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A review of *Lantana camara* studies in India

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Abstract- *Lantana camara*, a noxious weed, has been expanding and now established in many regions of the world, including India. As it poses major threats to ecosystem, it has been in the focus of control attempts. For the purpose of this research, various characteristics of *Lantana camara* are discussed and techniques to combat its invasion in India have been studied. Results reveal that species have become menace and expanding its range. Present research also suggest that more than 80% of studies focus on its impact, use, toxicity, and its therapeutic uses only. It thus comes out clear, that research focusing on path and progression of *Lantana camara*, besides knowing its ecology, is the need of the hour. Information of this kind, as presented in this research, is critically needed to plan-out a befitting response to protect the ecosystems at a matching scale; else it may be impossible to make any headway towards meaningful control with small, scattered and sporadic attempts.

Index Terms- *Lantana camara*, invasion, India, management, planning, review

INTRODUCTION

Globally, there is a surfeit of IAS that affects ecological processes and cause loss of biodiversity from native ecosystem (Gordon, 1998; McNeely, 2001; Dogra et al., 2010). This includes myriad of impacts such as alteration in ecosystem processes (Charles and Dukes, 2007; Devine and Fei, 2011), decline in abundance and richness of native flora (Capers et al., 2009), alteration in community structure (Gordon, 1998; Sanders et al., 2003) and many more. Invasion is considered as the second most widespread threat to global biodiversity next to habitat destruction (Park, 2004; Leadley et al., 2010). Risk is limited not only to loss in biodiversity but environment, economies, and humans are at loss as well (Andersen et al., 2004; Pimentel et al., 2000; Perrings, 2010; Hulme, 2012). Therefore global efforts are being made to control invasive species as these are considered to pose significant threats that are difficult to reverse.

Various definitions of invasive species have been proposed by internationally acclaimed organizations in invasion research (Table 1). Although defined variously by different authors, the definition of invasive species given by GISP is considered most pertinent to the present discussion which states that 'invasive alien species are non-native organisms that cause, or have the potential to cause, harm to the environment, economies, or human health' (GISD, 2010). The definitions convey that the benefit of an action, which may lead to the introduction or spread of an invasive species, is clearly outweighed by the potential harm caused by the species. In the context of invasive species definition, invasion potential of the species thus can be expressed as the weighted sum of dispersal movements, and accessibility from 'infected' bioregions to 'uninfected' bioregions and ability to maintain viable population.

Table I: Definitions of invasive species by organizations engaged in invasion research

Definitions	Organization
A species that is not native to the ecosystem under consideration whose introduction causes or is likely to cause economic or environmental harm or harm to human health.	National Invasive Species Council, 2001
Species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.	Convention on Biological Diversity (CBD)
Non-native organisms that cause, or have the potential to cause, harm to the environment, economies, or human health.	Global Invasive Species Programme (GISP)
Animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species.	International Union for Conservation of Nature (IUCN)
The Invasive Species Specialist Group uses definitions 1 and 2 for invasive species 1. Species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce. 2. Species whose introduction and/or spread threaten biological diversity (CBD).	Invasive Species Specialist Group (ISSG)
An alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health	Invasive Species Advisory Council (ISAC)

It is the invasion potential of species that enable it to be successful invaders and colonizers of the novel environments, whether introduced deliberately or accidentally (Dogra et al. 2009). This rapid and increasing rate of invasive potential and its establishment have very little prospect of reversing (Muniappan et al. 2009; Sharma and Raghubanshi 2011). More concretely, evidence is

accumulating that the rate of change in global ecosystem due to invasion potential is exceeding at pace with which we advance our understanding of the change (Lockwood et al., 2007; EEA, 2010). Developing regions are fast witnessing this change and particularly more evident in India.

India is abode of indigenous species and well known for its biodiversity hotspots. A large majority of exotics plaguing the country are natives of American continent, followed by Eurasia, Europe, Asia, Africa and Australia. Although, a large number of exotics have reached naturalization in India; only a few have noticeably altered the ecosystem structure and functions. Amidst them, *Lantana camara* stands out distinctly in the list of top invaders (Murali and Setty, 2001; Hiremath and Sundaram, 2005; Sharma and Raghubansi, 2006; Prasad et al., 2007; Sahu and Singh, 2008; Babu et al., 2009). *Lantana camara* is one such pantropical weed which is affecting ecosystem, and causing biodiversity loss at greater extent. The species is native of Central and South America and the Caribbean with geographical expansion between 35°N and 35°S (Day et al., 2003). Figure 1 depicts native and introduced distribution range of *Lantana camara* worldwide.

