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Invasive alien species as drivers in socio-ecological systems: local adaptations towards use of *Lantana* in Southern India

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Abstract *Lantana camara.* L (hereafter *Lantana)* was first introduced by the British into India in 1807 as an ornamental plant. Since then the species has spread across the length and breadth of the country. Attempts to control *Lantana* in India have not been successful. In this study, we analysed the use of *Lantana* by local communities in southern India and identified the possible causes and consequences of its use through the use of a household survey of the socio-economic profile of the user and nonuser households and an analysis of the ecological history of the communities. Communities have been using *Lantana* for over 25–30 years and apparently such use was not prompted by external agencies. The characteristics of user and nonuser households were similar, except that *Lantana* users were more literate and had a greater number of occupations per household than nonusers. Per capita income was similar between user and nonuser groups. For nonuser groups, their main income sources were from trading (44 %), wage labour (32 %) and forest resources (23 %). In contrast, the *Lantana* user groups substituted their loss of income from forest resources (7 %) by income from *Lantana* (46 %). The ecological history revealed that *Lantana* was adopted as a resource at a time when it was increasing in the landscape and

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traditional bamboo resources were in decline because of overuse by commercial enterprises and mast flowering. This change in ecological resource availability prompted a major shift in livelihoods for some in the area.

Keywords *Lantana* · Rural livelihoods · Invasive plants · Migration · Local trade

1 Introduction

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 international trade, for example, the European exploration in the South and Southeast Asia for spices, inevitably resulted in manifold changes in socio-ecological systems, including aspects such as culture, language, crop varieties, food habits, diseases and even in the natural history of the places or regions visited (Essl et al. 2011; Nunez and Pauchard 2010; Perrings et al. 2010). The European colonization of South America, Africa and Asia in the eighteenth century was perhaps one of the largest such movements and brought profound changes to these continents (Bhagwat et al. 2012; le Maitre et al. 2011). The European colonial powers moved plants from Latin America to Europe and to their colonial countries which contributed to an unprecedented movement of plants into new habitats, often physically distant from their native habitats (Kannan et al. 2013). The human colonizers engineered most of these movements for their own pleasure, welfare and survival in new countries and habitats (Kannan et al. 2013). In India, major plant introductions can be traced to the establishment of the East India Company's (EIC) botanical garden in 1786 (Royle 1840). Within a relatively short span of 8 years, the EIC brought over 300 plant species into the first botanical garden in Calcutta (now Kolkata) (Roxburgh 1814). 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. These introductions were accelerated by the directives of the Honourable 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. Many of these plant introductions went on to completely change the local cultural food habits of people; for example, tomatoes, potatoes, green chillies, all from South America, brought into India by the British, forever changed the culinary preparations and farming practices in India (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).

2 IAS and their impacts

Invasive alien species are one of the largest threats, second only to climate change, to biodiversity, ecosystem services and even land-use options and practices 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 US$ 633.9 million 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 and the exorbitant costs that control would incur (van Wilgen et al. 2012). Globally, there are very few examples of successful eradication of IAS, especially once a given IAS spans an area of tens of square kilometres or more (Mack and Lonsdale 2002; Moore et al. 2011). Some successful examples include the biological control of *Opuntia monacantha* in the Cape region in South Africa in 1913, *Lantana* in Hawaii and Fiji Islands in the 1900s (Broughton 2000; Perkins 1925; Zimmermann et al. 2004) and physical removal of *Eupatorium serotinum* in Australia (Mack and Lonsdale 2002). In South Africa, the Working for Water (WfW) programme is a classical example of a physical management approach, wherein through local community employment, IAS 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 have gone on to usurp native flora and fauna and disrupt the natural flow of ecosystem services and potentially altering local livelihoods and the larger social-ecological system (le Maitre et al. 2002; Richardson and van Wilgen 2004).

3 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 IAS could have several implications, ranging from ecological to sociocultural. On the ecological front, the naturalization of an IAS may lead to re-shuffling of the structural, compositional and functional elements of biodiversity and consequent changes in the quantity and quality of ecosystem services, and in extreme cases to displacement of native biota (Prasad 2012; Sousa et al. 2011; Sundaram et al. 2012; Sundaram and Hiremath 2012). 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 protected areas 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, especially for the rural poor, or disruption of the flow of cultural services such as culturally important species or landscape aesthetics (Pimentel 2005; Richardson and van Wilgen 2004). However, there are case examples of IAS providing positive elements to local livelihoods in providing provisioning services, income or aesthetic benefits (Shackleton et al. 2007; Table 1). This may include local adaptations and cultural integration of the species. Many local communities across the world have devised and developed ingenious adaptations to and use of invasive species. For example, *Acacia phyllodineae* is an IAS that has been successfully used as fuel wood, timber and food in different parts of the globe (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 fuel wood in India (Patel 1985). In South Africa, the Prickly Pear (*Opuntia ficus-indica*), an invasive from Central America, is used to

