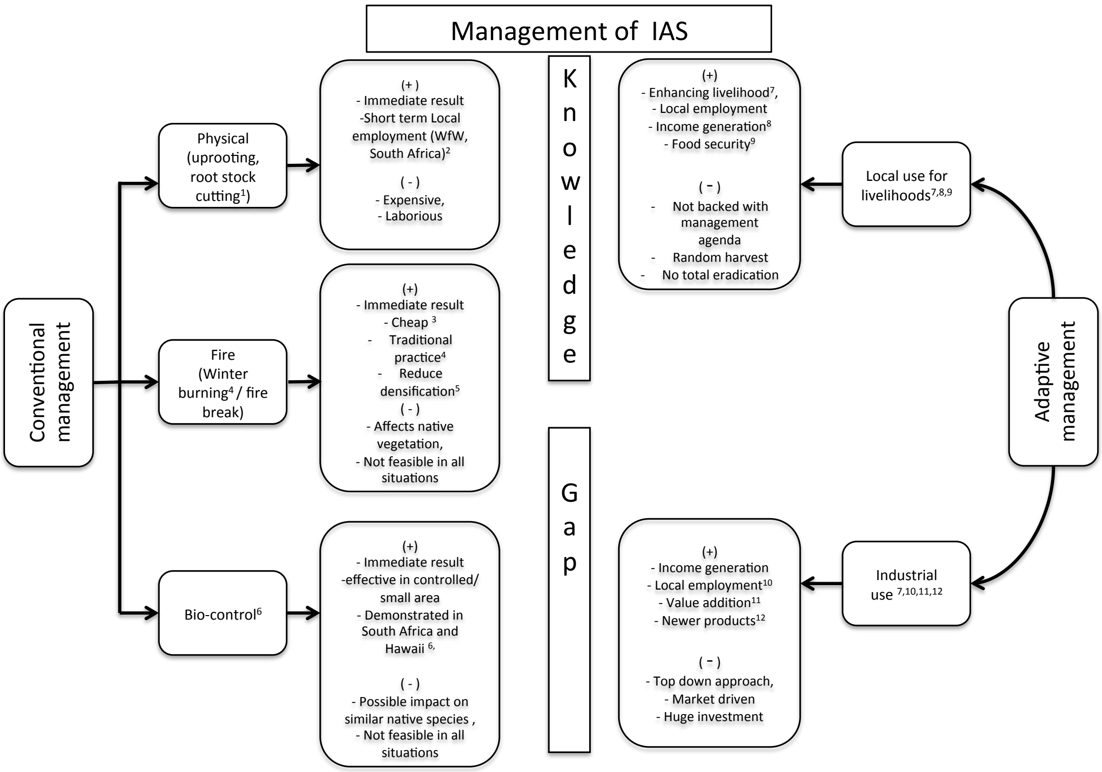
Given that communities have been using *Lantana*, I asked if such use makes any difference to the regeneration and thereby the management of *Lantana* at least at the local scale. Sites harvested were compared with those not harvested for the density of *Lantana*, regeneration and coppicing ability over two years. Harvested sites had significantly lower densities (40%) and lower regeneration (50%) compared to non-harvested sites (Chapter 4). Though initially there was profuse coppicing (more than 60%) of cut stems of *Lantana* in the moist deciduous forest (stems were cut in wet season), many of these eventually died (60% - 100%) either through the re-establishment of apical dominance or by herbivore predation. This was particularly prevalent when the primary stem was cut in the wet season, in effect killing the plant. This is an important aspect of my study in terms of management of *Lantana*, and substantiates the recommendation of Love et al. (2009) to cut the rootstock as effective management approach in *Lantana* removal, especially in Protected Areas in India. It is important to note that the cut rootstock method targets the primary stems and after cutting the primary stem is not uprooted. Love et al. (2009) argue that this prevents disturbance of the soil, which prevents the soil seed bank from being exposed to light and sometimes fire which promote their germination over the native species (van Wilgen and Richardson 2010). In this regard, I would recommend that cut rootstock method to be practiced during the wet months in a year to increase the mortality rate of *Lantana*.

