IUCN SSC Asian Elephant Specialist Group

Impact of Invasive Weeds on Asian Elephants and Their Habitats: A Comprehensive Overview and Guidance for Range Country Governance

2026

IUCN SSC Asian Elephant Specialist Group

Impact of Invasive Weeds on Asian Elephants and Their Habitats: A Comprehensive Overview and Guidance for Range Country Governance

Gaius Wilson*, T.N.C Vidya, Bibhuti Laskar, N Baskaran

*Corresponding Author: Gaius Wilson;

Email: gaiuswilsonin@gmail.com

Acknowledgements

We express our sincere gratitude to Sri Ramesh Kumar Pandey, Addl. Director General of Forests (WL), Ministry of Environment, Forests and Climate Change, Government of India, for generously providing key documents and reports on the management of invasive species in India. We also extend our thanks to Heidi Riddle and Belinda Stewart-Cox for their valuable comments to this document.

Citation: Gaius Wilson, T.N.C Vidya, Bibhuti Laskar, N Baskaran. 2026. Impact of Invasive Weeds on Asian Elephants and Their Habitats: A Comprehensive Overview and Guidance for Range Country Governance. *IUCN SSC Asian Elephant Specialist Group*

Photo credits: Gaius Wilson

CONTENTS

1. EXECUTIVE SUMMARY

Asian elephant habitats across their range are undergoing rapid ecological degradation driven by the spread of invasive plant species. These invasives—most prominently *Lantana camara*, *Chromolaena odorata*, *Mikania micrantha*, *Parthenium hysterophorus*, *Prosopis juliflora*, and several others—outcompete native vegetation, disrupt natural ecological processes, and diminish the availability of key forage essential for elephant survival. Their proliferation is closely linked to anthropogenic disturbance, land-use change, climate stress, and inadequate management responses, making invasive weed control an urgent conservation priority.

Invasive weeds alter habitat structure, degrade food resources, and obstruct elephant movement across landscapes. Dense thickets block access to water, mineral licks, and traditional migratory pathways, forcing elephants into human-dominated landscapes and escalating human–elephant conflict (HEC). Many invaders also intensify fire regimes, reduce soil quality, and alter water availability, creating feedback loops that undermine long-term ecosystem resilience. Studies across India demonstrate significant declines in grass biomass, grass quality, and native vegetation cover in areas dominated by *Lantana camara*, leading to altered elephant foraging behaviour and reduced habitat use.

The document highlights severe socio-economic implications for communities living near elephant habitats. As invasives degrade natural forage, elephants increasingly turn to crops, raising conflict, property damage, and risks to human safety. Invasive weeds themselves reduce pasture quality, inhibit access to forest resources, and raise management costs for forest departments and protected areas.

A series of case studies from Manas National Park show that integrated management including mapping, manual removal, community engagement, and sustained restoration can restore grassland ecosystems where invasives previously dominated. Manual uprooting of *Chromolaena* proved particularly effective, leading to improved native species recovery when applied consistently over several years. These success stories illustrate the importance of long-term investment, ecological restoration, and community participation in weed management.

To address these challenges systematically, the report outlines a set of comprehensive management strategies:

Early Detection and Rapid Response (EDRR): establishing monitoring systems, early warning networks, and rapid containment actions.
Prevention and control of introduction pathways: regulating soil and plant transport, nursery trade, machinery movement, and fire regimes.

Habitat restoration: re-establishing native grasses, shrubs, and tree species; reducing re-invasion through canopy recovery and soil conservation.

Integrated land-use planning: incorporating invasive species management into wildlife corridor plans, forest operations, and climate adaptation programs.

Community engagement: ecological education programs promoting awareness, supporting alternative livelihoods, involving local people in monitoring and restoration, and enabling invasive-biomass-based livelihood models.

Policy and governance alignment: strengthening national legislation, embedding invasive species control within protected area management plans, improving cross-sector coordination, and developing shared monitoring protocols across range countries.

Research and knowledge exchange: improving ecological understanding, advancing remote sensing and modelling tools, and enhancing data sharing through region-wide platforms.

The report further emphasizes the need for robust and sustainable funding mechanisms including government allocations, international aid, and private-sector partnerships to ensure consistent invasive species management. Long-term success depends on strong institutional capacity, training for conservation practitioners, and coordinated action across political borders.