Table 1 Examples of invasive alien species local adaptation 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	GISP (2012) (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 et al. (2004), Mwangi and Swallow (2005)

supplement the diet of people, provide fodder and has been adopted into local cultures and beliefs (Shackleton et al. 2007). Water hyacinth (*Eichhornia crassipes*), yet another IAS from South America, is used as a weaving material in several southeast Asian countries, particularly, in Bangladesh, Cambodia, Philippines and Thailand (Jafari 2010; Malik 2007).

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' (Warrren 2007), what defines a weed, alien or an unwanted species (Subramaniam 2001), how local people come to terms with IAS (Shackleton et al. 2007), 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 potentially 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 home 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. (2007) 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 IAS and in extending similar use with less resistance in places where the IAS are not yet used.

4 Local adaptation of IAS

In this paper, we 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 IAS 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 (Richardson and Rejmanek 2011) and approximately 50 countries around the world (Ghisalberti 2000). It is considered as one of the ten worst weeds (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 (Kannan et al. 2013). Since then the species has spread across the country and has displaced several native species (Bhatt et al. 1994; Dogra et al. 2009; Sahu and Singh 2008). For example, Ticktin et al. (2012) showed that expansion of *Lantana* caused a significant reduction (16 % in 10 years time) in the population size of an important nontimber forest product species, *Phyllanthus emblica* in southern India. Attempts to control *Lantana* in India have not been successful (Bhagwath et al. 2012). Physical, chemical and biological methods to remove *Lantana* (such as uprooting by deploying elephants or by applying chlorine iodide or by the introduction of insects from Mexico) have made little impact (Kannan et al. 2013).

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, while 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 fuel wood, in fencing their agricultural lands and as a substitute for bamboo and rattans to make baskets

Fig. 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)

and furniture (Fig. 1). From the context of human adaptations to biodiversity change (Fabricius et al. 2007) and in this specific context, to IAS, this example offers an opportunity to ask: (a) What are the critical socio-economic parameters that distinguish people or communities that use *Lantana* (the user group) compared to those who do not (the nonuser group)? (b) What are the key determinants that promote its use by communities? (c) Can such learning catalyse 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*? We discuss these questions in the larger social-ecological context of how local communities have responded to biodiversity changes both spatially and temporally.

5 Methodology

5.1 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

Table 2 Profile of nonuser and user households

Village	No. of households	Sample size		No. of respondents by ethnic groups	Duration of *Lantana* use (years)
		Nonuser	User		
Hannehola	48	8	10	Soligas (18)	<7
Kommudikki	21	12	0	Soligas (12)	Nil
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		

25–30 years ago for the Lantana basket weaver communities and more recently (<7 years) for *Lantana* furniture makers (Table 2). While the latter were prompted to use *Lantana* by external agencies, it is not immediately clear how the basket weavers (early adopters) took to *Lantana*. Personal interviews with respondents in this basket weaver group indicated that elder members of their respective families passed on the skills of using *Lantana* for basketry.

The study was located in the following sites: Hannehola (12°2′N, 77°34′E) and Kommudikki (11°59′N, 77°33′E) in MM Hills Reserve Forest in Chamrajanagar District, Pudhupatti (10°19′N, 78°8′E), Anjukullipatti (10°14′N, 78°4′E) and Vedasandur (10°19′N, 78°8′E) in Dindigul District and Cheelampalle (13°2′N, 78° 30′E) in Chittoor District in southern India. 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 400–600 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.

5.2 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.

5.2.1 Soligas

The Soligas were hunter-gatherers and one of the early inhabitants of MM Hills and are a designated Scheduled Tribe who are the most backward and underprivileged communities as per bylaws of Indian system of classification of castes (Ministry of Tribal Affairs 2009). Thurston (1909) described the Soligas as those inhabiting the jungles between Dimbhum and Kollegal near Mysore. Interaction with the elder members of this community revelled 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*) fruits, aralekai (*Terminalia chebula*) seeds for tannery, makaliberu (*Decalepis hamiltonii*) roots as a medicinal plant, sigekai (*Acacia concinna*) and antowala (*Sapindus trifoliatus*) nuts for local made shampoo powder and in turn sold cloth, sugar, etc. According to Soliga elders, the Public Distribution System (PDS) which provides subsidized food grains reached their village 10 years ago. Other than that there is no support from the Government to improve their livelihood. They lament that their traditional bamboo craft never received any support from the Government to procure the raw material as well as marketing the final products. Access to forest land and forest resources provided food security to Soligas. The Soligas practiced rain-fed agriculture and bamboo basket weaving was their traditional livelihood activity (Table 3); incidentally, the term Soliga also refers to people from bamboo thicket (Sundaram et al. 2012). The Kollegal Forest Department restricted their access to bamboo resources due to poor regeneration and declining natural stock of bamboo in this region. It directly affected the Soliga households those were highly dependent on bamboo for their livelihoods. In the recent past, they harvested and fabricated furniture made from *Lantana* and marketed them locally as well as in Mysore and Bangalore.