On the balance, my study indicated that on a local scale, harvesting of *Lantana* by the communities did have an impact on the density of *Lantana* for several years after harvesting (Chapter 4). However, the current level of use by the communities would not serve to control *Lantana* at a larger landscape level because current levels of availability of stems (supply) are far in excess of the current demand (Chapter 4). Thus, unless the current scale of use increases, by more families or communities and at larger volumes, the use of *Lantana* may not profoundly contribute to the management, at least in terms of what are regarded in the more formal sense of control of IAS. Yet, the ecological results of reduced densities and plant mortality shows that use could potentially have a significant role in reducing or controlling the spread of *Lantana* (Chapter 4).

Besides the role played by communities in management of *Lantana* as a spin-off of its use, little seems to have been done by the state in management of *Lantana* (Chapter 5) and there I also found a huge knowledge gap between conventional management practices and local adaptations (Figure 6.3.). Interviews with retired forest officers (n = 73) and analysis of archival documents revealed that the state had no comprehensive, cohesive, resourced and objectives driven policy or management plans for controlling the spread of *Lantana* (Chapter 2; Chapter 5). Participatory interactions separately with communities and forest department officers revealed an interesting difference in perspectives on the main drivers of *Lantana* invasion (Chapter 2, 3 and 5; Kannan et al. *in press*). Communities alleged that the current expansive spread of *Lantana* is primarily due to the control of winter forest fires since 1970s by the forest department in BR Hills WLS in South India (Sundaram et al. *in press*). Similarly Mandle et al. (2012) studied the woody plant invasion and fire regimes for 16 major woody invaders (including *Lantana*) across the globe and found that changes in fire regime as a result of forest fire management could lead to promotion of the invasion of woody species. Russell and Roberts (1996) report that relatively frequent, low intensity fire 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.

On the other hand, the forest department alleges that the communities' practice (now disused) of shifting cultivation (slash and burning) and human made fire (winter burning to induce growth of grass and wild yam) induced *Lantana* spread. Similar lines of argument were promoted by Love et al. (2009) who reported that a) the burning of *Lantana* promotes the germination of *Lantana* seeds from the soil seed bank which is exposed to light after the burning, and b) burning promotes secondary invasion of other weedy plants. However, Hiremath and Sundaram (2005) argue that different ecosystems respond differently towards forest fire. In this context it is noteworthy that Sundaram et al. (*in press*) found that the *Lantana*-fire-cycle hypothesis may indeed be useful but its usefulness is based on the phase of the *Lantana* invasion. They concluded that fire might help to control *Lantana* at the initial invasion phase of *Lantana*.

The bio-control programs against *Lantana* started way back in the 1900s in India (Chapter 2; Kannan et al. *in press*). However, the release of insects (*Teleonemia scrupulosa*) for *Lantana* control failed due to vigorous regrowth of *Lantana* and the climate variability (heavy monsoon rains, and harsh winter in northern India) led to heavy mortality of the bio-control agents (Singh et al. 2010). Clearly these differing observations indicate the need for the participation of local community and an adaptive management approach towards the management of IAS, i.e. one approach does not fit all situations. This represents a commonly encountered gap between management and local ecological knowledge (Figure 6.3.).



Ref: [1]Love et al. 2009; [2]Moore et al. 2011 ; [3]Hiremath and Sundaram 2005; [4]Sundaram et al. 2012; [5]Prasad 2012; [6] (Perkins 1925; Broughton 2000; Zimmermann et al. 2004); [7] Sankar et al. 2010; [7]Kull et al. 2011; [9]Shackleton et. 2011; [10]Geesing et al. 2004; [11]Jafari 2011; [12]Mwangi and Swallow 2005.