Overall, the report calls upon Asian elephant range countries to adopt a unified, evidence-based strategy to prevent, control, and reverse invasive weed impacts. Sustained investment, science-driven management, and regional cooperation are essential to preserve elephant habitats, safeguard biodiversity, and reduce human–elephant conflict.

2. INTRODUCTION

2.1 IMPORTANCE OF ADDRESSING INVASIVE WEEDS IN ASIAN ELEPHANT HABITATS

Invasive weeds pose a significant and growing threat to Asian elephant habitats across their range. These plant species, often introduced through human activity or natural dispersal mechanisms, can rapidly outcompete native vegetation, altering the structure and function of ecosystems. For elephants, that depend on diverse and dynamic landscapes to meet their complex dietary and spatial needs, the spread of invasive weeds can have profound consequences for both individual health and population sustainability.

Elephants are megaherbivores with large home ranges and diverse foraging habits. They require access to a variety of plant species to meet their nutritional requirements across seasons. Invasive weeds often reduce the availability of these essential forage species by displacing native vegetation. Invasive species like *Lantana camara* and *Chromolaena odorata* are known for their allelopathic properties; they release chemical compounds that inhibit the germination and growth of other plants, leading to reduced dietary diversity and seasonal food shortages. This can result in increased nutritional stress, lower reproductive rates, and higher mortality risks, especially during periods of drought or other environmental stressors.

The impact of invasive weeds extends beyond forage availability. Changes in vegetation composition can alter habitat connectivity and the spatial movement patterns of elephants. Invasive species may create dense, impenetrable thickets that obstruct traditional migration routes, forcing elephants to modify their movement behavior. This can increase human-elephant conflict as elephants navigate closer to agricultural lands and human settlements in search of accessible food and water. Additionally, altered landscapes can impact other species that share these habitats, disrupting ecological relationships that elephants play a key role in maintaining.

Addressing invasive weeds in Asian elephant habitats is also crucial for the long-term resilience of these ecosystems. Elephants function as ecological engineers, shaping landscapes through their feeding and movement behaviors. By reducing the dominance of invasive species, we can help preserve the ecological processes elephants facilitate, such as seed dispersal and vegetation cycling, which maintain habitat heterogeneity and biodiversity. Without targeted intervention, the unchecked spread of invasive weeds may disrupt these processes, leading to the degradation of critical elephant habitats and the broader ecosystems they support.

Effective management of invasive weeds requires a multifaceted approach that integrates scientific research, local knowledge, and collaborative conservation efforts. Early detection and rapid response programs are essential to prevent the establishment of new invasive species, while habitat restoration initiatives can help rehabilitate areas already affected. Engaging with local communities and stakeholders is also vital, as sustainable management practices depend on fostering long-term stewardship and mitigating the socio-economic impacts of invasive species.

Given the ecological, social, and economic implications, addressing invasive weeds in elephant habitats is an urgent priority. Safeguarding these environments not only ensures the survival of Asian elephant populations but also protects the broader ecological integrity of the landscapes they inhabit. A coordinated, evidence-based approach is essential to mitigate the impacts of invasive species and sustain the ecological balance that elephants and other wildlife rely upon for their future.

2.2 BACKGROUND ON THE PREVIOUS AsESG INVASIVE PLANT DOCUMENT (2010)

Prasad and Williams (2010) summarized the responses to an online survey by IUCN SSC Asian Elephant Specialist Group (AsESG) members on the extent and distribution of invasive plant species in Asian elephant habitat. The respondents provided their views on sites in nine range countries: India (Nilgiris-Eastern Ghats complex, Terai Arc landscape, northeastern India), Sri Lanka, Nepal, Bangladesh, Myanmar, Thailand, China, Malaysia (Peninsular Malaysia), and Indonesia (Sumatra).

