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continued on the back inside cover

Cover: Leaves and fruits of *Terminalia arjuna* in water colour artwork on cold pressed water colour paper by Bhama Sridharan.

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COMMUNICATION

Mapping invasive alien plants through citizen science: shortlisting species of concern for the Nilgiris

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Abstract: Species introduced from elsewhere are known as alien species. They may be introduced as crop plants or ornamental plants, or for timber. A small proportion of introduced species can become invasive thereby spreading at the cost of native species and habitats, negatively affecting biodiversity, food security, and human wellbeing. Despite the growing recognition of the threat of invasive alien species, we still lack information about the distribution and abundance of species widely accepted to be invasive. To address this information gap regarding invasive alien species distributions, we initiated a pilot citizen science effort to create an atlas of invasive plants in the Moyar-Bhavani landscape of the Nilgiri District. We aimed, through this pilot effort, to develop and test user-friendly mapping protocols and develop an interface for citizen scientists to use. Ultimately, we hope to create a model that can be scaled up to large conservation landscapes, such as the Western Ghats, the Central Indian Highlands, and the Himalaya.

Keywords: Biodiversity, conservation, introduced species, India, invasive species database, Moyar-Bhavani watershed, non-native plants, protocol, stakeholder workshop, threat, user-friendly, Western Ghats.

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Author contributions: SMR carried out the compilation of the database of invasive plants for the Nilgiris, prepared the poster on common invasive plants and participated in fieldwork. RR carried out the data analysis and participated in fieldwork. ST participated in fieldwork, was involved in shorlisting and finalization of the invasive plant list, and contributed to poster preparation. MB designed the study, and participated in fieldwork. AV designed and planned the study and participated in fieldwork. AH conceptualized and designed the study and participated in field work. All authors were involved in drafting and revising the manuscript.

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INTRODUCTION

People have moved species around the globe since time immemorial for food, fibre, fuel, sport, and aesthetic reasons. Such species, which have been introduced outside their natural range of distribution, are referred to as 'alien species' (or introduced or exotic species). Most alien species arrive in new environments intentionally, though some can arrive inadvertently as contaminants on known introductions or simply as stowaways. Examples of species introduced intentionally include plants and animals introduced for food (e.g., the African Catfish *Clarias gariepinus*), for timber and fuelwood (e.g., the Black Wattle *Acacia mearnsii*), or those introduced as ornamental plants (e.g., *Lantana camara*), and for the aquarium and pet trade (e.g., the Goldfish *Carassius auratus* and the Red-eared Slider *Trachemys scripta elegans*). An example of an inadvertent or accidental introduction is *Parthenium hysterophorus*, whose seeds are thought to have arrived in India as a seed contaminant of wheat imported from the Americas.

Although the vast majority of introduced species are of great value, a small proportion of these can become invasive. This refers to their becoming widespread and having negative impacts on biodiversity, ecosystem services, food security, or human health and wellbeing. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) identifies invasive alien species as amongst the greatest threats to biodiversity and ecosystem services globally, comparable with climate change, change in land (and sea) use, species overexploitation, and pollution (IPBES 2019).

In India too, we now recognise the threat of invasive alien species. One of India's National Biodiversity Targets (NBT4) focuses on preventing new invasive species introductions and controlling existing invasive species (MoEFCC 2014). Some states have gone further by formulating policy on invasive species management, Tamil Nadu being the first (TN-PIPER 2022).

Despite this growing recognition of the threat of invasive alien species, we still lack information about the distribution and abundance of species widely accepted to be invasive. Such information is vital to prioritise species and habitats for management interventions and provides a baseline against which to assess future invasive species spread.

To address this information gap regarding invasive alien species distributions, we initiated a pilot citizen science effort to create an atlas of invasive plants in the Moyar-Bhavani landscape of the Nilgiri District. Citizen science, which refers to a partnership between scientists and members of the public, is a growing field both in India and globally. Over the last decade the ubiquitousness of smartphones, plus access to the internet, has made it easier for people to record and share observations, leading to a growing number of such researcher-citizen scientist collaborations (see for example, https://citsci-india.org/projects/). In our specific case, scientists working in partnership with naturalists, students, community members, and forest managers could achieve the task of mapping invasive species at a scale, and within a timeframe, that would be meaningful for both researchers and managers—something that scientists on their own could not do. We aimed, through this pilot effort, to develop and test user-friendly mapping protocols and develop an interface for citizen scientists to use. Ultimately, we hoped to create a model that could be scaled up to large conservation landscapes, such as the Western Ghats, the Central Indian Highlands, and the Himalaya.

MATERIALS AND METHODS

Description of the study area

The Nilgiris District has a long history of plant introductions. The cool, temperate upper elevations of the Nilgiris attracted European settlers during the colonial period. They introduced many alien species as garden ornamentals (e.g., *Cestrum aurantiacum*, *Asclepias curassavica*, and *Cytisus scoparius*) and for fuelwood (e.g., *Acacia mearnsii* and *Eucalyptus* spp.). Many of these species have since become invasive, suppressing native species and altering habitats. The introduction of species to the Nilgiris continues to date, as the area is still of great horticultural importance and remains a source of exotic fruits, vegetables, and ornamental plants for the rest of southern India.