5.2.2 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.

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. 2004). However, because of its sheer abundance, *Lantana* was most preferred and predominantly used. 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). *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.

5.2.3 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. They practiced rain-fed agriculture and depended on labour (domestic/migration) and fuel wood collection for their livelihood (Table 3). Madanapalle and Palmanare are the nearby towns. They harvest, weave and sell the *Lantana* baskets to middlemen in their village.

5.2.4 Madigas

According to Buchanan (1807) and Plowden (1883), the Madigas were cobblers and agriculture wage labourers for the landlords and farmers. It is not clear when, where and

Table 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)*	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

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 dependent on agriculture as wage labourers. About 25 years ago, a certain Mr. Billappa discovered a huge demand for baskets, in the nearby market in Madanapalle, for transporting tomatoes 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.

5.3 Data collection and analysis

5.3.1 Ecological history of communities

To address whether the ecological history of communities might have predisposed them into adopting *Lantana* as an alternative raw material for bamboo, we traced the ecological history of these communities and bamboo resources. We 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, we develop a perspective over the use of *Lantana* by the community.

5.3.2 Households surveys of user and nonuser groups

Population details of each village were collected from the village headman (Table 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 socio-economic status of the user and nonuser households in the six study villages. The questionnaire focused on demographic and socio-economic 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 (nontimber forest products (NTFPs), bamboo basketry, fuel wood, etc.), trading (broom sticks, garlic and fruit retailing, etc.) and wage labour (Table 3). The percentage of labour days spent by each household on different occupations was calculated to understand the person days per important occupations. The per capita values for all the income sources were derived and the means and standard deviations were calculated. A 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 a Student's *t* test and ANOVA. All the statistics were performed by using R-(cmdr) version 2.14.2

Cash as well as noncash income was taken for the 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 was used to identify the cost of family labour in agriculture, forest resource collection, trading and *Lantana* craft (Purushothaman 2005). Per capita net income was calculated for all the income variables by dividing the income by family size.

6 Results

6.1 Livelihood profile of user and nonuser 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 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.

6.2 Socio-economic profile of user and nonuser groups

Several socio-economic 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 %) ($\chi^2 = 3.84$, d$f = 1$, $p < 0.05$). 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 4). Mean literacy (average number of people educated (years of school) in the household) was significantly higher for users (1.40 ± 1.31) compared to the nonusers (0.84 ± 1.11; $p < 0.0165$). On 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 groups with respect to age, assets held, family size and gender of the household head (Table 4).

Table 4 Socio-economic profile of nonuser and user households

	Nonuser ($n = 46$) Mean ± SD	User ($n = 66$) Mean ± SD	t value	p value
Age (years)	43.2 ± 11.0	43.1 ± 11.8	0.0165	$>0.9869^{ns}$
Assets (no.)	2.65 ± 2.54	2.66 ± 1.73	−0.0336	$>0.9733^{ns}$
Family Size (no. of people/hh)	4.19 ± 2.21	4.42 ± 1.53	−0.6049	$>0.5471^{ns}$
No. of Male/hh	1.43 ± 0.74	1.66 ± 0.79	−1.574	$>0.1186^{ns}$
No. of Female/hh	1.5 ± 0.69	1.45 ± 0.68	0.344	$>0.7316^{ns}$
Literacy (years of education) rate (no. of people)	0.84 ± 1.11	1.40 ± 1.31	−2.4353	$<0.0165^{*}$
Occupation (no.)	1.76 ± 0.89	2.07 ± 0.75	−1.9489	$<0.0545^{*}$
Land holding (m^2)	2,706 ± 3915	1,552 ± 3247	1.6433	$>0.104^{ns}$