It was felt that invasive plants were beginning to dominate most Asian elephant habitats: each site that was covered reported the presence of at least one of the seven invasives that were asked about in the survey, and the majority of the sites reportedly had these seven invasives being Extensive or Very common (the other choices in the survey being Not present, Rare, Common). These species were *Lantana camara*, *Chromolaena odorata*, *Mikania micrantha*, *Prosopis juliflora*, *Parthenium hysterophorus*, *Ageratum conyzoides*, and *Eichhornia crassipes*, with *Lantana* being reported from almost all the sites. *Chromolaena odorata*, *Parthenium hysterophorus*, and *Ageratum conyzoides* were the other highly prevalent species, reported from about three-fourths of the sites. *Lantana*, *Chromolaena*, *Mikania*, and *Eichornnia* were the most dominant species in terms of being classified as "Extensive" or "Very common". Sites that did not have extensive cover of the above seven species reported other invasives.

A big concern was that these invasives could reduce food resource availability for Asian elephants and potentially also exacerbate human-elephant conflict. Another important concern was that since some invasives were being eaten by elephants in some sites, these invasives could be dispersed by elephants, thus worsening the problem. In order to address these concerns and conserve elephants, it was felt that quantitative assessments of invasive plants in Asian elephant habitats were urgently required.

2.3 OBJECTIVES OF THE AsESG WORKING GROUP: TO DEVELOP A COMPREHENSIVE UNDERSTANDING AND ACTION PLAN FOR CONTROLLING INVASIVE WEEDS IN ASIAN ELEPHANT RANGE COUNTRIES

The primary goal of this AsESG Working Group is to develop a comprehensive understanding and action plan for controlling invasive weeds across Asian elephant range countries. This document is intended to support conservation practitioners, protected area managers, policymakers, and partner organizations working in elephant range countries. To achieve this, we focus on several interlinked objectives:

1. **Data Collection and Analysis:**
   Gather and synthesize existing research and field data on invasive weed species that impact Asian elephant habitats. This includes understanding existing policy frameworks at the national and regional levels, mapping their distribution, assessing their growth dynamics, and identifying critical gaps in current knowledge.

2. **Ecosystem Impact Assessment:**
   Evaluate the ecological effects of invasive weeds on Asian elephant habitats. This involves studying how these species alter native vegetation, disrupt food resources, and affect the overall health of the ecosystems elephants depend on.

3. **Development of Integrated Control Strategies:**
   Formulate an actionable plan that combines scientific research, field management techniques, and adaptive strategies. We considered various control methods—from mechanical and chemical interventions to biological controls and habitat restoration—to mitigate the adverse effects of invasive weeds.

4. **Habitat Restoration and Recovery of Native Vegetation**: After invasive weeds are removed, what next? A section on restoration is crucial to ensure long-term habitat health for elephants. Invasive removal without restoration can lead to soil erosion or simply another weed invasion. This section discusses restoration best practices, such as replanting native grasses, trees, or bamboo that Asian elephants use, and soil conservation measures post-clearance. It should emphasize the need for site-specific plans.

5. **Stakeholder Engagement and Policy Integration:**
   Collaborate with conservation experts, local communities, and policymakers to ensure the action plan is both practical and sustainable. Aligning our strategies with regional conservation policies and local knowledge is key to fostering long-term stewardship and effective management.

6. **Capacity Building and Knowledge Sharing:**
   Promote the dissemination of findings and best practices through workshops, training sessions, and collaborative platforms. Empowering local stakeholders and wildlife managers with the necessary tools and insights will help ensure the successful implementation of the action plan.

7. **Awareness and Sensitization**:
   Raise awareness among stakeholders about the harmful impacts of invasive species on Asian elephant habitat and agricultural fields, and how they are linked to food security. It is observed that some stakeholders plant exotic plants for their beauty; however, they do not realize the adverse impact these plants have on wildlife habitat and agricultural fields.

Through these objectives, the working group aims to create a robust, evidence-based roadmap that not only controls invasive weed species but also strengthens the resilience of elephant habitats for future generations.

Photo plate 2: A female elephant and her calf feeding on the grass amongst the <u>Lantana</u> <u>camara</u> thickets in Mudumalai Tiger Reserve, South India.

3. UNDERSTANDING THE IMPACTS OF INVASIVE WEEDS ON ASIAN ELEPHANTS AND THEIR HABITATS

3.1 DRIVERS AND EMERGING EFFECTS OF INVASIVE WEEDS IN ELEPHANT HABITATS

Invasive weed species are a growing concern in Asian elephant range habitats, particularly in regions where land-use changes, climate shifts, and human activities have altered natural ecosystems. These weeds, often introduced intentionally for agricultural or ornamental purposes, or unintentionally through trade and human movement, spread aggressively and disrupt native plant communities.