Our study area, the Moyar-Bhavani watershed of the Nilgiris, straddles two terrestrial ecoregions—southern Western Ghats moist deciduous forests and the southern Western Ghats montane rainforests. We used the ecoregion information included in the Indian Alien Flora Information database (v1.0 available at https://ilora2020.wixsite.com/ilora2020/data) and identified 378 plant species that have been introduced to these two terrestrial ecoregions (Pant et al. 2021). Of these, about 81 can be considered invasive alien species today, based on expert opinion. However, we felt that mapping the distribution and abundance of these many invasive species was an unreasonable ask of citizen scientists (i.e., volunteers, students, and forest department field staff). We therefore prioritised amongst these 81 species to arrive at a more

manageable shortlist of widespread and highly invasive species for citizen scientists to record. Here, we describe the process followed to create that priority list of invasive species as a precursor to creating a pilot citizen science atlas of invasive species.

Compiling, selecting, and shortlisting of invasive species

As a first step, in September 2017, we compiled a database of the 81 invasive plants for the Nilgiris using various sources such as Zarri et al. (2004), Keystone Foundation (2008, 2016), Narasimhan (2009), Khuroo et al. (2012), Hiremath & Sundaram (2013), and from personal observations. For each species, we included additional information on its origin, the range of elevations within which it is found, and its presence (or absence) in various habitats. We created a matrix to indicate species presence in these different habitats, i.e., dry and wet forest, grasslands, plantations, wetlands (marshes, peat bogs), and freshwater habitats (ponds, lakes, rivers, reservoirs) (Annexure 1).

The next step was to select a preliminary short-list of invasive species from amongst this list of 81 species. Our selection was informed by existing definitions of invasive species. The IPBES defines an invasive alien species based on its ecological and socio-economic impacts (IPBES 2019). An alternative definition is proposed by Colautti & MacIsaac (2004), who suggest that an invasive species is one that is both locally abundant, and widespread, distinguishing it from other introduced species. We combined these considerations into the following three criteria:

1. Species that were well known in the landscapes (a measure of the species' impacts and abundance)
2. Species that have spread into multiple habitats (a measure of the species' local abundance).
3. Species that occur over more than one altitudinal zone (a measure of the species' spread).

We shortlisted 34 species that met these three criteria (Annexure 2) and convened a stakeholder workshop later that same month to assess the appropriateness of the shortlist for the Nilgiris landscape. A scoring was done to reflect the presence of the species in different habitats, with '1' denoting a species' presence in only one habitat, '2' denoting its presence in two habitats, and so on.

The stakeholder workshop included participants from local conservation organisations, community-based organisations, academic institutions, and restoration practitioners. We added *Pennisetum clandestinum* and *Polygonum polystachyum* to the final shortlist during the workshop as these species were known to be spreading in the Nilgiris. On the other hand, *Acanthospermum hispidum*, *Argemone mexicana*, *Kalanchoe delagoensis*, *Opuntia stricta, Synedrella nodiflora*, and *Tithonia diversifolia* were excluded from the list because, despite being invasive, these were not considered widespread by the stakeholders. Later, we replaced *Senna alata* with *Senna spectabilis* after observing the rapid spread of *Senna spectabilis* during a field visit to Sathyamangalam Tiger Reserve, and based on expert opinion that *S. spectabilis* is of greater conservation concern.

Based on the workshop discussions, we selected 26 of the 34 shortlisted species for mapping invasive alien species in the Nilgiris (Annexure 3). We then prepared a field identification key with images of the plant parts (habit, twigs, leaves, flower, fruit, seeds) to help individuals identify species while mapping invasive species in the field. A hard copy of the field identification key was printed for reference. The naming of the species has followed the International Plant Name Index (IPNI).

RESULTS AND DISCUSSIONS

Over 70% of the species that we prioritised for the Nilgiris were categorised as 'invasive' in existing databases of invasive alien plants in India, namely the 'Khuroo list' (Khuroo et al. 2012) and the ILORA database (Pant et al. 2021) (Table 1). When comparing our list of 26 invasive alien species with Khuroo's, we found 19 species were assigned the status 'invasive', *Passiflora mollissima* was assigned the status 'naturalised/invasive', while *Senna spectabilis* and *Pennisetum clandestinum*, are considered to be 'cultivated' and 'naturalized', respectively. None of the remaining four species—*Cestrum aurantiacum*, *Gamochaeta purpurea*, *Polygonum polystachyum*, and *Solanum mauritianum* on our list appears on the Khuroo list, though several of their congeners do.

Meanwhile, the ILORA database has additions to the list of alien species that were absent in the Khuroo list. These include C. *aurantiacum* and *S. mauritianum,* which are assigned the status 'invasive' and 'naturalised alien,' respectively. Both species are on our priority list of 26 species. Apart from this, the invasion status of some species from the Khuroo list has been revised in the ILORA database. For example, *Phragmites australis* and *Pistia stratiotes* (again, both on our priority list of 26 species), considered invasive in the Khuroo list, are now listed as native in the ILORA database (ver. 1) and unlisted altogether in an updated version (1.1); this may be due to their cryptogenic origins. Overall, 24 out of the 26 invasive species shortlisted by us can be found in the ILORA database, with the exception of *P. polystachyum* and *G. purpurea*.