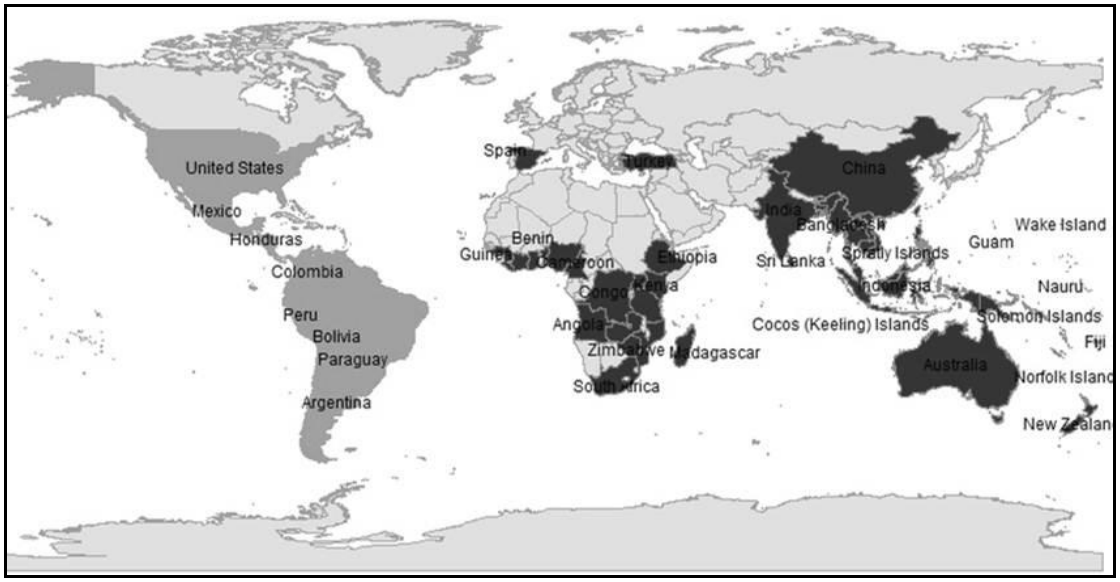

Figure 1:*Lantana camara* native (light grey) and introduced or naturalized (dark grey) regions(**Source:** Adapted and modified from Dayet al., 2003)

The genus being tropical in origin reaches its maximum diversity in the Caribbean, Central and northern South America (Taylor et al., 2012). In addition to the American species, some species are believed to have their origin in Africa and one species in India (Ghisalberti, 2000; Bhagwat et al., 2012). All species of *Lantana camara* despite of varied origin belong to Calliorheas section which is well characterized in the neotropics world (Sanders, 1987; Sanders, 2012). The diversity, broad geographic expansion and wide ecological tolerance are so inbuilt in species, that the Invasive Species Specialist Group (ISSG) considers it as among 100 of the "World's Worst" invaders (ISSG 2001).

The species has made itself indispensable in most parts of India. It was introduced in 1809 as an ornamental plant by the British in Calcutta Botanical Garden (Brandis, 1882; Aravind and Rao, 2001; Nanjappa et al., 2005). Voyaging two centuries of its establishment in India, at present it is considered to be extremely adaptable and prolific. Thus, it has its indiscriminate spread and presence in almost all regions of India including farm, pasture, fallow land and forest except the Thar Desert and its surroundings (Kannan et al., 2009; Aravind et al., 2010; Kimothy et al., 2010; Surampalli, 2010; Patel et al., 2011; Dobhal et al., 2011). Not only is the geographic range of *Lantana camara* still expanding in many regions of India, but the density of infestations within its range is increasing and has been recognized as a future threat to ecosystems (Roy et al 2002; Day et al. 2003; Sharma et al. 2005; Kohli et al. 2006; Dogra et al. 2009). An article in the widely-read magazine, Down to Earth (Sethi 2004), attests to the growing recognition of this problem by civil society, and to its no longer being a concern of the scientific community alone. Thus, the present research aims to review various aspects of *Lantana camara* research in India and the techniques adopted to combat its invasion. The study also aims to identify gaps in existing studies and what further research should be directed so that concrete headways to control invasion can be made.

A. Lantana camara: General description and invasion predicament

The word *Lantana camara* derives from Latin 'lento' which means to bend (Ghisalberti, 2000). The species was first described and given its binomial name by Linnaeus in 1753 (Munir, 1996; Kumarasamyraja et al., 2012). It is the genus of verbenaceae family with 600 varieties existing worldwide. *Lantana camara*, a native species of South, Central America and the Caribbean islands (Figure 3.1) (Baars, 2002), has its presence recorded even in Brazil, Florida, Jamaica, Mexico, and Trinidad. The species is spread over wide geographical range in neotropics but none is reported from Old World (Day et al., 2003; Sanders, 2006; GISIN, 2011). Some species of *Lantana camara* are also believed to originate from Africa and one from India (Lowe et al., 2003; Baars, 2002; Day et al., 2003; Heshula, 2009).