Figure 6.3. Knowledge gap between conventional and adaptive management approaches in managing IAS

Of particular concern is the absence of any effective and comprehensive strategies for control of *Lantana* in protected areas (Shaanker et al. 2010; Chapter 5). One of the oft-cited reasons in India for the inaction is that PAs are supposed to be inviolate and there can be no harvesting or removal of biological resources within them (Chapter 5). Under such a policy, management of *Lantana* within PAs does not arise. Yet, the broader goal of establishing and maintaining PAs is for conservation of native species. Thus, if this goal is jeopardized the implementation policy should be sufficiently flexible to allow removal or minimization of the threat, in this instance, that posed by an IAS. Indeed, the same PAs officially undertake a number of management programs including fire control, preventing grazing, NTFPs collection, and fuel wood collection to meet their broader conservation mandate (Chapter 5; Sundaram et al. *in press*), and thus removal of IAS can be viewed in the same light. Thus, it appears the PA management with respect to the threats posed by IAS is in need of review so that IAS can be managed. For example, in South Africa, every national park has a monitoring program and implementation plan for the control and even eradication of IAS within the PA boundaries (Foxcroft el al. 2007; Foxcroft et al. 2010).

6.5 Emergent issues

In summary, from the above review and critical analysis of *Lantana* as a resource, a number of issues emerge that have a bearing on the current perspective on IAS. Here I briefly discuss a few of these issues.

6.5.1 Definition of IAS: a socio-ecological perspective

The term IAS began to be first used after Charles Elton's work on invasion ecology published in his book on "The Ecology of Invasions by Animals and Plants" (Valery et al. 2008; Perrings et al. 2010a). Plants that moved out of their native habitats where termed as exotic, alien, non-native, imported, naturalized and Invasive Alien Species (Colautti and MacIsaac 2004; Valery et al. 2008). Most of the definitions of IAS have involved an ecological-economic-political context. President Clinton's Executive Order 13112 (1999) defined "an alien species as one whose introduction does or is likely to cause economic or environmental harm or harm to human health" (Sakai et al. 2001; Simberloff 2011). Perrings (2005) defined IAS as plants introduced consequent to international trade either deliberately or as an unintended byproduct (packaging material, vehicle of transport, and passengers on traded goods) of the import of other goods and services. Thus, he showed that international trade and the number of IAS are positively correlated. Richardson et al. (2010) defined IAS as species that "sustain self-replacing populations over several life cycles, produce reproductive offspring, often in very large numbers at considerable distances from the parent and/or site of introduction". Conspicuously missing from all these definitions is the reference of IAS as a resource that can potentially be used by people especially in poor countries (Siges et al. 2005; Shackleton et al. 2007; Kull et al. 2007; Pejchar and Mooney 2010; Patel 2011). My study, as well as those of a few earlier workers (e.g. Pejchar and Mooney 2010; Shaanker et al. 2010; Carruthers et al. 2011), have shown that the existing definitions may be too polarized and perhaps need to be reconsidered to accommodate the fact that besides being IAS, these species often have a resource value, and far from being merely academically interesting, local communities the world over have often made local adaptations to assimilate these resources into their culture and livelihoods. Thus, and especially in the context of regions of the world where people still depend on forest/plant resources for their survival and livelihoods, IAS can actually play a significant role as an additional bio-resource (Chapter 3; Siges et al. 2005; Shackleton et al. 2007; Kull et al. 2011; Patel 2011). Thus, as aptly summarized by Carruthers et al. (2011), the term IAS is a human construct and thus subject to scrutiny, criticism and likely to evolve over time. Thus, what is IAS in one region may not be in another. Or what is an IAS at one point of time may not be at another. In other words, I argue that IAS may be regarded from a socio-ecological perspective where the sociological and ecological interaction is fully considered in not only assessing but also managing the IAS. This is neither an atypical nor a trivial issue, as it concerns millions of people at the crossroads of IAS and livelihoods. I believe that an integration of the different perceptions, sociological-economic-ecological, can lead to not only a better appreciation of IAS, but also lead to evolution of adaptive management strategies that may be better than the current ones that are based purely on economic-ecological perspective.

6.5.2 IAS as a resource: analysis of tipping points

From a sociological perspective it is interesting to ask what makes people use an IAS as a resource, a plant that they had probably not known earlier. Can we understand the socio-ecological context by which an IAS becomes used? For example, what are the attributes that make an IAS usable (from the plant's side) and what are the attributes of the people that make them use the IAS (from the people's side). In other words, can we identify the tipping points for each of these? Analysis of these questions can help to trace the evolution of users of IAS from the state of them being powerless spectators to copers and eventually to adaptive managers (Fabricius et al. 2007).