Table 1. A comparison of the short-list of 26 priority invasive alien plants of the Nilgiris with existing national invasive species lists (ILORA version 1 and version 1.1).

Accepted scientific name of species	Family	Native region	Invasion status (Khuroo list)	Invasion status (ILORA)
Acacia mearnsii De Wild.	Mimosaceae	Australia	In	In
Ageratina adenophora (Spreng.) R.M.King & H.Rob.	Asteraceae	Central America	In	In
Ageratum conyzoides L.	Asteraceae	South America	In	In
Ageratum houstonianum Mill.	Asteraceae	Mexico	In	In
Alternanthera philoxeroides (Mart.) Griseb.	Amaranthaceae	South America	In	In
Asclepias curassavica R.Br. ex. DC.	Asclepiadaceae	Tropical America	In	In
Bidens pilosa L.	Asteraceae	South America	In	In
Cestrum aurantiacum Lindl.	Solanaceae	Central America	-	In
Chromolaena odorata (L.) King & Robin.	Asteraceae	Central America	In	In
Cytisus scoparius (L.) Link	Papilionaceae	Europe	In	In
Datura innoxia Mill.	Solanaceae	South America	In	In
Pontederia crassipes (Mart.) Solms.	Pontederiaceae	Brazil	In	In
Gamochaeta purpurea (L.) Cabrera	Asteraceae	South America	-	-
Lantana camara L.	Verbenaceae	Tropical America	In	In
Mikania micrantha Kunth	Asteraceae	Tropical America	In	In
Opuntia tuna (L.) Mill.	Cactaceae	Mexico	In	In
Parthenium hysterophorus L.	Asteraceae	Central America	In	In
Passiflora mollissima L.H.Bailey	Passifloraceae	Tropical South America	N/I	Nt
Pennisetum clandestinum Hochst. ex Chiov.	Poaceae	Tropical Africa	Nt	Nt
Phragmites australis (Cav.) Trin. ex Steud.	Poaceae	Temperate Eurasia	In	Native (ver.1); absent in ver.1.1
Pistia stratiotes L.	Araceae	North America	In	Native (ver.1); absent in ver.1.1
Polygonum polystachyum Wall. ex Meisn.	Polygonaceae	Himalaya	-	-
Prosopis juliflora (Sw.) DC.	Mimosaceae	Mexico & Central America	In	In
Senna spectabilis (DC.) H.S.Irwin & Barneby	Caesalpiniaceae	Tropical America	Cl	In
Solanum mauritianum Scop.	Solanaceae	South America	-	Nt
Ulex europaeus L.	Papilionaceae	Europe	In	In (ver.1); absent in ver.1.1

Cl—Cultivated | Cs—Casual | C/N— Casual/Naturalised | Nt—Naturalised alien | N/I—Naturalised/Invasive | In—Invasive.

The comparison of our list of priority invasive species for the Nilgiris with the Khuroo list and the ILORA database offers interesting insights. One is that invasion is a dynamic process, and a species' invasion status could change over time. For example, the Khuroo list (published in 2012) considered *Senna spectabilis* to be 'cultivated', but in the short time since, *Senna spectabilis* has become widespread and abundant in several parts of the Western Ghats, including the Nilgiris. Recent work by Anoop et al. (2021) suggests that elephants are aiding in its widespread and rapid dispersal. This change in the species' status is reflected in the ILORA database (see Table 1), which was compiled a decade after the Khuroo list.

Another interesting insight is that a species' 'alien' status is determined by biogeographic boundaries, not by geopolitical ones. In this case, *Polygonum polystachyum* (Himalayan Knotweed), which is native to the Indian Himalaya, does not appear on either the Khuroo list or the ILORA database. However, stakeholders in the upper elevations of the Nilgiris, a region that is biogeographically distinct from the Himalaya, consider the species to be invasive.

Overall, our results highlight the value of the ILORA databases as a starting point for any effort to compile a locally relevant list of invasive species. The ILORA database builds on the earlier Khuroo list, and also incorporates information from other existing databases (see Pant et al. 2021), making it the most comprehensive listing of invasive alien plants for India today. However, this also makes the database unwieldy in smaller regions. For instance, the ILORA database lists a staggering 120 invasive alien species for the Moyar-Bhavani watershed, which barely extends over 4,100 km^2. This might be because the watershed straddles two terrestrial ecoregions (i.e., the southern

Western Ghats moist deciduous forests and the southern Western Ghats montane rainforests). Nevertheless, mapping the distribution and abundance of these many species is a daunting task, even when energised by citizen-scientists. Here, our priority list of 26 invasive alien species for the Nilgiris underscores the value of local expert opinion in shortlisting species that are locally relevant. The ILORA database may still be useful when developing lists for large landscapes or states, but local expertise is invaluable in developing lists for smaller landscapes.