B. Biology

Lantana camara, also known as wild sage, is a thorny multi-stemmed, deciduous shrub with an average height of 2m (6ft). The shrub's taxonomic position is defined as belonging to the class of magnoliopsida, order lamiales, family verbenaceae and genus Lantana (GISIN, 2011). Stems are square in outline, covered with bristly hairs when green, often armed or with scattered small prickles (Figure 2a). *Lantana camara* possesses a strong root system (Figure 2b). The roots even after repeated cuttings give new flush of shoots. Leaves are opposite, simple, with long petioles, oval blades which are rough and hairy and have blunt toothed margins (Figure 2c). The leaves of *Lantana camara* have a strong aroma. Its flowers are small, multi-colored, in stalked, dense in flat-topped clusters with a corolla having narrow tube with four short spreading lobes (Figure 2d & e). Their flowers undergo color change subsequent to anthesis. These flowers occurs in cluster which includes white-pink-lavendar or yellow-orange-red mix. The yellow coloration of the flower provides visual cue to pollinators and change in color is initiated on the act of pollination. Berries of *Lantana camara* are round, fleshy, 2-seeded drupe with initially green in color and turning purple and finally to blue-black color (Figure 2f). However, the berries are very poisonous in nature though these are attractive to insects and birds. Seeds germination is easy and faster in *Lantana camara*. Table 2 summarizes the general characteristics of *Lantana camara*.

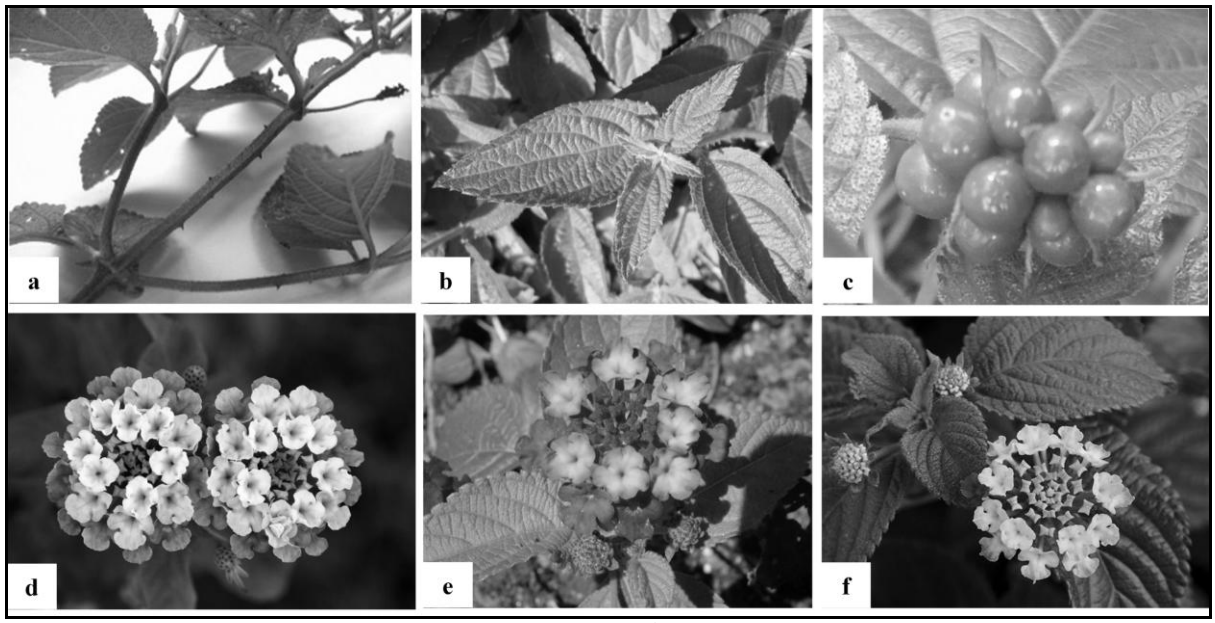

Figure 2: Characteristics of*Lantana camara*

Table II: General characteristics of *Lantana camara*

Characteristics	Description
Native	Tropical region in Central and South America
Synonym	*Camara vulgaris, Lantana scabrida*
Distribution	Naturalized in countries/islands between 35^0N and 35^0S latitudes
Conservation Status	Alien
Plant Category	Annuals and biennials, ground covers, perennials, shrubs
Plant Characteristics	Poisonous
Foliage Characteristics	Fragrant, evergreen, poisonous
Foliage Color	Dark green
Flower Characteristics	Long lasting, showy, unusual
Flower Color	Pink, yellow, orange
Tolerances	Drought, heat and humidity, pollution, slope, wind
Propagation Methods	From herbaceous stem cuttings
Pollinators	Lepidopteran species and thrip

C. Ecology

Lantana camara's widespread and diverse distribution is a reflection of its wide ecological tolerances. The species occurs in varied habitats ranging from open unshaded regions which include wastelands, rainforest edges, beachfronts, and forests disturbed by activities such as fire or logging (Thakur et al., 1992, in Rishi, 2009 cross ref). The species also thrive well in disturbed areas which

includes roadside, railway tracks and canals (Sharma et al., 2005; Kohli et al., 2008; Dogra et al., 2010). Anthropogenic activity further aggravates the invasion and allows it to spread (Day et al., 2003). The two principal ingredients for successful establishment are its growth under varied climatic conditions and no cap on temperature or rainfall limit. Table 3 summarizes habitat requirements of *Lantana camara*.

