

Article

Invasive Plant Species in the National Parks of Vietnam

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Abstract: The impact of invasive plant species in national parks and forests in Vietnam is undocumented and management plans have yet to be developed. Ten national parks, ranging from uncut to degraded forests located throughout Vietnam, were surveyed for invasive plant species. Transects were set up along roads, trails where local people access park areas, and also tracks through natural forest. Of 134 exotic weeds, 25 were classified as invasive species and the number of invasive species ranged from 8 to 15 per park. An assessment of the risk of invasive species was made for three national parks based on an invasive species assessment protocol. Examples of highly invasive species were *Chromolaena odorata* and *Mimosa diplotricha* in Cat Ba National Park (island evergreen secondary forest over limestone); *Mimosa pigra*, *Panicum repens* and *Eichhornia crassipes* in Tram Chim National Park (lowland wetland forest dominated by melaleuca); and *C. odorata*, *Mikania micrantha* and *M. diplotricha* in Son Tra Nature Conservation area (peninsula evergreen secondary forest). Strategies to monitor and manage invasive weeds in forests and national parks in Vietnam are outlined.

Keywords: biological invasion; exotic weeds; forests; national parks; Vietnam

1. Introduction

Vietnam is a tropical country with a rich biodiversity, including 2393 non-vascular plants and 11,373 vascular plants [1]. However, of the 448 plant species listed in the Vietnam red data book, 44 species are critically endangered, 186 species are endangered and a further 213 species are vulnerable [2]. Forests provide important refugia for threatened habitats and species. The total forest area in Vietnam is nearly 13.3 million ha (39.5% cover) [3], of which natural forest constitutes 10.3 million ha. Approximately 2.2 million ha of this is classified as special-use forest comprising 30 national parks (NP), 58 natural conservation areas (NCA), 11 species conservation areas (SCA), 45 historical forest areas (HFA) and 20 scientific forest areas (SFA). These are distributed as follows: the north-east region has 5 NPs, 19 NCAs, 14 HFAs and 4 SCAs; the north-west region has 10 NCAs, 1 HFA and 2 SFA; the Red river Delta region has 4 NPs, 3 NCAs, 5 HFAs and 2 SFAs; the northern central region has 5 NPs, 10 NCAs, 4 HFAs and 1 SFA; the southern central and high-land regions have 5 NPs, 15 NCAs, 8 HFAs and 5 SFAs; the south-east region has 6 NPs, 5 NCAs, 4 HFAs and 4 SFAs; and the Mekong Delta region has 5 NPs, 5 NCAs, 11 HFAs and 1 SFA [4].

According to Canh and Hai [1] the forests are under increasing pressure from disturbance. Except for some weeds of agricultural lands and waterways, for example *Mimosa pigra* in the Mekong delta [4,5], alien invasive plant species have received little attention in Vietnam. In the forest sector, research in this field is almost absent. In a country report on forest invasive species, Thu [6] recorded 6 invasive plant species in Vietnam. In the region, by comparison, knowledge of invasive plant species is mixed, ranging from first reports [7] to documentation and assessment of their invasive capacity [8,9]. In contrast, there are numerous studies on invasive plant species elsewhere in the world [10–12].

The terms “invasive species” was defined in the executive order 13112 of the United States in 1999 [13] and in Vietnam Biodiversity Law in 2008 [14], as “Invasive species means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health”. Other terms, such as likely invasive, potential invasive and introduction were also clarified [15–17].