Significant codes: 0 '***' 0.0001 '**' 0.001 '*' 0.05 '.' 0.1 '^{ns}'; ns, not significant

hh household

6.3 Income profile of the user and nonuser 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. There was a significant difference between the groups with respect to the income obtained from the collection of forest resources. The nonuser group obtained nearly threefold more income from forest resources, excluding *Lantana*, compared to the user group ($p < 0.001$) (Table 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 the forest for the nonuser group was US$ 0.16 ± 0.19 compared to that for the user of US$. 0.09 ± 0.10 ($p < 0.0328$) (Table 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 per household by members of the two groups was nearly the same (Table 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

Table 5 Annual per capita income profile of the nonuser and user households

Income	Nonuser		User		*t* value	*p* value
	Mean ± SD US$. ($n = 46$)	(%)	Mean ± SD US$. ($n = 66$)	(%)		
Agriculture	2.39 ± 5.69	1	4.88 ± 15.78	1	−1.1801	>0.2412^{ns}
Forest	75.65 ± 101.71	23	23.97 ± 28.25	7	3.3579	<0.001**
Labour	107.15 ± 128.02	32	89.12 ± 133.64	27	0.7196	>0.4735^{ns}
Livestock	0.95 ± 4.60	0	1.65 ± 9.87	1	−0.4952	>0.6215^{ns}
Trading	146.3 ± 281.7	44	58.92 ± 111.62	18	1.9971	<0.0507*
Lantana	0	0	153.44 ± 138.59	46		
Total	332.49 ± 246 72	100	332.04 ± 150.13	100	0.0109	>0.9913^{ns}

ANOVA test shows that the income level varied significantly between nonuser and user groups ($F_{(1,550)} = 10.3740$, $p < 0.001^{**}$) and within the group income vary significantly ($F_{(4,550)} = 19.5848$, $p < 0.0001^{***}$)

Significant codes: 0 '***' 0.0001 '**' 0.001 '*' 0.05 '.' 0.1 '^{ns}'; ns, not significant

USD 1 = INR 55 as on July 2012

Table 6 Per capita daily income from major income sources

Per capita man day income	Nonuser (US$.)	User (US$.)	*t* value	*p* value
Forest	0.16 ± 0.19	0.09 ± 0.10	2.181	<0.0328*
Trading	0.16 ± 0.47	0.12 ± 0.25	0.479	>0.6333^{ns}
Lantana	0	0.29 ± 0.27		

Significant codes: 0 '***' 0.0001 '**' 0.001 '*' 0.05 '.' 0.1 '^{ns}'; ns, not significant

USD 1 = INR 55 as on July 2012

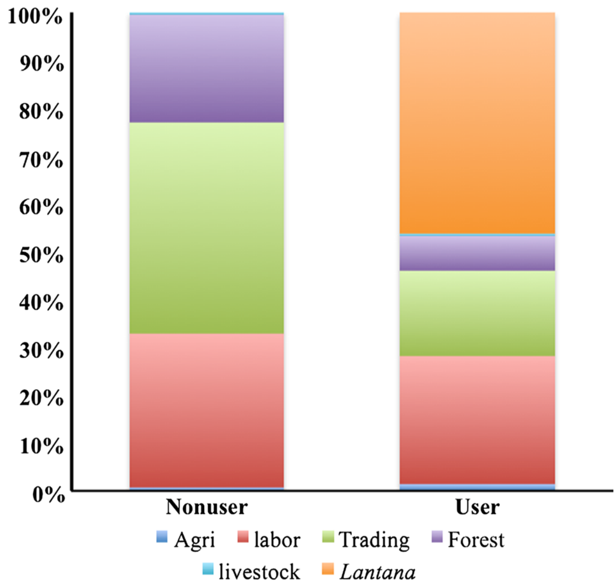

Fig. 2 Relative income sources (%) of the user and nonuser groups

differences in the percent of income contributed by the different sources between the two groups (Table 5 and Fig. 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.

Respondents in the user group were further divided into age class: (a) >20–30 years, (b) 31–40 years, (c) 41–50 years and (d) above 51 years. A significant proportion of the respondents belonged to 25–40 years 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* (0.011) but the income from trading across the age class was not significant ($p > 0.060$) (Table 7). It seems the younger age class (20–30 years) earn more income from forest and *Lantana* and the elder age class (above 51 years) earn more from trading, as they are not able to frequently go to forest to procure the raw materials.