Table III: Habitat description of *Lantana camara*

Habitat Parameters	Requirements
Light Range	Sun to full Sun
pH Range	4.5 - 8.5
Temperature	Intolerant of frequent or prolonged freezing
Annual Rainfall Range	1000 - 4000mm
Soil Range	Mostly sandy to clay loam
Water Range	Semi-Arid to Normal
Altitude	Less than 2000 m above sea level
Light conditions	Prefers unshaded habitats, can tolerate some shade

D. Life Cycle

A typical life cycle of *Lantana camara* commences with dispersal of seeds by various dispersal agents such as fruit-eating birds and few mammals (Figure 3). An individual plant produces up to 12,000 fruits each year (Mack et al., 2000). Various studies illustrates that the process of germination process starts once the seed has travelled through the gut of a bird or mammal (Khoshoo and Mahal, 1967). Pollination by insects such as butterflies, moths, bees and thrips are common (Goulson and Derwent, 2004). Besides these, vegetative mode of propagation includes, spread through layering, or reshooting. *Lantana camara*'s repetitive growth at base of stems confirms its tenacity. Various studies have attributes seed viability ranging from 2-5 years (Wijayabandara et al., 2011). However, exact time of seed viability is still unknown and is mostly dependent on plant varieties, soil types and moisture levels (Raizada and Raghubanshi, 2010). Anthropogenic disturbances (burning, slashing, clearing, construction activities) facilitate its germination and propagation. The growth of the plant occurs all year round but the peak is reached after summer rains. The species takes only few weeks to germinate. The dryness and open canopy promotes early germination. The mature thickets once established, continue to persist for long. The plant starts producing seeds after completing one season. In the area of its establishment, it competes with native flora and subsequently smothers pasture through its allelopathic nature. The species die only under extreme. A typical life cycle of species is depicted in Figure 3.

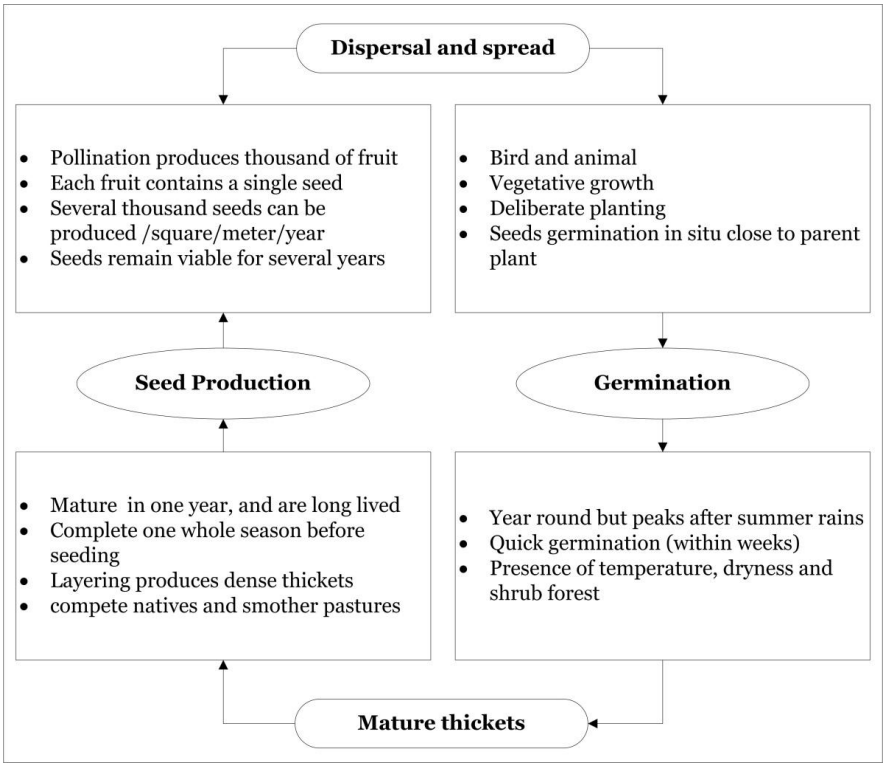

Figure 3: Life cycle of*Lantana camara*

E. Uses

Lantana camara though being a noxious weed has several minor uses, mainly in herbal medicine. There are series of research studies conducted on the exploitation of chemical constituents present in different parts of the plant species. Table 4 summarizes uses of *Lantana camara*. The studies demonstrate that extracts from the leaves can be employed to combat antimicrobial, fungicidal, insecticidal and nematicidal problems. Its potential to serve as biocide has also been illustrated in several researches (Begum et al., 2004; Dharmagadda et al., 2005). Table 4 summarizes the uses of *Lantana camara*.