Photo plate 3: Lantana camara in bloom. Introduced to India from South America in the 1800s as an ornamental plant, Lantana camara has since spread extensively, encroaching on Asian elephant habitats and posing a significant challenge to elephant conservation.

In many elephant habitats across Asia, invasive weeds such as *Lantana camara*, *Chromolaena odorata*, and *Parthenium hysterophorus* have become dominant. These species thrive in disturbed areas, including degraded forests, grasslands, and riparian zones, often outcompeting native vegetation. Their rapid spread is facilitated by their high seed production, efficient dispersal mechanisms, ability to produce toxins and resistance to local herbivory. Additionally, the proliferation of invasive weeds can affect local communities that share landscapes with elephants.

Invasive plants can reduce agricultural productivity, limit access to traditional grazing lands, and, in some cases, alter human-wildlife interactions by influencing elephant movement patterns, sometimes driving them closer to human settlements in search of food.

Cattle grazing can significantly influence the spread and establishment of invasive weeds through repeated disturbance to native vegetation and soils. Heavy or unmanaged grazing reduces the cover and abundance of native grasses and forbs, creating open niches that opportunistic invasive species readily exploit; this pattern has been documented in rangelands where livestock disturbance has facilitated dominance by invasive grasses such as cheatgrass and other non-native forbs at the expense of perennial natives (Molvar et. al. 2024). Soil disturbance and compaction from trampling can disrupt biological soil crusts and seedbeds of native plants, lowering ecological resistance to invasion and increasing bare ground — conditions that many invasive species exploit to gain a foothold. As habitats become degraded and dominated by unpalatable invasive plants, the quality and availability of forage for both wildlife and livestock decline, prompting cattle to move deeper into remaining natural areas in search of grazing. This deeper encroachment further disturbs previously intact vegetation, accelerates soil exposure, and facilitates the spread of invasive weed propagules into elephant habitats, creating a reinforcing cycle of degradation and invasion.

The spread of invasive weeds has profound ecological consequences for elephant habitats, impacting vegetation structure, biodiversity, and habitat functionality. Some of the most significant effects include:

3.2 FORAGE IMPACTS

These invasive plants alter the structural and compositional diversity of ecosystems, reducing the availability of native forage species essential for elephants. Many of these weeds are unpalatable or toxic, further restricting food options for elephants. As a result, elephants are forced to modify their foraging behaviors, travel greater distances in search of suitable food, or shift their dietary preferences, which may have cascading effects on their health and population dynamics.

3.3 HABITAT FRAGMENTATION AND ACCESSIBILITY ISSUES

Many invasive weeds form impenetrable thickets, restricting elephant movement within their home ranges. Species like *Prosopis juliflora* and *Mimosa pigra* create dense barriers in wetland and riparian habitats, making it difficult for elephants to access critical resources such as water sources and mineral licks. Such restrictions can force elephants to alter their migratory routes, increasing their vulnerability to human-wildlife conflicts and poaching risks.

Photo plate 4: Lantana camara forming thick impenetrable thickets in Mudumalai Tiger Reserve, South India.

3.4 CHANGES IN FIRE REGIMES AND ECOSYSTEM DYNAMICS

Some invasive weeds, such as *Chromolaena odorata*, contribute to altered fire regimes by increasing the frequency and intensity of wildfires. These species produce large amounts of dry biomass, which serves as fuel for fires that burn hotter and longer than natural grassland or forest fires. Such intense fires can lead to the destruction of native vegetation, soil degradation, and loss of essential habitat features like shade-providing trees, further reducing habitat suitability for elephants.

Photo plate 5: Forest fires spread rapidly due to invasive weeds such as Lantana camara - Mudumalai Tiger Reserve, South India.

3.5 IMPACT ON WATER SOURCES

Certain invasive species, such as *Typha* and *Salvinia*, aggressively colonize water bodies, leading to the depletion of water resources by increasing evapotranspiration and blocking access to drinking water. In arid and semi-arid elephant habitats, these changes can force elephants to travel longer distances to find water, increasing their energy expenditure and potential for conflict with humans.