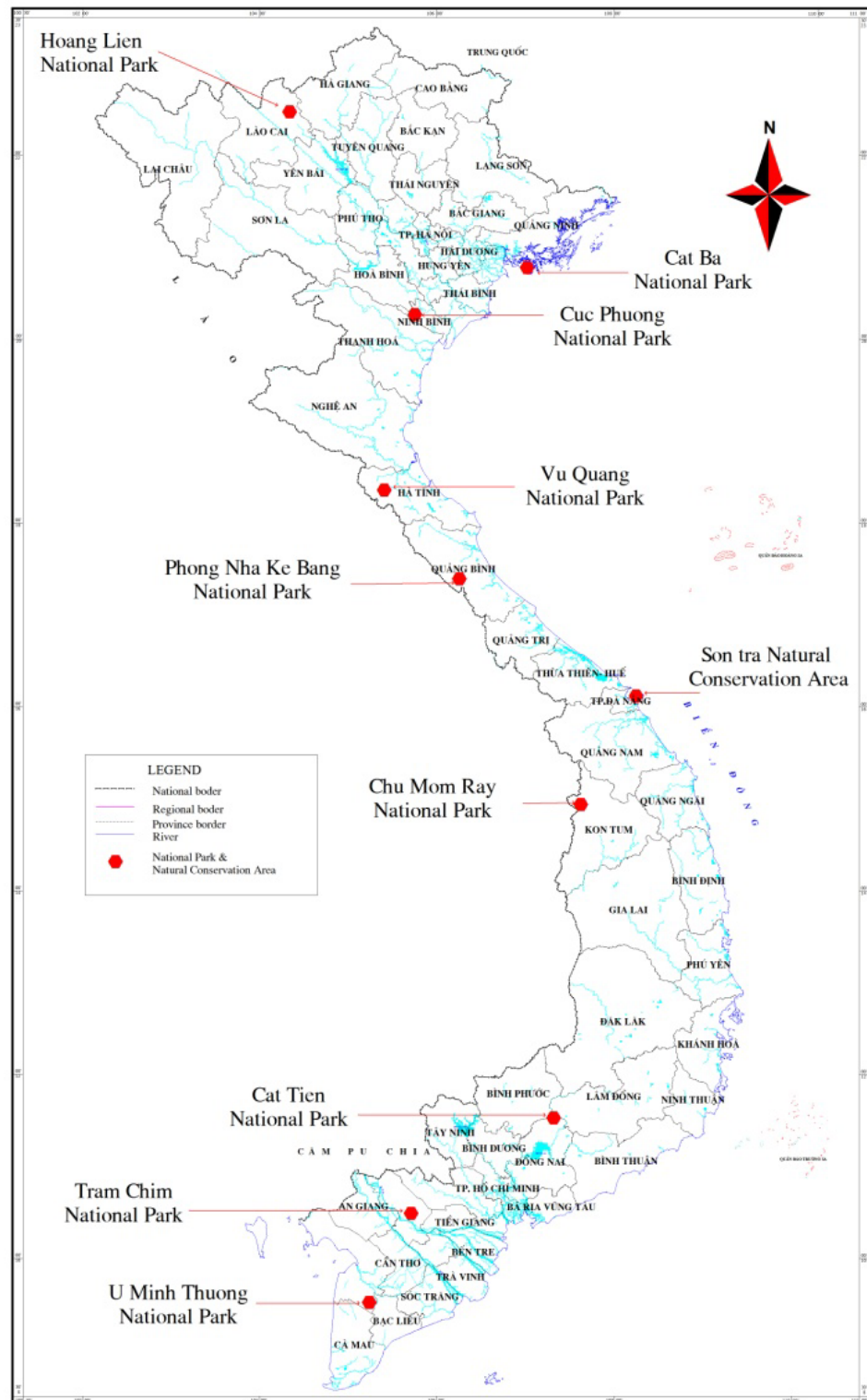
Invasion by aggressive alien species causes serious problems for biodiversity, the environment, ecosystem structure and function and can impact on human health [18,19]. It is estimated that US\$1.4 trillion is the annual management cost for invasive species worldwide States [20–22]. According to Rejmanek [23], effective management of weed invasion should follow three main steps from prevention, early detection to control or eradication. This paper reports for the first time on the alien plant species that are invasive in national parks in Vietnam and thus adds to previous studies in the wider region [24]. This information is essential for foresters so they can recognize the presence of alien and invasive plant species at their park, for committees of each national park to focus their priority in protecting biodiversity, and to inform managers or policy makers within the Department of Natural Conservation (Ministry of Agriculture and Rural Development) with responsibility for producing national response strategies for invasive plants.

2. Methods

Representative conservation forests, ranging from mountain forests to wetland forests throughout Vietnam, were selected for surveillance. The areas investigated were: Hoang Lien NP, Cat Ba NP,

Cuc Phuong NP, Vu Quang NP, Phong Nha-Ke Bang NP, Son Tra NCA, Chu Mom Ray NP, Cat Tien NP, U Minh Thuong NP and Tram Chim NP (in order from the north to the south of Vietnam in Figure 1).

Figure 1. Surveillance locations.



The methodology of surveillance of alien plant species was based on a protocol developed by the National Parks Service, USA [25]. Transects (3 to 12 m in width) were set up from April to September 2011 through forests and also along roads where local people usually access disturbed areas, and along channels and ditch sides for wetland parks. A comprehensive list of 956 non-indigenous species in Vietnam was documented based on references such as Flora of Vietnam [26–28], Vietnam Forest Trees [29,30], and Plant Species in Vietnam [31–33] as background data for field observers. For unknown weed species, herbarium specimens were collected to indentify in the laboratory. Data on habitat type, site conditions, abundance, distribution, percentage cover, and reproduction, were recorded in IPANE survey forms [34]. Species were determined to be Invasive Alien Species (IAS), Likely Invasive (L.IAS) or Potentially Invasive (P.IAS) based on criteria described by the Massachusetts Invasive Plant Advisory Group [35] and Decision #22/2011/TT-BTNMT of the Ministry of Nature Resource and Environment, Vietnam [36].

Species listed as IAS meet the following criteria: (1) non-native in Vietnam; (2) having biological potential for rapid and widespread dispersal and establishment in minimally managed habitats, for dispersing over spatial gaps, and for existing in high number; (3) be naturalized in the parks; (4) be common in a region of habitat types or widespread in Vietnam; (5) have high number of individual forming stands in minimal managed habitats; (6) be able to out-compete other species; and (7) have the potential for rapid growth, high seed or propagule production and dissemination, and establishment in natural plant communities. Likely invasive species (L.IAS) meet first three criteria plus at least one occurrence in parks that has high individual numbers and is known to be invasive elsewhere. Potentially invasive species (P.IAS) meet first two criteria above plus pose an imminent threat to biodiversity and naturalization is anticipated.