Shackleton et al. (2007) hypothesized that use or otherwise of IAS could be largely a function of the time since its invasion and the traits of the species. Besides this, as evident from my study, it appears that the attributes leading to their use could be more complicated and could be significantly informed by the local context and by the cultural setting of the local communities. Thus, the same IAS, such as *Lantana*, might easily be adopted as a bio-resource in one setting and completely ignored in another.

Analysing the history of introduction of *Lantana* and its use by communities in South India, I have identified few tipping points that may have resulted in the use of *Lantana* as a bio-resource by the local communities (Figure 6.4.).

- The first tipping-point was the deliberate introduction of *Lantana* into British settlements of colonial India. Perusals of the correspondence between the English colonial officials show that there was a careful planning of the climatic match of plants before they were introduced to a particular region. Thus, temperate plants were introduced into the hills and mountains, while plants from South America were brought into the plains (Chapter 2; Kannan et al. *in press*). In other words, there was a tacit match already made on the habitat suitability. It thus not surprising that a species like *Lantana* soon spread from the botanical gardens into the wild. This subjective match of climatic equivalence between the sites of origin and import has now been well corroborated by ecological niche modeling predictions. Indeed it is inconceivable that without such a match being made, that species can become invasive (Thomas and Ohlemuller 2010).

- The second tipping-point was the escape of *Lantana* into the wild from the botanical gardens, and coffee estates (Chapter 2; Kannan et al. in press). Archival records show that there was no overt concern about this though it was distinctly observed and discussed over the initial periods of spread. I do realize however that at that time there was no wider discourse about the potentially negative impacts of deliberate plant introductions, and that the term IAS did not even exist. Nonetheless, with historical hindsight, this inaction allowed *Lantana* to move freely into different parts of the country. For example, multiple introductions of *Lantana* as a hedge plant in several hill stations, coffee plantations in Coorg and different parts of the Western Ghats helped spread the plant.

- The third tipping-point was dispersal of *Lantana* and its escape into wild habitats. Birds and mammals played a major role in carrying *Lantana* seeds and dispersing them over far distances into the wild habitats (Aravind et al. 2010). Categorizing *Lantana* as a weed and the absence of early detection or monitoring practices facilitated its further spread. Perkins (1924) reported that the introduction of

Indian Mynah birds into the Hawaii Islands, to control grass army worm (*Spodoptera mauritia*), which attack sugar cane, facilitated the further spread of *Lantana* by dispersing the seeds to far distances.

- The fourth tipping-point was extensive land use changes and transformation of forests, especially due to forest logging, indiscriminate extraction of bamboo and establishment of commercial plantations; these facilitated the invasion of *Lantana* into these disturbed sites (Chapter 3; Chapter 4; Shaanker et al. 2004b). This could be an important tipping-point where the native flora gave way to *Lantana* (Sundaram and Hiremath 2012; Ticktin et al. 2012). This phenomenon is mirrored by Nepstad et al.'s (2008) argument about the land use, forest and climate change in the Amazon, which led to near-term Amazon forest dieback and possible invasion by grass and herb species. This view is also supported by Sundaram et al. (*in press*) who showed that the protracted invasion of *Lantana* in the study site in south India could be due to control of winter burning (*Tharagu bengi*) which normally inducing the growth of grass species including bamboo and wild yam and control weeds.

- A fifth tipping-point was evident when some communities took to using *Lantana* as a resource. This was a result of the interaction of several seemingly unrelated drivers, notably a decreasing abundance of bamboo and rattans as an economic resource and an increasing abundance of *Lantana* (Chapter 3 and 4; Kannan et al. 2009; Shaanker et al. 2010).

Each of these tipping-points represented a major change in the extent and dynamics of *Lantana* in India; introduction, establishment, log phase expansion. Had different choices or combinations of factors occurred at that time, the current extent of *Lantana* might have been very different. In each instance, there was strong link between social or economic decisions and ecological implications, except the fifth, where an ecological change resulted in a socioeconomic shift.