Local expertise is also vital for identifying emerging threats. One illustration of this is the expert inclusion of *Cestrum aurantiacum* and *Solanum mauritianum,* neither of which appears on the Khuroo list. Both species are relatively recent additions to the database on alien species in India (even though they are listed as invasive alien species in global databases such as CABI and GISD). Another is the expert inclusion of *Senna spectabilis,* which was earlier listed as cultivated (in 2012) and has now been listed as invasive (in 2021). Given that published information about invasive species in India is still incipient, and that a large proportion of this information is dominated by a few species (Hiremath & Sundaram 2013), comprehensive databases like ILORA are constrained by the information that they can build on. In such a situation, expert opinion of local community members, forest managers and botanists must continue to inform the listing and prioritising of invasive alien species, in conjunction with existing databases.

CONCLUSION

There are an estimated 220–225 invasive alien plants in India (Khuroo et al. 2012; Pant et al. 2021). A few, such as *Lantana camara* and *Prosopis juliflora* are very widespread (Hiremath & Sundaram 2013). Others are more regional in their distribution, though locally abundant and widespread, e.g., *Acacia mearnsii* in the upper elevation regions of the Western Ghats (Nayak et al. 2023), or *Anthemis cotula* in the Kashmir Himalaya (Reshi et al. 2012). Yet the distribution and abundance of each invasive alien species, and even the number of invasive alien species, is expected to change in time. A citizen-science approach is best placed to track these changes and build an atlas of invasive alien plants for India.

To enable citizen scientists to contribute easily and continuously to such an atlas, it is important that they are not overwhelmed by the large number of invasive alien plants across India. Instead, they need to work with a shorter list of species that is relevant to the area they live in. The process that we have followed for prioritising invasive plants for the Nilgiris could provide a replicable model for other regions as well.

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Annexure 1. Presence of invasive species in different habitats.

	Name of the species	Family	Common name	Native	Elevation	Dry forests	Wet forests	Grasslands	Plantations	Wetlands/ Marshes/ Peat bogs	Freshwater (Ponds/ Rivers/ Lakes/ Reservoirs)	Scoring	Ref
1	*Alternanthera ficoidea* (L.) P.Beauv.	Amaranthaceae	Red threads, Joseph's coat	Brazil	100– 800 m					+		1	1,2
2	*Alternanthera paronychioides* A.St.-Hil.	Amaranthaceae	Smooth joy weed flower	South America & West Indies	Up to 800 m					+		1	1,3
4	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Alligator weed	South America	Up to 1,000 m					+	+	2	1
5	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	Sessile Joy weed	Tropical America	200–1,500 m	+				+	+	3	1
6	*Amaranthus spinosus* L.	Amaranthaceae	Spiny Amaranthus	America	Up to 1,500 m	+						1	1
7	*Gomphrena serrata* L.	Amaranthaceae	Prostrate Gomphrena	South America	Up to 1,000 m	+			+			2	1
8	*Catharanthus roseus* (L.) G.Don.	Apocynaceae	Madagascar Periwinkle, Rosy Periwinkle	Tropical America	Up to 1,800 m	+			+		+	3	1
9	*Cascabela thevetia* (L.) Lippold	Apocynaceae	Yellow Oleander	Peru	Up to 1,400 m				+			1	1
10	*Pistia stratiotes* L.	Araceae	Water Lettuce	South America	Up to 1,400 m					+	+	2	1,2
11	*Asclepias curassavica* L.	Asclepiadaceae	Scarlet Milkweed	Tropical America	>500 m	+				+	+	3	1,2
12	*Acanthospermum hispidum* DC.	Asteraceae	Starbur, Goat's head, Bristly Starbur	Brazil	Up to 1,000 m	+	+		+			3	1,2
14	*Acmella radicans* (Jacq.) R.K.Jansen	Asteraceae	White Spot flower	Southern America	Up to 1,000 m	+				+		2	3
15	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae	Crofton weed	Mexico	300–2,500 m		+	+	+		+	4	1
16	*Ageratum conyzoides* L.	Asteraceae	Goat weed, White weed	South America	Up to 2,000 m	+	+	+	+		+	5	1,3
17	*Ageratum houstonianum* Mill.	Asteraceae	Blue weed	Central America	Up to 1,300 m	+	+	+	+		+	5	1
18	*Ambrosia artemisiifolia* L.	Asteraceae	Common Ragweed	North America	Up to 1,000 m		+	+	+			3	1,2
19	*Anthemis cotula* L.	Asteraceae	Stinking Chamomile, Wild Chamomile	Temperate Eurasia	Up to 1,600 m			+	+			2	1
20	*Bidens biternata* (Lour.) Merr. & Sherff.	Asteraceae	Spanish needles	America	Up to 2,000 m	+	+	+	+			4	1,3