Three study areas, Cat Ba NP, Tram Chim NP and Son Tra NCA were then chosen to assess the risk of invasive species based on published protocols [37,38]. The risks (I-Rank) were categorized into 4 classes, namely High (H), Medium (M), Low (L) and Insignificant (I).

3. Results

The vegetation type for the 10 parks that were surveyed is given in Table 1. In the North of Vietnam, of 38 alien plant species at Hoang Lien NP, 6 species were invasive alien plant species (IAS) and 3 were identified as potential invasive plant species (P.IAS). At Cat Ba NP, 38 alien plant species were discovered, including 8 IAS and 7 P.IAS. In Central Vietnam, the four study areas (Cuc Phuong, Vu Quang, and Phong Nha Ke Bang national parks and Son Tra natural conservation area) had 49, 49, 45 and 53 alien plant species, respectively. The corresponding number of invasive plant and potential invasive plant species were 8 IAS and 2 P.IAS, 5 IAS and 4 P.IAS, 6 IAS and 4 P.IAS, and 5 IAS and 5P.IAS, respectively. The number of alien plant species was 52 and 65 species for Chu Mom Ray and Cat Tien NPs in the Highland region, of which there were 7 and 6 IAS, and 3 and 6 P.IAS, respectively. There was one likely invasive plant species in Cat Tien NP. For the wetland national parks in the South-western region, there were 5 IAS, 1 L.IAS and 5 P.IAS of a total of 44 alien plant species were found at Tram Chim NP whilst U Minh Thuong NP had 5 IAS and 6 P.IAS of 47 alien plant species. From this initial surveillance of invasive plant species in 10 parks in Vietnam, 134 alien plant species

were recorded (Appendix 1), of which 25 species were invasive, likely invasive and potential invasive species (Table 1).

Table 1. Description of vegetation and the number of alien and invasive plant species for the 10 parks surveyed in Vietnam.

Site	Type of vegetation	Alien plant species	Invasive plant species
Hoang Lien NP	The topography is divided into high mountain (95.7% area) and valley (4.3% area). There are 4 forest types: broadleaf evergreen seasonal submontane tropical forest; evergreen wet tropical forest at <1800 m; mixed coniferous and broadleaf evergreen forest at 1800–2200 m; and sub-tropical forest at 2200–2600 m. There are <i>ca.</i> 2000 plant species in 200 families, including valuable and rare species, such as <i>Abies delavayi</i> , <i>Alnus nepalensis</i> , <i>Calocedrus macrolepis</i> and <i>Taxus wallichiana</i> .	38	9
Cat Ba NP	The main vegetation is evergreen tropical forest on limestone hills and mountains, but it had been extensively exploited. Some areas have secondary forest where shrubs are dominant. There are 1561 plant species in 149 families, of which 69 are valuable and rare species such as <i>Annamocarya sinensis</i> , <i>Chukrasia tabularis</i> , <i>Pelthophorum tonkinensis</i> and <i>Podocarpus fleurii</i> .	38	15
Cuc Phuong NP	The main type of vegetation is evergreen rain forest on limestone mountains. There are 1983 plant species in 229 families, mainly Acanthaceae, Asteraceae, Euphorbiaceae, Fabaceae, Lauraceae, Moraceae and Rubiaceae. The park is one of the seven richest biodiversity areas in Vietnam.	49	10
Vu Quang NP	The park contains 1612 plant species in 191 families. The vegetation is divided into forest types according to altitude: evergreen submontane forest at 100–300 m; evergreen forest at 300–1000 m; evergreen forest at 1000–1400 m with dominant species in the Cupressaceae and Podocarpaceae; evergreen forest at 1400–1900 m dominated by the Elaeocarpaceae, Fabaceae, Lauraceae and Magnoliaceae; and evergreen forest at 1900–2200 m dominated by <i>Rhododendron</i> and species in the Elaeocarpaceae, Fagaceae and Lauraceae.	49	8
Phong Nha Ke Bang NP	There are 4 main types of forest: closed moist evergreen forest on limestone mountains dominated by <i>Chukrasia tabularis</i> , <i>Dendrocnide sinuata</i> , <i>Excentrodendron tonkinense</i> and <i>Fagraea fragrans</i> ; secondary forest on limestone mountains dominated by <i>Litsea cubeba</i> , <i>Mallotus paniculatus</i> and <i>Rhapis cochinchinesis</i> ; stands of shrub and scattered trees on limestone with dominant species such as <i>Aporosa villosa</i> , <i>Sapium discolor</i> , <i>Sterculia alata</i> and <i>Syzygium bonii</i> ; and closed tropical moist evergreen forest on hills with <i>Anogeissus acuminata</i> , <i>Dillenia scabrella</i> , <i>Dipterocarpus obtusifolius</i> and <i>Pometia pinnata</i> . There are 2651 plant species in 193 families.	45	12

Table 1. Cont.