Table IV: Uses of *Lantana camara*

Parts Used	Uses	References
Plant	Act as hedge plant, provide perch sites and cover	Ghisalberti et al., 2000; Day et al., 2003
Flower	Nectar source for butterflies and moths	Mohan Ram and Mathur, 1984; Day et al., 2003
Bark	Astringent and used as a lotion in cutiginous eruptions, leprous ulcers	ISSG, 2008; TrekNature, 2009
Stalks	Raw material for paper pulp which is used for wrapping, writing and printing paper	Ray et al., 2006; Naithani and Pande,2009
	Making baskets and temporary shelters	Kannanet al., 2008
	Used as Biofuel	Sharma et al., 1988; Prasad et al., 2001
Leaves	Boiled and applied for swellings and pain in the body	Singh et al., 1996; Noble et al., 1998; Nagaoet al., 2000
	Alkaloidal fractions lower blood pressure, accelerate deep respiration and stimulate intestinal movements	Singh et al., 1996; Noble et al., 1998; Nagaoet al., 2000
Plant extracts	Drought-tolerant plant so good candidates for xeriscaping	Rauch, and Weissich, 2000
	Used in folk medicine for the treatment of cancers, chicken pox, measles, asthma, ulcers, swellings, eczema, tumors, high blood pressure, bilious fevers, catarrhal infections, tetanus, rheumatism and malaria	Chavan and Nikam 1982; Sharma and Sharma, 1989; Day *et. al.*, 2003; Begum et al., 2003; Sharma, 2007

F. Impacts

Lantana camara have many negative impacts including potential to disrupt succession cycle, displacing native biota resulting in decreased biodiversity (Murali and Setty, 2001). Its infestations alter the structural and floral composition of native communities (Sharma and Raghubanshi, 2010). As the density of *Lantana camara* in forest increases, allelopathic interactions increase and hence there is decline in species richness (Day et al., 2003). It is a major problem in agriculture lands in various regions of India because once established the species forms dense and impenetrable thickets thereby outcompeting native pastures, blocking the movement of grazers in addition to causing poisoning. *Lantana camara* has numerous secondary impacts as it harbors serious pests such as malarial mosquitoes and tsetse flies, resulting in grave health issues. These alter fire regimes significantly by providing fuel load provided. The species has been implicated in destructive wildfire in various regions of India (Hiremath and Sundaram, 2005). The summary of impacts caused by *Lantana camara* is enlisted in Table 5.

Table V: Impacts of *Lantana camara*

Impact	References
Disrupts succession and decreases biodiversity	Ghisalberti, 2000; Saxena, 2000; Day et al., 2003
Understorey competitor for forestry	Asner, 2005; Sharma et al., 2005; FSI, 2006; ISSG, 2009
Reduce the economic viability of the crops	Day et al., 2003; Sharma et al., 2005
Allelopathic qualities reduces the vigor of native plant species and limits their productivity and interferes with harvesting	Sharma et al., 1988; Sharma and Sharma, 1989; Sharma et al., 2005
Loss of pasture in grazing areas	Humphries and Stanton, 1992; Weber, 2003; Walton et al., 2006
Poisoning of Livestock by plants	Pass and Heath, 1978; Mcsweeny et al., 1982; Sharmaet al., 1999; Sharma et al., 2007
Seeds are poisonous if ingested	GISP, 2008
Affect agriculture by outcompeting native pastures	Sharma et al., 2005; Walton et al., 2006; GISP, 2008
Handling plant may cause skin irritation or allergic reaction	Day et al., 2003
Interferes with the mustering of cattle causing death of stock by poisoning	Yadava and Verma, 1978; Sharma, 1994; Swarbrick et al., 1998
Reduce productivity in orchards	Holm et al., 1991
Harbors Pests	Day et al., 2003

G. The Problem

Lantana camara is considered a problem weed in many parts of India in which it has been introduced (Iyengar, 1933). Due to its prolific nature of flowering and dispersal, the species tends to alter the structure of the terrestrial ecosystem by gregarious presence. The species forms dense thickets and tends to eliminate the native species (GISIN, 2011). *Lantana camara* become the understorey species in disturbed native forest thus dominating the flora, causing disruption in succession and loss in biodiversity. The allelopathic activities of plant tend to reduce the vigor of other species in its proximity. In addition to its impact on grazing lands, *Lantana camara* often causes a reduction in yield or impedes harvesting in plantations. Also, species has potential to contaminate the gene pool of the

rare plant species. Elsewhere the native species of *Lantana camara* belong to the section Calliorheas, so the major threat is competition rather than hybridization. It is a very effective competitor against native colonizers in presence of light, soil moisture and soil nutrients. One of the obvious changes that occur with the replacement of forest understorey is decrease in community biomass. Allelopathy characteristics of species enable it to survive secondary succession and become monospecific thickets. For example, allelopathic effects resulting in either no growth or reduced growth close to *Lantana camara* have been demonstrated in Christella dentata (fern), Morrenia odorata L. (milkweed vine), Lolium multiflorum L. (rye) and various crops such as wheat (Triticum aestivum), corn (Zea mays) and soyabean (Glycine max) (Sharma et al., 1997).

Fire regimes are altered immensely by the presence of the *Lantana camara* in natural systems (Hiremath and Sundaram, 2005). The species burns readily in hot and dry conditions. Its occurrence on forest margins are seen as major threat to community, as a result of increased inroads of fire into the forest. This is particularly so when the species occurs on edges of forest tracks and creeks in natural forests such as in national parks.