	Name of the species	Family	Common name	Native	Elevation	Dry forests	Wet forests	Grasslands	Plantations	Wetlands/ Marshes/ Peat bogs	Freshwater (Ponds/ Rivers/ Lakes/ Reservoirs)	Scoring	Ref
21	*Bidens pilosa* L.	Asteraceae	Beggar's tick or Spanish needle	America	Up to 3,600 m	+	+	+	+			4	1
22	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	Siam weed	North America	Up to 1,000 m	+	+		+		+	4	1
23	*Crassocephalum crepidioides* (Benth) S.Moore	Asteraceae	Fireweed	Tropical Africa	Up to 1,800 m					+	+	2	1
24	*Erigeron karvinskianus* DC.	Asteraceae	Australian Daisy	Mexico	1,000–2,000 m			+	+			2	1
25	*Flaveria trinervia* (Spreng) C.Mohr	Asteraceae	Sprengel	Central America	Up to 2,000 m	+			+			2	4
26	*Galinsoga parviflora* Cav.	Asteraceae	Gallant soldier	Tropical America	Up to 2,000 m	+	+		+	+		4	1
27	*Gamochaeta coarctata* (Willd.) Kerguélen	Asteraceae	Grey everlasting	South America	1800–2,200 m		+	+	+			4	1
28	*Gamochaeta purpurea* (L.) Cabrera	Asteraceae	Purple Cudweed	North America	500–2,600 m		+	+				3	1
29	*Mikania micrantha* Kunth	Asteraceae	Mile-a-minute	North, Central and South America	Up to 1,000 m	+	+		+			3	1
30	*Parthenium hysterophorus* L.	Asteraceae	Carrot grass, Congress grass	America	Up to 1,400 m	+	+	+	+			3	1,4
31	*Synedrella nodiflora* (L). Gaertn.	Asteraceae	Cinderella weed	West Indies	Up to 800 m	+			+			2	1
32	*Tithonia diversifolia* (Hemsl.) A.Gray	Asteraceae	Mexican Sunflower	South America	500–1,900 m	+	+		+			3	1
33	*Tridax procumbens* L.	Asteraceae	Coat button	Mexico	Up to 1,000 m	+			+			3	1
34	*Cardamine trichocarpa* Hochst. ex A.Rich.	Brassicaceae	Bittercress	Temperate Eurasia	>1,200 m			+	+			3	4
35	*Lepidium didymum* L.	Brassicaceae	Swine Cress	Tropical America	Up to 2,200 m	+			+			2	1,5
36	*Opuntia tuna* (L.) Mill.	Cactaceae	Spiny Pest Pear	Mexico	50– 900 m	+						1	1,2
37	*Opuntia stricta* (Haw.) Haw.	Cactaceae	Pricky Pear	Mexico	300–1200 m	+						1	1
38	*Senna alata* (L.) Roxb.	Caesalpiniaceae	Christmas Candle, Candle brush	South America	Up to 1,200 m	+						1	1
39	*Senna occidentalis* (L.) Link	Caesalpiniaceae	Septic weed, Coffee weed	South America	Up to 1,500 m	+						1	1
40	*Casuarina equisetifolia* L.	Casuarinaceae	Australian Pine	Australia, Malaysia & Pacific Islands	Up to 1,500 m	+			+			2	1
41	*Ipomoea carnea* Jacq.	Convolvulaceae	Pink Morning Glory	South America	Up to 1,000 m	+				+	+	3	1,6

	Name of the species	Family	Common name	Native	Elevation	Dry forests	Wet forests	Grasslands	Plantations	Wetlands/ Marshes/ Peat bogs	Freshwater (Ponds/ Rivers/ Lakes/ Reservoirs)	Scoring	Ref
42	*Ipomoea indica* (Burm.) Merr.	Convolvulaceae	Blue Dawn Flower	South America	Up to 1,500 m			+	+			2	1
43	*Kalanchoe delagoensis* Eckl. & Zeyh.	Crassulaceae	Chandelier plant	Madagascar	Up to 1,000 m	+				+	+	3	1
44	*Chrozophora plicata* (Vahl) A. Juss. ex Spreng.	Euphorbiaceae	_	Tropical Africa	Up to 1,000 m	+						1	2
45	*Croton bonplandianus* Baill.	Euphorbiaceae	Railway weed	South America	Up to 900 m	+						1	4
46	*Euphorbia cyathophora* Murray	Euphorbiaceae	Painted Poinsettia	North and South America	Up to 1,000 m	+						1	1,6
47	*Euphorbia helioscopia* L.	Euphorbiaceae	Sun Spurge	West Asia	1000–2000 m	+	+					2	1,4
48	*Euphorbia hirta* L.	Euphorbiaceae	Common Spurge	Tropical America	Up to 1,400 m	+			+			2	1,4
49	*Aeschynomene americana* L.	Fabaceae	Shyleaf, Common Aeschynomene	Tropical America	Up to 1,000 m	+				+		2	1
50	*Aeschynomene indica* L.	Fabaceae	Indian Joint Vetch	North and Central America	Up to plains to 2,000 m	+	+			+		3	1
51	*Cytisus scoparius* (L.) Link	Fabaceae	Scotch Broom	Western and Central Europe	1,800–2,400 m			+	+			2	1
52	*Prosopis juliflora* (Sw.) DC.	Fabaceae	Algaroba, Mesquite	South America	Up to 1,000 m	+						1	1
53	*Stylosanthes hamata* (L.) Taub.	Fabaceae	Caribbean Stylo	Central America	Up to 1,800 m			+	+	+		3	1,6
54	*Ulex europaeus* L.	Fabaceae	Gorse	Western Europe	1,800–2,000 m			+	+	+		3	1
55	*Miconia crenata* (Vahl) Michelang.	Melastomataceae	Soapbush	Tropical America	Up to 1,200 m		+		+			2	1
56	*Acacia mearnsii* De Wild.	Mimosaceae	Black Wattle	Australia	>1,600 m		+	+	+	+		4	1
57	*Desmanthus virgatus* (L.) Willd.	Mimosaceae	Hedge Lucerne	Tropical America	Up to 1,000 m	+						1	1
58	*Leucaena latisiliqua* (L.) Gillis.	Mimosaceae	Horse Tamarind	Tropical America	Up to 150 m	+			+			2	1
59	*Mimosa pudica* L.	Mimosaceae	Touch-me-not	South America	Up to 1,800 m	+	+			+		3	1
60	*Vachellia farnesiana* (L.) Wight & Arn.	Mimosaceae	Needle bush, Sweet Acacia	Tropical America	Up to 1,000 m	+						1	1
61	*Broussonetia papyrifera* (L.) Vent.	Moraceae	Paper Mulberry	East Asia	Up to 1,000 m	+						1	1
62	*Argemone mexicana* L.	Papaveraceae	Mexican Prickly Poppy	South America	Up to 1,000 m	+			+			2	1