Site	Type of vegetation	Alien plant species	Invasive plant species
Son Tra NCA	There are four main vegetation types: broadleaf evergreen tropical rain forest dominated by species in the Dipterocarpaceae, Fagaceae, Magnoliaceae, Meliaceae and Rubiaceae; secondary forest where plants regenerate with the Bambusoideae; pasture land and shrub dominated by <i>Melastoma candidum</i> , <i>Phragmites maximus</i> and <i>Rhodomyrtus tomentosa</i> ; and acacia and eucalypt plantations. There are 985 plant species in 143 families.	53	12
Chu Mom Ray NP	The forest is typical of the High Land region. There are 7 vegetation types: closed evergreen tropical rain forest; closed evergreen subtropical rain forest; dry semi-evergreen tropical forest; broadleaf woodlands of dry tropical forest; secondary forest dominated by <i>Bambusa procea</i> and <i>Pseudoxytenanthera albo-ciliata</i> ; and grassland. There are 1895 plant species in 184 families. Key families include the Dipterocarpaceae, Fabaceae, Fagaceae, Lythraceae, Meliaceae, Sterculiaceae and Theaceae. The park contains flora typical of south-eastern Vietnam, and species in the Dipterocarpaceae and Fabaceae are common. There are 1615 plant species in 125 families, of which some are valuable and rare species such as <i>Azelia xylocarpa</i> , <i>Dalbergia bariensis</i> , <i>D. mammos</i> and <i>D. cochichinensis</i> . There are 4 vegetation types: evergreen broadleaf forest; semi-deciduous forest; mixed tree and bamboo forest; bamboo forest; and wetland areas.	52	12
Cat Tien NP	The vegetation comprises a mixture of seasonally inundated grassland, regenerating melaleuca forest and open swamp. <i>Melaleuca</i> species are distributed throughout the park, both in plantations and in scattered patches in areas of grassland or open swamp. There are 130 species in 50 families. There are five grassland communities dominated by <i>Eleocharis dulcis</i> , <i>E. ochrostachys</i> , <i>Ischaemum rugosum</i> , <i>Panicum repens</i> or <i>Vossia cuspidata</i> .	65	12
Tram Chim NP	The park contains 243 plant species in 84 families. Melaleuca forest is distributed throughout the park. There are 6 habitat types: melaleuca forest on waterlogged peat-land; melaleuca forest on clay soils; mixed forest on peat swamp; <i>Phragmites vallatoria</i> grassland; open swamp; <i>Nymphaea nouchali</i> swamp; and channels.	44	12
U Minh Thuong NP		47	12
Total number of species		134	25

For each of the three parks where weed risks were assessed in detail, the threats of invasive species were different (Tables 2 and 3). *Chromolaena odorata* and *Mimosa diplotricha* were placed in the highest risk category at Cat Ba NP. *Chromolaena odorata* was widely distributed over ca. 1000 ha, occurring along roads, on barren land where trees had been felled, under disturbed forest cover, near the beach, and also on some small islands. *Mimosa diplotricha* was present in high numbers, sometimes climbing over other species leading to their death. At Son Tra NCA, in addition to the above two species, *Mikania micrantha* was also of high risk. Hundreds of hectares were invaded

including sides of hills and forest edges. In places, *M. micrantha* together with a local creeper species, *Operculina turpethum*, smothered vegetation causing tree death.

Table 2. The risk (I-Rank) of invasive alien plant species at three parks The risks were categorized into four classes, High (H), Medium (M), Low (L) and Insignificant (I).

Family	Scientific name	Region of origin	I-Rank		
			CB ¹	ST ²	TC ³
Asteraceae	<i>Ageratum conyzoides</i> L.	Central America	L	L	L
	<i>Chromolaena odorata</i> (L.) King & H. E. Robins	Central America	H	H	I
	<i>Mikania micrantha</i> Kunth.	Central and South America		H	
	<i>Parthenium hysterophorus</i> L.	Central America	M		
Fabaceae	<i>Leucaena leucocephala</i> (Lam.) de Wit	Tropical America	L		
	<i>Mimosa diplotricha</i> C. Wight ex Sauvalle	Central America	H	H	M
	<i>Mimosa pigra</i> L.	Mexico, Central and South America	L	M	H
	<i>Mimosa pudica</i> L.	Central America	L	M	L
Poaceae	<i>Eupatorium odoratum</i> L.	Central America			
Pontedriaceae	<i>Eichhornia crassipes</i> (Maret.) Solms	Brazil			H
Verbenaceae	<i>Lantana camara</i> L.	Central America	L	L	

¹ Cat Ba national park; ² Son Tra natural conservation area; ³ Tram Chim national park.