Overall, the encroachment of invasive weeds in Asian elephant habitats poses a significant conservation challenge. Their ability to outcompete native species, alter ecosystem processes, and limit elephant movement threatens the long-term sustainability of these landscapes. Addressing this issue requires an integrated approach that combines habitat restoration, active management of invasive species, and collaboration with local communities to ensure both ecological balance and human-wildlife coexistence.

3.6 IMPACT OF INVASIVE WEEDS: CASE STUDIES

Case Study (1)

Impact on elephant behaviour

One comprehensive demonstration of the behavioural response of Asian elephants to invasive species was in the context of Lantana in Mudumalai Tiger Reserve, southern India (Wilson *et al*. 2014). This study was carried out from 2009-2010 and included observations of adults and subadults feeding on browse and grass, as well as characterisation of feeding sites. From feeding observations, feeding rates (trunkfuls/minute; Sivaganesan 1991, Baskaran 1998) and stepping rates (steps/minute; analogous to the number of fine-scale sites accessed per minute) were quantified. Feeding sites were characterised by measuring environmental variables, such as *Lantana camara* invasion (average stem girth), canopy cover, browse density, and percentage grass cover) in 10 x 1-m plots in 50-500 m transects. Elephants were not found to feed on *Lantana camara*. Using stepwise multiple regression Wilson *et al*. (2014) showed that feeding rate was negative associated with the *Lantana camara* invasion and stepping rates were negatively associated with grass cover and positively associated with browse density. Path analysis also showed an overall negative effect of *Lantana camara* on feeding rates, with indirect effects coming largely from the reduced grass cover due to *Lantana camara* presence.

Case study (2)

Impact on elephant habitat use

Wilson *et. al.* (2013) tested whether the addition of *L. camara* to a model consisting of measured environmental variables improved predictions of habitat use by elephant in Mudumalai Tiger Reserve, India. Elephant dung density was used to assess elephant habitat use from 62 line transects 1-km in length. Results indicated that habitat and impact of human settlements significantly influenced elephant habitat use at a landscape scale. However, there found no evidence for the hypothesis that the addition of *L. camara* significantly predicted elephant habitat use at the landscape level. They then tested the association of *L. camara* on elephant habitat use in the dry deciduous forest (DDF) where there was a significant interaction between DDF and *L. camara*. In the DDF, *L. camara* significantly predicted elephant habitat use. They concluded that while no significant effects of *L. camara* were seen at the level of an entire reserve, at a finer scale and in specific habitats negative effects of this invasive plant on elephant habitat use were observed.

Case Study (3)

Reduction in Forage Availability

Invasive weeds often replace native grasses, shrubs, and tree saplings that form the bulk of an Asian elephant's diet. For example, *Lantana camara* creates dense thickets that prevent the regeneration of native grass species, reducing the availability of nutritious forage. In support of this, a feeding ecology study on Asian elephants in Nilgiri Biosphere Reserve, Southern India conducted during 1991-1993 that assessed the grass dynamics to compare with the feeding ecology including grass and browse ration selection (Baskaran 1998 and Baskaran et al. 2010), recorded the effect of *Lantana camara* on the grass community by assessing the rate of *Lantana camera* domination (where it outweighed the native vegetation in terms of area cover), thereby influencing the grass dynamics factors viz. grass height, grass cover, grass green condition and grass biomass. The results of the assessment are as follows:

Effect of *Lantana camara* on native grass species in Nilgiri Biosphere, India.

Domination of *Lantana camara* on native grass species: During 1992, *Lantana* dominated over the native grass species in 7% of the 2268 – 1m² plots laid across the dry deciduous and dry thorn forests of Nilgiri Biosphere Reserve, with Dry Thorn Forest (DTF) experiencing a higher domination i.e. double (10% of the 1080 plots laid) that of Dry Deciduous Forest (DDF) (5% out of 1188 plots laid).