	Name of the species	Family	Common name	Native	Elevation	Dry forests	Wet forests	Grasslands	Plantations	Wetlands/ Marshes/ Peat bogs	Freshwater (Ponds/ Rivers/ Lakes/ Reservoirs)	Scoring	Ref
63	*Passiflora foetida* L.	Passifloraceae	Stinking Passionflower	Brazil & West Indies	Up to 1,800 m	+	+					2	1
64	*Passiflora mollissima* L.H.Bailey	Passifloraceae	Banana Passionfruit	Tropical South America	Up to 1,800 m	+	+		+			3	1
65	*Phalaris minor* Retz.	Poaceae	Little-seeded Canary grass	Mediterranean region	Up to 1,800 m	+	+			+		3	1,2
66	*Phragmites australis* (Cav.) Trin. ex Steud.	Poaceae	Common Reed	Temperate Eurasia	Up to 1,000 m	+	+			+	+	4	1,2
67	*Polypogon monspeliensis* (L.) Desf.	Poaceae	Rabbitfoot grass	Temperate Eurasia	Up to 1,000 m			+		+		2	1
68	*Chloris barbata* Sw.	Poaceae	Swollen windmill grass	Tropical America & Africa	Up to 2,000 m	+				+		2	1
69	*Urochloa panicoides* P. Beauv.	Poaceae	Liverseed grass	Tropical America	Up to 1,700 m	+						1	1
70	*Antigonon leptopus* Hook. & Arn.	Polygonaceae	Coral vine	South America	Up to 1,000 m	+						1	1
71	*Pontederia crassipes* Mart.	Pontederiaceae	Water Hyacinth	South America	Up to 2,000 m					+	+	2	1,2
72	*Monochoria vaginalis* K.B.Presl.	Pontederiaceae	Pickerel weed	Southeast Asia	Up to 1,200 m					+	+	2	1
73	*Calceolaria mexicana* Benth.	Scrophulariaceae	Ladies purse	Mexico	1800–2,000 m			+	+	+		3	2,4
74	*Ailanthus altissima* (Miller) Swingle	Simaroubaceae	Tree of heaven	China	Up to 2,000 m	+						1	1
75	*Cestrum aurantiacum* Lindl.	Solanaceae	Orange Jasmine	North and South America	1,200–2,600 m		+	+	+			3	1
76	*Datura innoxia* Mill.	Solanaceae	Downy Thorn-apple	Tropical and subtropical America	Up to 1,800 m	+	+					2	1
77	*Datura stramonium* L.	Solanaceae	Common Thorn-apple	Tropical America	Up to 2,700 m	+	+		+		+	4	1
78	*Solanum mauritianum* Scop.	Solanaceae	Tobacco tree	South America	Up to 2,200 m		+	+	+		+	4	1,2
79	*Solanum seaforthianum* Andrews	Solanaceae	Brazilian Nightshade	Tropical America	1,300–1,500 m	+						1	1
80	*Lantana camara* L.	Verbenaceae	Big Sage	Central and South America	Up to 2,000 m	+	+	+	+		+	5	1,4
81	*Stachytarpheta jamaicensis* (L.) Vahl.	Verbenaceae	Jamaican Blue Spike	South America	Up to 800 m	+	+					2	1

Ref: 1—www.cabidigitallibrary.org | 2—efloraofindia.com | 3—flowersofindia.net | 4—https://indiabiodiversity.org | 5—https://wgbis.ces.iisc.ac.in/biodiversity/sahyadri_enews/newsletter/issue42/bibliography/The-alien-flora-of-Kashmir-Himalaya.pdf | 6—https://www.gbif.org