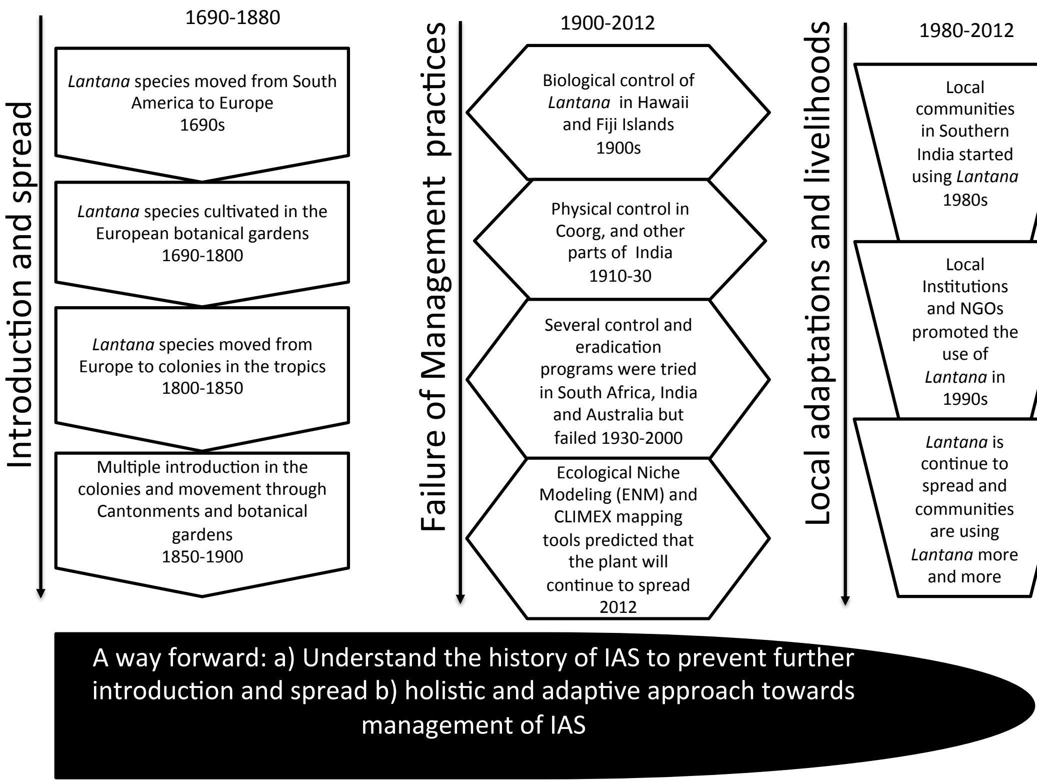


Figure 6.4. Reflections from my study: from introductory pathways to local adaptations

6.5.3 Can use of IAS lead to its management?

The primary aim of all IAS programs is to control or even eradicate the plant species, which is nearly always designed and implemented through a top-down approach (Keller and Lodge 2010). However, these are often very resource demanding (le Maitre et al. 2011; van Wilgen et al. 2011). In this context, can peoples' use of IAS serve as a means to control or limit the spread of the IAS? How does it compare with top-down state approaches? Can local use and state's top down approach be integrated? Are there examples of reasonable management of IAS using peoples' use as an approach? Under what conditions could local control possibly have some effect? If integrated measures have to be put in place, what would or should its contours be? These are some challenging questions and have to be clearly navigated with care for them to be effective.