Effect of *Lantana camara* on grass height, cover and green condition: When *Lantana camera* dominated over the grass community in a given area, it retarded the growth, reduced the percent cover, percent green condition of the grass species in the area. For example, a mean grass height of 80cm was observed in areas / plots without *Lantana* domination (Fig. 01), whereas in nearby *Lantana* dominated areas / plots, an average growth of <50 cm was observed in the DDF of Nilgiri Biosphere. Similarly, the grass cover and green condition of the grass in *Lantana* dominated plots were significantly lower than those found in plots without *Lantana* domination (Fig. 01).

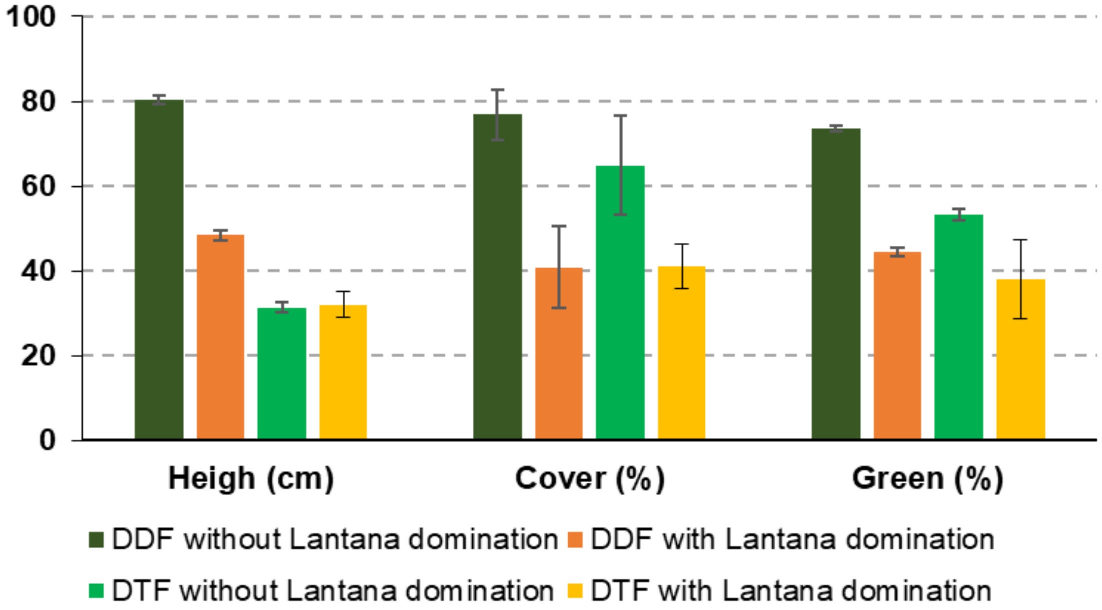

Figure 01: Grass parameters (mean ± SE) difference in plots (1m² n = 2268) with and without Lantana camera domination in the dry deciduous forests (DDF) and dry thorn forests (DTF) of Nilgiri Biosphere during 1992. Note: The difference in all grass parameters observed in plots with and without Lantana domination were statistically significant both in DDF and DTF except for grass height in DTF.

Effect of *Lantana camera* on grass biomass: *Lantana camera* domination has not only affected the growth, cover and green condition of the grass, but also the biomass. For example, grass biomass per m^2 in areas without *Lantana* domination was 750g in the dry deciduous tracts of Nilgiri Biosphere, whereas the grass biomass under *Lantana* dominated areas was $87g/m^2$, which is lesser by almost nine folds (Fig. 02). A similar suppression of *Lantana* on grass species was observed in DTF areas of the landscape (Fig. 02).