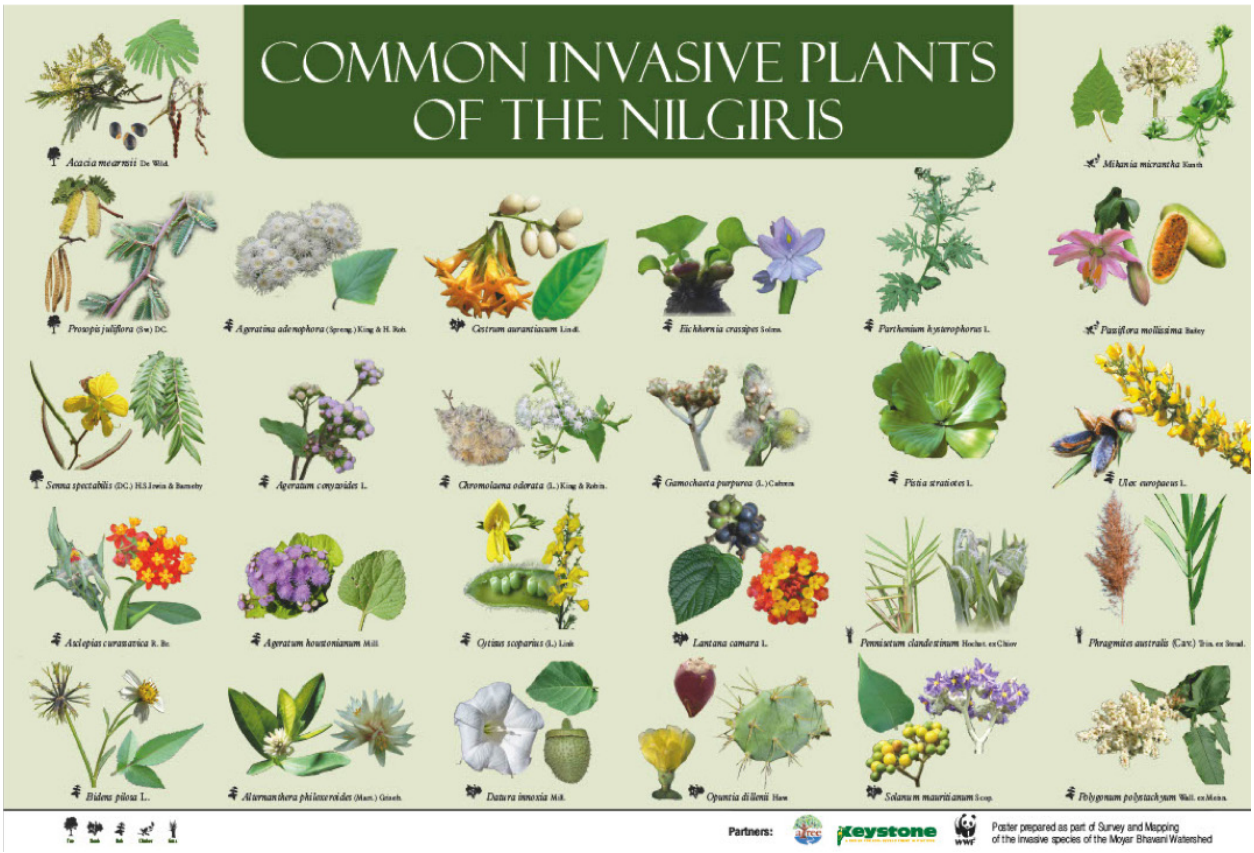
Annexure 2. Shortlisted species.

	Name of the species	Criterion 1[1]	Criterion 2[1]	Criterion 3[1]	Reference[2]
1	*Acacia mearnsii* De Wild.	Yes	Yes	Yes	1
2	*Acanthospermum hispidum* DC.	Yes	Yes	Yes	1
3	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Yes	Yes	Yes	1
4	*Ageratum conyzoides* L.	Yes	Yes	Yes	1
5	*Ageratum houstonianum* Mill.	Yes	Yes	Yes	1
6	*Alternanthera philoxeroides* (Mart.) Griseb.	Yes	Yes	Yes	1
7	*Alternanthera sessilis* (L.) R.Br. ex DC.	Yes	Yes	Yes	1
8	*Argemone mexicana* L.	Yes	Yes	Yes	1
9	*Asclepias curassavica* R.Br.	Yes	Yes	Yes	1
10	*Bidens pilosa* L.	Yes	Yes	Yes	1
11	*Cestrum aurantiacum* Lindl.	Yes	Yes	Yes	1
12	*Chromolaena odorata* (L.) King & H.Rob.	Yes	Yes	Yes	1
13	*Cytisus scoparius* (L.) Link	Yes	Yes, spread widely	High altitudes	1
14	*Datura innoxia* Mill.	Yes	Yes	Yes	1
15	*Pontederia crassipes* Mart.	Yes	Yes	Yes	1
16	*Gamochaeta purpurea* (L.) Cabrera	Yes	Yes	Yes	1
17	*Kalanchoe delagoensis* Eckl. & Zeyh.	Yes	Yes	Yes	1
18	*Lantana camara* L.	Yes	Yes	Yes	1
19	*Mikania micrantha* Kunth	Yes	Yes	Yes	1
20	*Opuntia tuna* (L.) Mill.	Yes	Yes	Yes	1
21	*Opuntia stricta* Haw.	Yes	Yes	Yes	1
22	*Parthenium hysterophorus* L.	Yes	Yes	Yes	1
23	*Passiflora mollissima* L.H.Bailey	Yes	Yes	Yes	1
24	*Phragmites australis* (Cav.) Trin. ex Steud.	Yes	Yes	Yes	1
25	*Pistia stratiotes* L.	Yes	Yes	Yes	1
26	*Prosopis juliflora* (Sw.) DC.	Yes	Yes	Yes	1
27	*Senna alata* (L.) Roxb.	Yes	Yes	Yes	1
28	*Senna occidentalis* (L.) Link	Yes	Yes	Yes	1
29	*Solanum mauritianum* Scop.	Yes	Yes	Yes	1
30	*Synedrella nodiflora* L. Gaertn.	Yes	Yes	Yes	1
31	*Cascabela thevetia* (L.) Lippold	Yes	Yes	Yes	1
32	*Tithonia diversifolia* (Hemsl.) A.Gray	Yes	Yes	Yes	1
33	*Tridax procumbens* L.	Yes	Yes	Yes	1
34	*Ulex europaeus* L.	Yes	Yes	Yes	1