Mimosa pigra (Figure 2), *Panicum repens* and *Eichhornia crassipes* significantly impacted Tram Chim NP. According to a file at the Scientific Research and Environment Division of Tram Chim NP, a few small clumps appeared in 1984–1985. Ten years later *M. pigra* had invaded 150 ha [39], reaching 490 ha in 2000, 960 ha in 2001 and 1845 ha in 2002 (Triet pers. comm.), and ca. 2000 ha in 2009 [40]. *Mimosa pigra* can co-occur with other invasive species [41] including *E. crassipes* and *P. repens*, and they have invaded ca. 40 ha of *Eleocharis dulci* grassland. *Panicum repens* has now invaded ca. 8 ha of natural inundated grasslands and about 300 ha of *Oryza rufipogon* grassland. *Eichhornia crassipes* was present in all park channels, and along with *M. pigra* and *P. repens*, has invaded 5 natural inundated grassland communities.

Figure 2. *Mimosa pigra* infesting Tram Chim National Park (NP).



Table 3. The risk (I-Rank) of likely and potential alien plant species at three parks. The risks were categorized as in Table 2.

Family	Scientific name	Region of origin	Group	I-Rank		
				CB ¹	ST ²	TC ³
Amaranthaceae	<i>Amaranthus spinosus</i> L.	Central America	P.IAS		L	
Araceae	<i>Pistia stratiotes</i> L.	Unknown	P.IAS			M
Asteraceae	<i>Bidens pilosa</i> L.	Central America	P.IAS	I	M	
	<i>Xanthium strumarium</i> DC. (strumarium Auct. non L.)	Europe and America	P.IAS	L		
Cactaceae	<i>Opuntia stricta</i> Willem	America	P.IAS	I		
Convolvulaceae	<i>Cuscuta chinensis</i> Lamk.	China	P.IAS	M		L
Papaveraceae	<i>Argemone mexicana</i> L.	Mexico and West Indies	P.IAS			
Passifloraceae	<i>Passiflora foetida</i> L.	Tropical America	P.IAS	I		M
Poaceae	<i>Panicum repens</i> L.	Tropical and North Africa, Mediterranean	L.IAS			M
	<i>Pennisetum polystachyon</i> (L.) Schult	Africa	L.IAS		M	
	<i>Phragmites australis americanus</i> (Saltonstall, Peterson and Soreng)	North America	P.IAS			L
Salviniaceae	<i>Salvinia cucullata</i> Roxb.	India to SEA, not native in Vietnam	P.IAS			M
Verbenaceae	<i>Stachytarpheta jamaicensis</i> (L.) Vahl	Tropical and sub-tropical America	P.IAS		I	
Zingiberaceae	<i>Hedychium gardnerianum</i> Sheppard ex Ker Gawl	Himalaya, India, Nepal, and Bhutan	P.IAS	I		

¹ Cat Ba national park; ² Son Tra natural conservation area; ³ Tram Chim national park.

4. Discussion

Invasive plant species such as *Chromolaena odorata*, *Ageratum conyzoides*, *Amaranthus spinosus*, *Bidens pilosa*, *Mikania micrantha* and *Mimosa diplotricha* mainly infested disturbed areas such as in secondary forests and along walk trails in primary forests. Clearly, people as well as the biological attributes of the weeds are aiding dispersion. The numbers of alien and invasive plant species were higher in the more disturbed parks such as those in the central and high-land regions of Vietnam where over-exploitation was evident. These observations suggest that there should be restricted access to infested areas during forest rehabilitation. They further indicate the need for careful planning of tourist access ways when developing management plans for national parks. Allen *et al.* [42] identified a close correlation between the number of visitors and the alien weed population. It is planned that this preliminary study will lead to in depth investigation into the correlation of non-native plant species with other aspects, such as native, rare, threatened and endangered plant species; park area; elevation; roads, trails, and rivers distances; temperature; longitude; latitude; and other attributes along the lines with discussed by Allen *et al.* [42].

Alien and invasive plant species not only directly cause a decline in indigenous species, but they can alter ecosystems to such an extent that environmental harm ensues [43]. Various models have been used to describe the dynamics of weed invasions [43]. For example, Macdougall and Turkington [44] used “driver” and “passenger” models to examine whether native plant richness and relative abundance affected by two dominant grasses, *Poa pratensis* and *Dactylis glomerata*, in Cowichan Garry Oak reserve, Canada. However, Didham *et al.* [45] pointed out three limitations of this approach because of experiment manipulation, small scale experimentation, and indirect linkage among factors. It would be useful to explore the driver, back-seat driver and passenger models for future studies in Vietnam to categorize species for priority attention and management by those authorities responsible for the forest estate.

This first list of invasive alien plant species for Vietnam highlights the need for in-country monitoring of forest weeds. In the global status of invasive forest tree species, Hayson and Murphy [46] reported on just 29 species in Asia and Vietnam was not featured. Similarly, there is little published knowledge on invasive weeds for nearby countries such as Cambodia [7] and Lao PDC [47]. Sharing of knowledge within the region will be important for managing invasive weeds, especially for those species that are widely distributed [48–50].