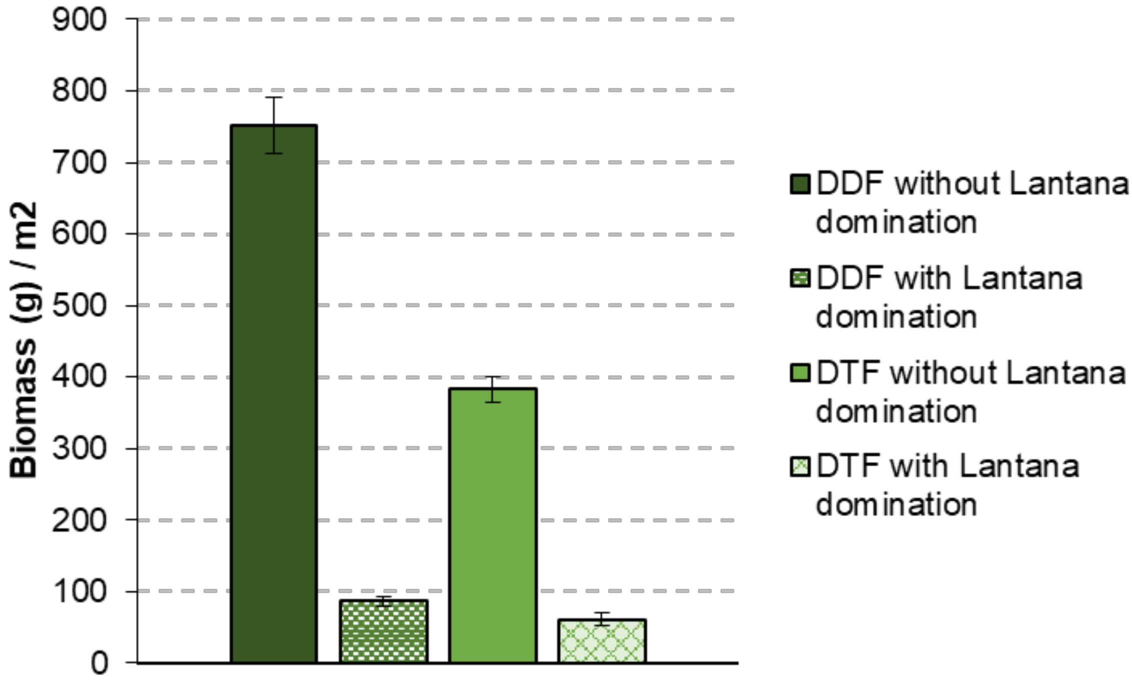

Figure 02: Grass biomass difference in plots (1m² n = 505) with and without Lantana camera domination in the dry deciduous forests (DDF) and dry thorn forests (DTF) of Nilgiri Biosphere during 1992. Note: The difference in grass biomass observed in plots with and without Lantana domination were statistically significant both in DDF and DTF except for grass height in DTF.

While the *Lantana camara* invasion has become more intense since 2010 in Nilgiri Biosphere, it is likely to have extended its domination much more at present compared to the recorded extent in 1992. These results clearly demonstrate that *Lantana camara* significantly reduced the quality and quantity of grass species, which form the principal diet of elephants in Nilgiri Biosphere Reserve (Baskaran 1998 and Baskaran et al. 2010). Due to such negative effects by alien invasion on native grass, elephants are expected to depend more on browse and that could affect the tree species community in the long-run.

Similarly, *Parthenium hysterophorus* is known to outcompete palatable vegetation in grasslands, leaving elephants with fewer food choices. Over time, this decline in native forage quality can lead to malnutrition, reduced reproductive success, and increased stress on elephant populations.

4. IMPORTANCE OF CONTROLLING THE SPREAD OF INVASIVE WEEDS

4.1 THREATS TO WILD ASIAN ELEPHANT ECOLOGY: DIRECT AND INDIRECT IMPACTS OF INVASIVE WEEDS

Invasive weeds pose both direct and indirect threats to wild Asian elephant ecology by altering habitat structure, forage availability, and movement pathways. Many invasive plant species displace native grasses, shrubs, and trees that elephants rely on for food, reducing dietary diversity and nutritional quality. Dense infestations can also form physical barriers that restrict access to water sources, seasonal feeding areas, and traditional movement corridors. Indirectly, invasive weeds can modify fire regimes, soil properties, and vegetation succession, leading to long-term habitat degradation and reduced ecosystem resilience within elephant ranges.

Photo plate 6: A bull elephant feeding on the grass and bamboo amongst a weed infested landscape in Mudumalai Tiger Reserve, Tamil Nadu, South India.