[1] Note on criteria:
Criterion 1—Species that are well known in the landscapes (a measure of the species' impacts and abundance) |
Criterion 2— Species that have spread into multiple habitats (a measure of the species' local abundance) |
Criterion 3—Species that occur over more than one altitudinal zone (a measure of the species' spread).
[2] References: 1—Personal communication, 18 January 2017: V. Anita, H. Ankila, B. Milind, Samuel Thomas, Shiny M. Rehel (corroborated by observation of workshop participants).

Annexure 3. Final list of species for mapping invasive alien species in the Nilgiris.

	Name of the species	Habit	Common name
1	*Acacia mearnsii* De Wild.	Tree	Black Wattle
2	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Herb	Crofton Weed
3	*Ageratum conyzoides* L.	Herb	Goat Weed
4	*Ageratum houstonianum* Mill.	Herb	Floss Flower
5	*Alternanthera philoxeroides* (Mart.) Griseb.	Herb	Alligator Weed
6	*Asclepias curassavica* L.	Herb	Milk Weed
7	*Bidens pilosa* L.	Herb	Blackjack
8	*Cestrum aurantiacum* Lindl.	Shrub	Orange Cestrum
9	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Herb	Siam Weed
10	*Cytisus scoparius* (L.) Link	Herb	Scotch Broom
11	*Datura innoxia* Mill.	Shrub	Downy Thorn-apple
12	*Pontederia crassipes* Mart.	Herb	Water Hyacinth
13	*Gamochaeta purpurea* (L.) Cabrera	Herb	Purple Spoonleaf everlasting
14	*Lantana camara* L.	Shrub	Wild Sage
15	*Mikania micrantha* Kunth	Shrub	Bitter Vine
16	*Opuntia tuna* (L.) Mill.	Shrub	Prickly Pear
17	*Parthenium hysterophorus* L.	Shrub	Parthenium
18	*Passiflora mollissima* L.M.Bailey	Climber	Banana Passion
19	*Phragmites australis* (Cav.) Trin. ex Steud.	Grass	Common Reed
20	*Prosopis juliflora* (Sw.) DC.	Tree	Mesquite
21	*Senna spectabilis* (DC.) H.S.Irwin & Barneby	Tree	American Cassia
22	*Solanum mauritianum* Scop.	Shrub	Bugweed
23	*Pistia stratiotes* L.	Herb	Water Lettuce
24	*Ulex europaeus* L.	Herb	Common Gorse
25	*Pennisetum clandestinum* Hochst. ex Chiov	Grass	Kikuyu Grass
26	*Polygonum polystachyum* Wall. ex Meisn.	Herb	Himalayan Knotweed



Annexure 4. Poster on common invasive plants of the Nilgiris.

Author details: Shiny Mariam Rehel strategises ecological restoration projects, overseeing native flora nurseries and projects related to pollinators. She builds networks with global forums on biodiversity, and within local government bodies. Reshnu Raj R S is an ecologist, currently undertaking doctoral studies at School of Natural Science, Massey University, where he investigates the effects of anthropogenic activities on the environment. Samuel Thomas supports work focused on regenerating and restoring critical ecosystems in the Hindu Kush Himalaya. Milind Bunyan is a forest ecologist with research interests in invasive alien species, landscape ecology and restoration ecology. Milind uses RS-GIS to characterise ecosystems and communities and develop tools for restoring landscapes. Anita Varghese develops long-term goals, research and action steps on field for the implementation of projects under the Biodiversity and Climate Change programmes. Ankila Hiremath is a plant ecologist with an interest in ecosystem restoration and novel ecosystems. She works in tropical dry forests and savannas on invasive species and their ecological and socio-economic impacts.

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