Conventional management approaches are top-down and the state is primarily responsible for controlling and eradicating the IAS (Keller and Lodge 2010). The controls of *Opuntia monacantha*, Australian *Acacia*, *Prosopis juliflora* etc. are typical examples of control of IAS by the state in different countries (Zimmermann et al. 2004; van Wilgen et al. 2010). Some of these control measures have been effective but nearly always incurred at a huge investment of resources, in terms of both labour, money and of course, time (le Maitre et al. 2011). But for many other species that have gone past their log phase of spread, state control measures are unlikely to be effective. In fact it is interesting to note that for many species where state controlled top-down approaches have failed (e.g. *Lantana camara*, *Lonicera Japonica* (Japanese Honeysuckle), *Impatiens glandulifera*, etc.) the species have gone on to become IAS (Bhagwat et al. *in press*; Pysek and Prach 1995; Richardson and Rejmanek 2011). In a recent study, Moore et al. (2011) argued that the effectiveness of top-down approaches is a function of the area over which the IAS has spread. If the area of spread is < 1 000 ha the species is amenable for eradication, if < 2 465 ha it is amenable for management and if > 2 465 ha it cannot be controlled. At the latter stage, the IAS can become pan-regional or pan-country (e.g. *Lantana camara*, *Eichhornia crassipes, Prosopis juliflora*). In India alone, it is estimated that the spread of *Lantana* is over 13 million ha (Bhagwat et al. *in press*). Accordingly, it is beyond any form of conventional control; furthermore even if attempted, the cost would be exorbitant (Love et al. 2009). In summary, the top-down approaches are straightforward but their effectiveness is constrained by the extent of spread of IAS. In the absence of control, the species can spiral into its expansive state as is witnessed with *Lantana* in India.

Under this scenario, I ask if use of IAS as a resource by communities can offer an alternative, bottom-up approach to manage IAS. My studies have shown that use of *Lantana* by local communities can lead to significant reduction of stem density and regeneration of *Lantana* (Chapter 4). In other words, just like many other non-timber forest products, harvesting can lead to substantial reduction of *Lantana* in the area where they are extracted. In this context, use of *Lantana* can potentially serve as a tool to manage IAS though not necessarily to eradicate it. I argue that this approach where the use of IAS can lead to the management is not trivial and could be regarded as an alternative method of management. However, the effectiveness of this approach is subject to the scales and volumes of its operation.

6.5.4. IAS as bio-resource: conflict with regional and national impacts

It is likely that use of IAS as a bio-resource can conflict with the mainstream impacts that it may have regionally or nationally. However, the key to resolution of such conflict lies in weighing the (in) effectiveness of state control measures on the one hand (Chapter 5) and the associated cost that the IAS thus incurs on the ecosystem, and the effectiveness of local adaptation that manage the IAS on the other. As long as the latter does not further add to the spread of the IAS, but helps in locally arresting the IAS, IAS as a bio-resource should not be seen to conflict with the regional and national impacts it might have. For example, in India, the spread of *Lantana* has undoubtedly impacted native flora and fauna and ecosystem services (Love et al. 2009; Dobhal et al. 2011; Prasad 2012). However, the local use of *Lantana* as a bio-resource has not further exacerbated the problem; rather if anything, the use of *Lantana* has been able to successfully reduce densities of the IAS in the neighbourhood from where they have been extracted. In this context, local use of IAS cannot clearly eliminate the negative impacts of IAS but it can reduce the negative impacts to the extent it is used (Perrings et al. 2010b). Use of *Eichhornia crassipes* (Water hyacinth) in certain Southeast Asian countries has led to the management of this species in those areas (Jafari 2010). Indeed in certain parts of south India, heavy use of *Lantana* for the past 30 years, has decimated the predominant vegetation cover offered by *Lantana* so much so, that the local forest department has restricted the extraction of *Lantana* (Personal observation). In short, the advocacy of local use of IAS should not conflict with the long-term interest of controlling the IAS so long as the local control is undertaken in that manner.