On social frontage, *Lantana camara* affects human health. The species harbors malarial mosquitoes in bushes resulting in health problems. These pests were previously brought under reasonable control through clearing of vegetation that harbored them. Subsequently, these species colonizes these cleared grounds resulting in disease carrying pests reinvading cleared areas inhabited by humans and domestic stocks (Greathead, 1971).

Lantana camara is a major problem in agricultural areas in most regions of India as it forms dense thickets, spread gregariously, outcompete pasture species, and affects both flora and fauna. The field cases occur mainly in young animals that have either been newly introduced into an area where *Lantana camara* grows (Sharma, 1997), or are without access to other fodder. Children and adults in many countries often consume ripe fruits of *Lantana camara*, without any ill effects. However, consumption of green fruit has proved to be fatal in some parts of India (Sharma, 1997). Apart from causing death of livestock, sub lethal doses of *Lantana camara* toxin causes reduction in potential production, manifested abortion, loss of milk production in dairy cows, and chronic wasting in beef cattle.

Thus, in summation, *Lantana camara* invasion in natural ecosystem results in widespread loss of native species diversity and disrupts ecosystem structure and functioning (Iyengar, 1933; Khoshoo and Mahal, 1967; Murali and Setty, 2001; Dixon, 2003; Sharma et al., 2005; Tumaneng-Diete, 2007; Sahu and Singh, 2008; Kohli, 2009; Dobhal et al., 2011; Sharma and Raghubanshi, 2012; Taylor et al., 2012). However, very little quantitative evidence is available to validate these claims in Indian settings. Information on potential harm caused by anthropogenic induced activities facilitating invasion is also lacking. The studies relating to techniques adopted to combat *Lantana camara* invasion potential in India have been reviewed in greater details in the subsequent section and an attempt has been made to identify gaps in existing studies. This would further help in aligning future research directions so that an informed and target specific management and planning can be implemented.

FRAMEWORK FOR *LANTANA CAMARA* MANAGEMENT IN INDIA – GAP ANALYSIS

Lantana camara tends to defy classic life-history theory through embodying contrasting traits such as by being good colonizers as well as good persisters (D'Antonio and Meyerson 2002); or may benefit from their homoclimatic origins and from the scarcity of natural enemies in the areas it invaded and become established (Colautti et al. 2006). Various attempts have been made in curbing the *Lantana camara* invasion however these techniques have suffered a setback in one or the other aspects.

A. Control and Manage

Till date, various control measures have been employed to curb *Lantana camara* infestations in India, but none have been able to completely curtail its invasion. Control measure involving mechanical methods are coupled with certain drawbacks such as problem of re-growth which is imminent if the rootstock is not removed while weeding (Babu et al., 2009); suitability of such method is for smaller areas only and not recommended in areas susceptible to erosion (Babu et al., 2009).

Various authors have proposed control of *Lantana camara* through application of chemicals (Achhireddy et al., 1985; Sharma et al., 1988). Glyphosate is marginally effective as a foliar spray and regrowth is common. Fluroxypyr (Vista) plus aminopyralid when applied twice within 6 months is effective, but costly. Even, Fluroxypyr applied as a basal application is consistently effective. However, these suggestions are still in documentation stage and little has been done in this regard to serve as effective measure to combat the growth of the species. Secondly, the use of such chemicals tend to cause harm to the native biota of the ecosystem thereby affecting food chain, soil health, causing water pollution and giving genesis to ancillary problems.

A number of biological control organisms have been studied for controlling *Lantana camara* spread. There are no effective agents available on an operational scale till date. Biological organisms for controlling *Lantana camara* include Ophiomyia Lantanae (fruit-mining fly), Calycomyza lantanae (agromyzid seedfly), Teleonemia elata (leaf-sucking bug), Teleonemia scrupulosa (leaf-sucking bug) but mostly failed as they have several varieties or forms resulting in complicating the introduction and establishment of exotic insects. Several other host specific insects such Diastema tigris (flower-mining moth), Salbia haemorrhoidalis (leaf-floding caterpillar), Uroplata girardi (leaf-mining beetle), Octotoma scabripennis (leaf-mining beetle) and Epinotia Lantanae (flower-mining moth) have been introduced from time to time for the biological suppression of *Lantana camara* but have not been effective in controlling its infestation. The main reasons for failures being the extreme variability of the plants, the extensive climatic range it invades and high level of parasitism on the natural enemies. Several researches on other candidate agents undergoing host specificity and potential impact studies are underway (Rao et al., 1971; Sankaran et al., 1971; Sen-Sharma and Mishra, 1986; Thakur et al., 1992; Sharma et al., 2005) and no concrete results have been reported despite the efforts of entomologists worldwide. The failure of

biocontrol program directs to think that long-term management will rely on integrated management approach which not only involves control measures, instead strategies directed to intercept species at each stage of invasion to be adopted to combat invasive species. All conventional control methods require extensive management and continuous follow-ups and this is an ongoing process. Table 6 summarizes use and when not to use of all above cited control measures. Thus, it is important for control programs to focus on techniques which would be effective and less cost intensive for better and sustainable management of *Lantana camara*. One such technique include mapping and modeling *Lantana camara* which would act as early detection tool and help manage invasion in current and future scenarios.