6.4 Ecological history of bamboo resources

We 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; Setty 1973; Shanmuganathan 1956). However, post-1970, triggered by the huge bamboo resources, several commercial interests sprang up. In 1973, K.R.V. Setty who was a Deputy Conservator of Forest of Kollegal Forest Division wrote to the Kollegal forest division working plan 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 1991–1992 to

Table 7 Age classification of annual per capita income for the user groups

Age group (year)	21–30 Mean ± SD ($n = 14$)	31–40 Mean ± SD ($n = 17$)	41–50 Mean ± SD ($n = 18$)	Above 51 Mean ± SD ($n = 17$)	*F* value	Pr (>*F*)
Age (years)	27.2 ± 2.35	36.9 ± 3.38	46.8 ± 3.00	58.6 ± 3.37	297.4	0.0001^{***}
Forest (US$.)	44.70 ± 39.99	19.13 ± 34.60	15.58 ± 10.06	20.62 ± 12.22	3.689	0.0165^{*}
Lantana (US$.)	259.15 ± 216.12	114.77 ± 106.65	127.9 ± 68.30	132.10 ± 105.67	3.973	0.0118^{*}
Trading (US$.)	20.53 ± 76.86	22.22 ± 56.35	77.27 ± 125.65	107.82 ± 142.24	2.591	0.0607^{ns}

Significant codes: 0 '***' 0.0001 '**' 0.001 '*' 0.05 '.' 0.1 '^{ns}'; ns, not significant

USD 1 = INR 55 as on July 2012

13,973 tonnes in 1998–1999 (Shaanker et al. 2004). Such was the indiscriminate extraction that in the 2002–2004 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. Compounding 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 Reserve Forest range which were major sources of bamboo for basketry and Chandrika were removed from the bamboo felling areas and bamboo extraction by local and state agencies in these areas was banned (Misra 2002). The final straw was the fact that part of those areas that were allocated as bamboo felling areas in Kollegal range namely Cowdally (90 km^2), Chikkailur (247 km^2) and MM Hills (310 km^2) was subsequently notified to come under the jurisdiction of the Cauvery Wildlife Sanctuary (1,027 km^2) 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 so. If any, they had to pay the forest department for the bamboo they obtained. Under these circumstances, it appears that they took to *Lantana*, which was increasingly abundant. This, the use of an IAS by local communities seems to have been driven by several factors (loss of bamboo, increase in *Lantana*, traditional occupational skill) that came into play at about the same time.

7 Discussion

7.1 Invasive alien species: landscapes transformers

Invasive alien plants, with their rapid growth rates and wide adaptability, can 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 currently 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. 2007). 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 IAS the world over bears testimony to the frequent failure of these programmes with a few exceptions, such as the case of Working for Water programme in South Africa (van Wilgen et al. 2012).

7.2 Adaptation towards IAS

In recent years, alternative approaches to coming to terms with IAS have been mooted. 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 proposition is nested in the social-ecological systems framework of inexorable two-way links between ecological stock and flows and social outcomes and actions, from a landscape governance scale down to household level livelihoods. This is well illustrated in the human-dominated tropical landscapes, where a large proportion of people depends upon scores of NTFPs for their livelihoods (Mahapatra and Shackleton 2011; Rist et al. 2010; Saha and Sundriyal 2012). Thus, any IAS control or management initiatives need to consider the impact not only on the IAS, but also the livelihoods of local people. Unfortunately, this dilemma has failed to be addressed sufficiently in the literature on IAS. 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). The first option is rarely encountered at a local level usually because of the spatial scale of invasion as well as the logistics of control. 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 (*Australian acacia) are well recorded; each of these initiatives seems to have come from within the local community (Geesing et al. 2004; Shackleton et al. 2007). 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. (2007) have attempted to unravel the social, cultural, political and economic factors, which may have driven local communities to use an 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, the 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 the use of IAS and may potentially to 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 the 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 has been characterized 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 nontimber forest product species, *Phyllanthus emblica*, decreased by 16% in areas infested by *Lantana*. While data do not exist, it could be assumed that such loss may have translated into loss of income for people dependent on this forest resource. Under this scenario, the communities may be forced to consider using the invasive as a resource. While there is no unequivocal evidence to support this hypothesis, 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. 2004). Second, during this period, the area saw a steep increase in the density of *Lantana* with clear effects on the native biological resources (Aravind et al. 2010; Sundaram and Hiremath 2012). Under this complex mix of local drivers, it is tempting to suggest that the abundant biomass of the IAS 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 forests and wastelands.

7.3 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 (Kannan et al. 2013). 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 nontimber 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, has been weaving baskets and other articles from bamboo. Many families of these communities have been using *Lantana* for the past 25–30 years. In many 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 paper, the restricted access to a forest resource such as bamboo and NTFPs has seemingly predisposed the communities to choose other abundant alternatives in the region. This matches the trajectory illustrated by Shackleton et al. (2007). 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 the 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 socio-economic 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 specializing 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.

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. We suggest 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 (Nunez and Pauchard 2010; Perrings et al. 2005).

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