The invasion by two *Mimosa* species is causing great concern in many parts of Vietnam. In particular, *M. pigra* not only invades wetland areas on the sides of rivers and canals, it can infest undisturbed swamps as well as disturbed lands such as industrial tree plantations and rice fields. In addition to impacts on biota, *M. pigra* can prevent people accessing rice fields, reduces water flow in irrigation channels and keeps animals from feeding areas. For example, in Quang Nam province, in Central Vietnam, it grows spontaneously along roads and in rice fields [51], and in Thuan Bac district, Ninh Thuan province, it has invaded bare lands planned for industrial parks [52]. Warnings have been posted in Da Nang province [53,54], Hue city [55], Thac Ba lake (Yen Bai province) [56], and in the South-western region [57]. In Tri An lake, Dong Nai province, *M. pigra* is called the “silent killer” [58], as it now occupies some 1300 ha of the lake.

Not only is *M. pigra* now widespread in Vietnam, it is rapidly dispersed over spatial gaps away from introduction points, hence its occurrence in Cat Tien national park and Vinh Cuu nature reserve. One of the habitats in Cat Tien national park is the 3370 ha wetland that includes Bau Sau swamp (crocodile swamp), Bau Ca swamp (fish swamp), and Bau Chim swamp (bird swamp) which are connected to the Dong Nai river in the wet season. This is a Ramsar site and provides an important feeding area for migratory birds. In addition, Bau Sau is a key habitat for 50 rare IUCN-listed species including reptiles, birds, mammals and plants. The park also has significance because it is a transition zone to the last remaining lowland semi-evergreen forest in the region. Though there has been much effort to eradicate invasive weeds since 2007, they still dominate. Consequently, the feeding area for birds continues to narrow and the number of birds is decreasing (Minh Personal Communication).

A similar issue occurs at the Ramsar site in Tram Chim national park. This is one of the last remnants of the Plain of Reeds wetland ecosystems in the Mekong delta and is an important habitat for the threatened Eastern Sarus Crane (*Grus antigone*) as well as 9 other globally threatened migratory birds. According to the Director of Tram Chim national park, the number of Eastern Sarus Crane has declined with the increase in *Mimosa pigra* over time (Hung Personal Communication). Some

pessimistically state that the Mekong delta will become a calamity due to invasion by *M. pigra* [59]. There is an urgent need to develop efficient methods to control and eradicate this alien species.

These numerous reports on invasions of *M. pigra* species are examples of the considerably negative impacts of invasive plant species, and they could rise warm attention on other species which may have similar problematic. Studies on the impacts of other invasive plant species on biodiversity, ecosystem, and even human health are also required. They will essential for foresters and committees of each national park to focus their priority in protecting biodiversity, and managers or policy makers within the Department of Natural Conservation (Ministry of Agriculture and Rural Development) with responsibility for producing national response strategies for invasive plants.

Chromolaena odorata has invaded many secondary forests from North to South-east Vietnam, and was particularly evident in Cat Ba national park and Son Tra natural conservation area. This invasive species is easily dispersed and forms dense stands. It is not known when this species was introduced to Vietnam. It appears to be having a major impact similar to that described elsewhere [60] including preventing the establishment of native species. However, a detailed assessment of the impact of this species on biodiversity and ecosystem function has yet to be carried out in Vietnam. A case study such as that undertaken in South Africa [61] should be applied in Vietnam.

A range of initiatives should be implemented to better monitor and manage invasive weeds in forests and national parks in Vietnam. Firstly, field and reference guides on the 25 invasive plant species should be produced as soon as possible using existing publications [62,63] as a guide. This will encourage forest protection and national park staff to recognize and report on invading weeds. Secondly, to minimise the introduction of new invasive species, a coordinated framework should be developed across the range of authorities responsible for the forest estate. Early detection and rapid response plans can then be developed [64]. A key aspect will be to predict the future distribution and impact of the major invasive plant species [65]. In this first project, it was not possible to survey all the different topographies and vegetation types and detailed information on populations could not be obtained. The work needs to be extended using approaches defined by Rejmánek [23].

In the national action plan on biodiversity orientation towards 2020 [66], two main tasks were identified for the control and management of alien invasive species. These are: to investigate and collect data; and to adopt and carry out strategies to prevent and control alien invasive species. The initial results of the current project provide the beginning for this plan. Much more needs to be done as the threat from invasive species for biodiversity, the environment and human health is paramount. Therefore, a national invasive weed plan for their early detection and rapid response should be implemented as has been achieved in many countries [64,67].

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Conflict of Interest

We declare that this is our original piece of work and does not conflict with the interests of other individuals except where acknowledged. Contributions including professional advice and help from others are detailed in the acknowledgments.

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Appendix 1. List of alien plant species in 10 national parks in Vietnam.