Table VI: Impacts of *Lantana camara*

Techniques	When to use	When not to use
Biological Control	• Biocontrol agents are available and not already present	• Biocontrol agents, if affect important species
Mechanical control	• Area suitable for access by machinery without significant damage and action • Not leading to further land degradation	• Close to rivers, creeks and drainage and lines, as damage to soil will impair water quality and increase erosion • If not possible to follow up with treatments such as chemical or manual removal
Manual removal	• Cheap labor available • Limited area to clear • When used as a follow-up technique after fire or mechanical removal	• Cost of labor outweighs land value
Fire control	• Extensive area • Little risk of fire spreading	• Species may increase the intensity and frequency of fire inappropriately. Not to be used unless treatment with chemical

B. Early detection and management

There are few empirical studies in India that look at *Lantana camara* for its ability to invade, despite it widespread distribution (Mohan Ram and Mathur 1984; Mathur and Mohan Ram 1986; Bambaradeniya et al. 2002; Napompeth et al. 2003; Sahu et al. 2008; Raghubanshi and Tripathi 2009). With the advent of satellite based remote sensing, many workers have recognized the possibility of mapping the distribution of invasive species (Tucker 1979; Anderson et al. 1998; Zhang et al. 2002; Underwood et al. 2003; Yang et al. 2007). However such techniques have not been of much use for mapping invasive species forming the forest understory. Despite being a serious threat to the ecosystem, *Lantana camara* has not been systematically mapped due to the difficulties posed by the technology. There is insufficient information of its distribution and the impact of its associated harm, which is critical for planning conservation. There are a few studies that have demonstrated the application of remote sensing in studying *Lantana camara* (Prasad et al. 2006; Kandwal et al. 2009). However for such accurate mapping of invasive species, it is important to consider the phenological stage of species at the time of satellite image acquisition. A combination of remote sensing techniques, GIS and expert knowledge offer potential to detect understory invasion through development of models and risk maps. However, till date, no such attempts have been reported in this direction to develop invasion risk map of *Lantana camara*.

C. Legislation

India has several statutes addressing issues associated with invasive alien species. However, there is neither a core policy nor legislative framework of common elements, goals and definitions. Also there has not been a concerted attempt made to harmonize the relevant laws and regulations to ensure uniform and consistent practice. Also, there are gaps in addressing management and control of invasive species in legislation and policy. Relevant legislation includes The Destructive Insects and Pests Act, 1914 and amendments; Indian Forest Act, 1927; Wildlife (Protection) Act, 1972; Forest (Conservation) Act, 1980; Environment Protection Act, 1986; The Plants, Fruits and Seeds (Regulation of Import into India) Order 1989 (PFS Order 1989); Livestock Importation Act, 1898 and the Livestock Importation (Amendment) Ordinance, 2001; National Policy and Macrolevel Action Strategy on Biodiversity, 1999; The Biological Diversity Act, 2002; The Plant Quarantine (Regulation of Import into India) Order, 2003; National Environment Policy, 2004; The Prevention and Control of Infectious and Contagious Disease in Animals Act, 2009; but none is exclusively intended to deal with the invasive alien species and in particularly for *Lantana camara* control and management (FAO 2003; CBD 2005; CITES 2005; MoEF 2008; CIA 2008; APFISN 2009; GISP 2009). In addition, there is no full proof system of reporting about the existence of invasive in India either through the government officials or the general public. Thus, only when a species becomes invasive and starts affecting socio-economically, measures are taken for its eradication and control (Asia-Pacific Forest Invasive Species Network report 2009). Several attempts to assess the risks posed to ecosystems, habitats and species by some invasive species within India have been carried out. However, most assessments are done at the local level only. Thus, it is important to develop control and management framework that focuses on strategies and actions which would be effective and less cost intensive for better and sustainable management of *Lantana camara*.

ALTERNATIVE APPROACHES TO CURTAIL *LANTANA CAMARA* INVASION

As discussed in previous sections, fully effective control techniques are not currently available for this notorious weed. In many areas, the sheer size of the infestations coupled with low land values makes conventional control not feasible. However mechanical clearing and hand pulling are suitable for small areas and fire can be used over large areas. Also there are several control chemicals which are most effective when applied to re-growth following other treatments. Given the limited success of bio-control till date in most areas, it is therefore important for planners and managers to develop strategies aimed at best utilization of the species. This may include planning to use the species as means of generating livelihood opportunities through craft making, creating market for herbal medicine or serve as biofuel agents through involvement of community. These practices will likely not only curb the invasion but simultaneously make people aware of the consequences of plant invasion. With this purview, some of the potential commercial uses of *Lantana camara* are enlisted below.