6.5.5 Socio-ecological systems, scales and policy

It is now well recognized that social and ecological systems operate in an integrated manner and it is almost impossible to deal with them independent of each other (Armitage et al. 2009). In many ways, both directly and indirectly, social changes can lead to ecological changes and vice versa. Thus, the dynamics of IAS can be viewed and analysed in a social-ecological context. The introduction of *Lantana* from South America to India as an ornamental plant was a social decision (as part of the decision by the British to establish an horticulture industry in the countries that they colonized). However, years later this social decision led to significant ecological impacts in which the species spread rapidly into many unintended regions in the country leading to the usurpation of native flora and fauna and loss of critical ecosystem services. Ticktin et al. (2012) showed that expansion of *Lantana* caused a significant reduction in the population size of an important non-timber forest product species, *Phyllanthus emblica*. Also the species spread into areas traditionally occupied by yet another important bio-resource, bamboo. These changes caused a substantial loss of livelihoods of rural people dependent upon native biological resources. Challenged thus, the rural communities evolved several social responses among which were, migration to far away coffee estates and stone quarries, wage labour in forestry related activities or increased vulnerability. A certain proportion of the community that obviously did not do any of these explored using *Lantana* to substitute for lost native resources and lost livelihoods. Thus, an ecological change, which originally was created by a social decision, had a social implication whereby the resource was adapted by local communities, effectively completing a circle of responses. This use had a local level ecological impact in decreasing densities and population size of *Lantana*. Understanding this dynamics in a socio-ecological context as described here can be useful in arriving at a more informed and inclusive management strategy for IAS as the two domains are not independent. Hoole and Berkes (2010) argued that active programs to recouple the two could have enormous benefits for biodiversity conservation and local livelihoods.

6.5.5.1 Scale: International, national and regional

The importance of scale (spatial and temporal) of analysis is important in understanding the dynamics of IAS as also for their management. This is more so in complex situations such as the IAS where the interactive partners influencing the dynamics involve both society and the environment as argued above. This has been stressed by the Millennium Ecosystem Assessment (MA 2005. The MA undertook analysis at multiple scales from community to global with showing that analysis at one scale often revealed a different understanding to analysis at a different scale (Fabricius et al. 2007; Cundill and Fabricius 2009). Local communities, who have a more immediate and direct dependency on ecosystem services, are expected to be more sensitive to changes in ecosystem condition and services. Their perceptions are expected to be fine grained (Berkes 2000) and to that extent, local communities are not mere "passive spectators" but "active managers of ecosystems" (Floke et al. 2005). Thus, in the context of management of IAS, decisions regarding IAS should ideally consider the perspective of local communities and integrate them to arrive at adaptive co-management strategy.

Scale related differences were clearly evident in my study. For example, in Chapter 4, the analysis of harvesting impacts indicates that the local harvesting has a negative impact on the densities and population size of *Lantana* at the local scale. But at the landscape or Protected Area scale, these impacts are negligible. Similarly, in Chapter 2, I presented analysis of *Lantana* invasion patterns at three different scales, which together give a more integrated picture than one alone. Similarly, examination of incomes from *Lantana* at a community or village level would not reveal the differences apparent at an intra-community level in which users and non-users were disaggregated. It is thus vital that knowledge across scales be integrated to ensure that they lead to judicious management.

6.5.5.2 Local adaptation and Policy implications

An important issue related to the management of IAS is the policy framework under which the management or control can be planned and executed (Keller and Lodge 2010). As mentioned elsewhere the current policy of the state in managing IAS is straightjacketed in the traditional view that IAS should only be controlled or eradicated and only done via a top-down approach. This monolithic view has gained credence over the years and any attempt to offer alternative approaches have not been received favorably. However, for reasons explained in earlier sections, and the fact that IAS is a good example of complex social-ecological system, it is necessary that differing perceptions come together and allow for local management devices to integrate into mainstream control, eradication or management. Lucy et al. (personal communication) discussed the dichotomized decision making process (between the state and the local stakeholders) and argued that in the long run it would add value if the perception of the state and the local communities were integrated. In other words, from a hitherto exclusive model of management, policies should be made that incorporate local perceptions in managing IAS; this could be an ideal situation where both perceptions and stakeholders (the state vs. the communities) are in a win-win mode.

In summary, I conclude that viewing IAS from a socio-ecological context could be more enriching in not only understanding the drivers and tipping-points that may have led to the establishment of a species as IAS but also in eventually designing strategies for their management that are more comprehensive than what conventional management schools offer. To date only a few studies on IAS have been comprehensively addressed in a socio-ecological perspective. Clearly there is a need to extend similar analysis to a number of other IAS and communicate to policy and management plans that are grounded in realities of social compulsions and biological realities of the region.

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