Family	Scientific name	Region of origin	Family	Scientific name	Region of origin
Acanthaceae	<i>Ruellia tuberosa</i> L.	Central America	Asteraceae	<i>Sphaeranthus africanus</i> L.	Africa
	<i>Thunbergia grandiflora</i> (Rottl.) Roxb.	Northern India		<i>Sphaeranthus indicus</i> L.	India
Amaranthaceae	<i>Alternanthera paronichyoides</i> A. St.-Hil.	Central America		<i>Synedrella nodiflora</i> (L.) Gaertn.	Tropical America
	<i>Alternanthera sessilis</i> (L.) A. DC.	Southern Asia or Tropical America		<i>Tithonia diversifolia</i> (Hemsl.) A. Gray.	Eastern Mexico and Central America
	<i>Amaranthus spinosus</i> L.	Tropical America		<i>Tridax procumbens</i> L.	Tropical America
	<i>Celosia argentea</i> L.	Africa		<i>Xanthium inaequilaterum</i> DC.	South Eastern America, Western Mexico and West Indies
	<i>Gomphrena celosioides</i> Mart.	Tropical America	Bixaceae	<i>Bixa orellana</i> L.	Tropical America
Annonaceae	<i>Annona muricata</i> L.	Caribbean and Central America	Boraginaceae	<i>Heliotropium indicum</i> L.	Tropical America
	<i>Annona reticulata</i> L.	Tropical America	Campanulaceae	<i>Sphenoclea zeylanica</i> Gaertn.	Tropical Africa
Araceae	<i>Pistia stratiotes</i> L.	Unknown	Capparaceae	<i>Cleome rutidosperma</i> DC.	Tropical Africa
Asteraceae	<i>Ageratum conyzoides</i> L.	Central America		<i>Cleome spinosa</i> Jacq.	Tropical America
	<i>Bidens pilosa</i> L.	Central America	Casuarinaceae	<i>Casuarina cunninghamiana</i> Miq.	Australia
	<i>Centratherum punctatum</i> Cass.	Tropical America	Convolvulaceae	<i>Aniseia martinicensis</i> (Jacq.) Choisy	Tropical America
	<i>Chromolaena odorata</i> (L.) R. M. King & H. Rob.	Central America		<i>Cuscuta chinensis</i> Lamk.	China
	<i>Crassocephalum crepidioides</i> (Benth.) S. Moore	Tropical Africa		<i>Evolvulus nummularius</i> (L.) L.	North & South America

Appendix 1. Cont.

Family	Scientific name	Region of origin	Family	Scientific name	Region of origin
Asteraceae	<i>Elephantopus mollis</i> Kunth.	West Indies and Tropical America		<i>Ipomoea hederifolia</i> L.	Americas
	<i>Eupatorium adenophorum</i> Spreng.	Mexico		<i>Ipomoea quamoclit</i> L.	Tropical America
	<i>Eupatorium odoratum</i> L.	Central America		<i>Ipomoea triloba</i> L.	Tropical America
	<i>Galinsoga parviflora</i> Cav.	South America	Cyperaceae	<i>Cyperus rotundus</i> L.	Eurasia
	<i>Grangea maderaspatana</i> (L.) Poir.	Africa, Asia		<i>Cyperus</i>	Africa and Southern America
	<i>Mikania micrantha</i> Kunth.	Central and Southern America		<i>Fimbristylis miliacea</i> (L.) Vahl.	Tropical America
	<i>Parthenium hysterophorus</i> L.	Central America			
Euphorbiaceae	<i>Euphorbia heterophylla</i> L.	Southern US to Argentina and West Indies	Fabaceae	<i>Sesbania herbacea</i> (Mill.) MacVaugh	Central America
	<i>Euphorbia hirta</i> L.	Central America	Lamiaceae	<i>Hyptis brevipes</i> Poit.	Central America
	<i>Euphorbia tithymaloides</i> L.	Florida to northern South America		<i>Hyptis rhomboidea</i> Mart. & Gal.	Mexico
	<i>Ricinus communis</i> L.	Africa		<i>Hyptis suaveolens</i> (L.) Poit.	Tropical America
Fabaceae	<i>Acacia auriculiformis</i> A. Cunn. Ex Benth	Australia		<i>Leonotis nepetifolia</i> (L.) R. Br.	Tropical Africa
	<i>Acacia longiflora</i> (Andr.) Willd.	Australia		<i>Mentha arvensis</i> L.	Europe, Western Asia, India and Nepal
	<i>Acacia mangium</i> Willd.	Australia		<i>Mentha piperita</i> L.	Europe
	<i>Acacia saligna</i> (Labill.) Wendl	Australia	Liliaceae	<i>Asparagus plumosus</i> Bak.	Southern Africa
	<i>Aeschynomene americana</i> L.	Central and South America	Lythraceae	<i>Lagerstroemia indica</i> (L.) Pers.	China, Korea and Japan

Appendix 1. Cont.