A. Handicrafts

Lantana camara has not only made itself ubiquitous it has also made itself indispensable. Some unpublished literature has apparently suggested that certain species rely on *Lantana camara* and a crash will be imminent if there is uncontrolled removal of this weed. Thus this call for attention in removal of this weed and many parameters will have to be considered when attempting such an exercise. Thus instead of eliminating, its advised to utilize such species as means of generating livelihoods or put it to various commercial use.

In the Male Madeshwara Hills in Karnataka, the project to control *Lantana camara* is an interesting mix of community involvement into conservation practices with payoffs for both (Aravind et al. 2006; Kannan et al. 2008). *Lantana camara* parts are being used effectively in making furniture which is cheaper than cane and equally sturdy. The furniture lasts long and does not get easily eaten away by termites. Soligas, the tribal artisans of South India are ingeniously utilizing the invasive weed *Lantana camara*, as a substitute for rattan and W. tinctoria, and converting it into value added products such as furniture, toys and articles of household utility (Kannan et al. 2008). Currently, nearly 50 replicas of cane furniture and 25 designs of toys produced by these artisans from *Lantana camara*. ATREE is helping the tribals in marketing and certification of *Lantana camara* products, marked *Lantana camara* crafts (LCC). This innovative idea won the Global Development Marketplace award in 2003. Through recent support from Rainforest Concern, the use of *Lantana camara* has been extended to additional communities in south India to develop their own administrative structures and formalize market linkages. Attempts are also being made to design and diversify the range of products.

Lantana camara seemed to have overrun Lachhiwala village, 24 km from state capital Dehradun, occupying almost one lakh hectares of land. Lantana's reputation did not daunt the villagers as they have given it an economic value. They use Lantana and mud to make the walls of their houses as well as chicken coops. Stripped of the bark, the insect- and pest-resistant Lantana stems are put to varied use-the sturdier ones make good furniture, the pliant are fashioned into trays and baskets. The pungent Lantana leaves have been used to make excellent mosquito repellents and incense sticks. Such innovative use of the weed brings in Rs 75,000 a year for each of the families there. And it has earned the village a new name: Lantana village. The credit for the success of this experiment goes to the scientists of the Dehradun-based NGO Himalayan Environmental Studies and Conservation Organization (HESCO) which provides logistic and marketing support to the villagers. Experiments like that of Lantana village shows that innovation can perk up a weak economy.

B. Herbal Medicine

Lantana camara has several therapeutic uses, mainly as herbal medicine (Sharma et al. 1988; Sharma and Sharma 1989; Ghisalberti 2000; Sharma et al. 1999). There has been much work conducted in India on the chemical constituents of *Lantana camara*; extracts from the leaves exhibit antimicrobial, fungicidal, insecticidal, nematicidal, biocidal activity (Sharma and Sharma 1989; Begum et al. 2000; Saxena 2000; Sharma et al. 2007). Lantana oil is used externally for leprosy and scabies (Ghisalberti 2000). Plant extracts are used as medicine for the treatment of cancers, chicken pox, measles, asthma, ulcers, swellings, eczema, tumors, high blood pressure, bilious fevers, catarrhal infections, tetanus, rheumatism, malaria and atoxy of abdominal viscera (Begum et al. 2000).

C. BioFuel

Lantana camara twigs and stems serve as useful fuel for cooking and heating in many regions of India (Sharma et al. 1988), although it is less important than other fuel sources such as windrows, woodlots or natural bush (Varshney et al. 2006). Its use for fuel ethanol production is recommended in various research findings (Sharma et al. 1988; Inada et al. 1997; Varshney et al. 2006). Biofuels obtained from twigs and stems serve useful fuel for cooking and heating in many regions of India.

D. Kraft Pulping

Paper industries are in search for possible non wood renewable raw material that can replace traditional forest based species like wood and bamboo. *Lantana camara*, having 75.03% hollo-cellulose, 8.461%Extractive, 18.21% lignin and 2.31% silica can be a good potential source of raw material for paper making (Ray et al. 2006). Researches by Ray et al. (2006), Naithani and Pande (2009), Bhatt et al. (2011) have demonstrated *Lantana camara* as potential source of raw material for paper making. Thus, it is important to develop a management framework keeping in purview benefits and limitations of various control techniques for sustainable management of *Lantana camara*.

CONCLUSION

Lantana camara is one of the notorious weeds causing dramatic and apparently irreversible degradation of natural communities in India. Much has been done on the chemical, mechanical and biological control of the species without identifying the target sites and prioritizing the same. Given the ecological value of the native community, preventing detrimental impacts of invasion is of utmost importance. Early detection is the most effective way to reduce the impact of such species. Currently, there is little information available on spatial distribution of *Lantana camara* invasion and its potential geographic spread. Creating spatially explicit model of *Lantana camara* invasion risk will allow planners and managers to undertake appropriate measures. This will enable to counter negative change to sustain conservation efforts for the progeny. The more promising areas for future research are the modeling and mapping invasion risk potential. Integration of such techniques is likely to result in improved control and mitigation strategies.

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