Family	Scientific name	Region of origin	Family	Scientific name	Region of origin
Fabaceae			Malvaceae	<i>Hibiscus cananbinus</i> L.	Africa
	<i>Crotalaria micans</i> Link.	Tropical America		<i>Hibiscus sabdariffa</i> L.	Tropical Africa
	<i>Delonix regia</i> (Hook.) Raf.	Madagascar		<i>Sida acula</i> Burm. f.	Central America
	<i>Desmodium adscendens</i> (Sw.) DC	Tropical Africa and South America		<i>Sida rhombifolia</i> L.	New World tropics and subtropics
	<i>Glycyrrhiza glabra</i> L.	Europe - Mediterranean	Marsileaceae	<i>Marsilea quadrifolia</i> L.	Azores and Europe
	<i>Leucoena leucocephala</i> (Lam.) deWit	Tropical America	Melastomataceae	<i>Clidemia hirta</i> (L.) D. Don	Tropical America
	<i>Macroptilum atropurpureum</i> (DC.) Urb.	From Texas to Peru, Brazil and to Carribbean	Muntingiaceae	<i>Muntingia calabura</i> L.	Tropical America
	<i>Mimosa diplotricha</i> C. Wight ex Sau valle	Tropical America	Myrtaceae	<i>Eucalyptus camendulensis</i> Dehnh	Australia
	<i>Mimosa pigra</i> L.	Mexico, Central and South America		<i>Eucalyptus globulus</i> Labill	Australia
	<i>Mimosa pudica</i> L.	Central America		<i>Eucalyptus grandis</i> Hill. Ex Maiden	Australia
	<i>Pachyrhizus erosus</i> (L.) Urb.	Mexico		<i>Eucalyptus robusta</i> Sm.	Eastern Australia
	<i>Pithecellobium dulce</i> (Roxb.) Benth.	Mexico, Central and South America	Nyctaginaceae	<i>Boerhavia erecta</i> L.	Central and South America
	<i>Senna alata</i> (L.) Roxb.	Mexico	Numphaeaceae	<i>Victorica amazonica</i> (Poepp.) J.C. Sowerby	Tropical South America
	<i>Senna hirsuta</i> (L.) H.S. Irwin & Barneby	Tropical America	Onagraceae	<i>Ludwigia octovalis</i> Jacq.	Tropical America
	<i>Senna occidentalis</i> (L.) Link.	Tropical America	Oxalidaceae	<i>Oxalis corymbosa</i> DC	Central and Southern America

Appendix 1. Cont.

Family	Scientific name	Region of origin	Family	Scientific name	Region of origin
Papaveraceae	<i>Argemone meiciana</i> L.	Mexico and West Indies	Poaceae	<i>Melinis repens</i> (Willd.) Zizka	Africa
Passifloraceae	<i>Passiflora foetida</i> L.	Southern America		<i>Panicum repens</i> L.	Tropical and North Africa, Mediterranean
Pinaceae	<i>Pinus caribaea</i> Morelet	West Indies and Central America		<i>Paspalum conjugatum</i> P. J. Bergius	Tropical America
Piperaceae	<i>Peperomia pellucida</i> (L.) Kunth	Tropical America		<i>Pennisetum polystachion</i> (L.) Schult.	Tropical Africa to India
Plantaginaceae	<i>Scoparia dulcis</i> L.	Tropical America		<i>Pennisetum purpureum</i> Schumacher.	Tropical Africa
Poaceae	<i>Axonopus compressus</i> (Sw.) Beauv.	South America		<i>Phragmites australis</i> (Saltonstall, Peterson and Soreng)	Northern America
	<i>Brachiaria mutica</i> (Forsk.) Stapf.	Tropical Africa and America			
	<i>Cenchrus ciliaris</i> L.	India, Mediterranean, Tropical and Southern Africa	Polygalaceae	<i>Polygala paniculata</i> L.	From Mexico and West Indies to Brazil
	<i>Chloris barbata</i> Sw.	Central and South America	Pontedriaceae	<i>Eichhornia crassipes</i> (Maret.) Solms	Brazil
	<i>Cynodon dactylon</i> (L.) Pers	Southern Europe	Portulacaceae	<i>Portulaca pilosa</i> L.	Americas
	<i>Dactyloctenium aegyptiacum</i> (L.) Willd	Africa		<i>Portulaca oleracea</i> L.	Europe
	<i>Digitaria longiflora</i> (Retz.) Pers.	India	Rubiaceae	<i>Hedyotis corymbosa</i> (L.) Lamk.	Tropical Africa, Madagascar and India

Appendix 1. Cont.

Family	Scientific name	Region of origin	Family	Scientific name	Region of origin
Poaceae	<i>Echinochloa colona</i> (L.) Link	India		<i>Spermacoce exilis</i> (L.O. Williams) C. D. Adams	Africa and Malesia
	<i>Echinochloa crusgalli</i> (L.) P. Beauv	Subtropical and temperate areas	Salviniaceae	<i>Salvinia cucullata</i> Roxb.	India to SEA, not native in Vietnam
	<i>Eleusine indica</i> (L.) Gaertn	Africa	Sapindaceae	<i>Cardiospermum halicacabum</i> L.	North and Tropical America
	<i>Eriochloa polystachya</i> Kunth	Tropical America		<i>Sapindus saponaria</i> L.	Mexico and South America
	<i>Hymenachne amplexicaulis</i> (Rudge) Nees	Central and South America	Solanaceae	<i>Physalis angulata</i> L.	Tropical America
	<i>Leersia hexandra</i> Sw.	Tropical America		<i>Solanum americanum</i> Mill.	North and South America
			Verbenaceae	<i>Lantana camara</i> L.	Central America
	<i>Panicum maximum</i> Jacq.	Africa		<i>Stachytarpheta jamaicensis</i> (L.) Vahl	Caribbean