4.2 ECONOMIC AND SOCIAL COSTS: EFFECTS OF INVASIVE WEEDS ON HUMAN-ELEPHANT CONFLICT AND LIVELIHOODS

The spread of invasive weeds often exacerbates human–elephant conflict by degrading natural foraging habitats and pushing elephants toward agricultural lands and settlements in search of food and water. This increases crop damage, property loss, and risks to human safety, placing economic strain on rural communities and conservation authorities alike. Invasive weeds can also reduce pasture quality, limit access to forest resources, and increase management costs for landholders and protected area managers, thereby undermining local livelihoods and eroding community support for elephant conservation.

4.3 CONSERVATION IMPERATIVES: HOW CAN WE CONSERVE CRITICAL ASIAN ELEPHANT HABITAT AND BIODIVERSITY HOTSPOTS?

Controlling invasive weeds is essential for conserving critical Asian elephant habitats and the biodiversity hotspots they support. Elephant landscapes often overlap with regions of high ecological value, where invasive species threaten native plant communities, associated wildlife, and key ecological processes. Effective invasive weed management helps maintain habitat connectivity, supports natural regeneration, and preserves ecosystem functions such as nutrient cycling and seed dispersal. By prioritizing invasive species control, conservation efforts can enhance habitat quality for elephants while safeguarding broader biodiversity and ecosystem integrity.

Photo plate 7: Cut-and-burn removal of Lantana camara in Mudumalai Tiger Reserve. This method was attempted but found to be less effective, as complete eradication also requires removal of the root system.

5. BEST PRACTICES AND STRATEGIES FOR MANAGING INVASIVE WEEDS IN ASIAN ELEPHANT HABITATS

5.1 STRATEGIC FRAMEWORK FOR PREVENTION AND LONG-TERM MANAGEMENT

Given the ecological, social, and conservation impacts outlined above, effective management of invasive weeds in elephant habitats requires coordinated, evidence-based strategies that prioritize prevention, control, and long-term habitat resilience. Preventing and minimizing the spread of invasive weeds in Asian elephant habitats requires an integrated approach that combines ecological science, proactive monitoring, and landscape-level management. The goal is to address the invasion process at its earliest stages, preventing establishment, reducing pathways of introduction, and maintaining habitat resilience through sound land-use and restoration practices.

Prevention begins with vigilance (*Invasive Species Report* and the *Lantana CAMPA* framework). Early detection systems must be localized and continuous, incorporating both scientific monitoring and community observation.

5.2 EARLY DETECTION AND RAPID RESPONSE (EDRR)

A core lesson from numerous reports (for example, ICFRE, 2020; National Authority CAMPA, 2022) is that prevention begins with vigilance. Early detection systems must be localized and continuous, incorporating both scientific monitoring and community observation.

- Establish baseline inventories of invasive species presence using geospatial tools and standardized field surveys.
- Develop an early warning network involving forest departments, park managers, local communities, and researchers who can flag new invasions before they expand.
- Implement rapid response protocols to eradicate or contain small infestations using manual, mechanical, or chemical methods appropriate to local conditions. This "detect and act fast" approach reduces management costs and prevents large-scale ecological damage.

5.3 CONTROL OF INTRODUCTION PATHWAYS

Many invasions originate through human-mediated pathways such as transport of contaminated soil, livestock movement, nursery trade, or post-disturbance colonization. Preventing new introductions requires tightening controls along these vectors.

- Regulate the movement of soil, plant material, and machinery from infested to uninfested areas, particularly in road construction, mining, and agricultural operations near elephant ranges.
- Promote the use of certified clean seeds and planting materials in habitat restoration or afforestation programs.
- Establish quarantine measures for nurseries, plantations, and forest product depots to prevent accidental introduction of invasive weeds.
- Manage fire and disturbance regimes carefully, as frequent fires and canopy openings often facilitate the rapid colonization of invasives such as *Lantana camara*, *Mikania micrantha*, and *Chromolaena odorata.*

5.4 HABITAT MANAGEMENT AND RESTORATION FOR RESILIENCE

Healthy, diverse ecosystems are naturally more resistant to invasion. Maintaining habitat integrity is therefore a long-term prevention strategy.

- Promote native vegetation cover through enrichment planting and assisted regeneration, especially in disturbed or degraded patches.
- Restore canopy cover in forest edges and riparian corridors to reduce light availability for shade-intolerant invaders.
- Encourage mixed-species planting schemes that mimic natural vegetation structure and reduce open ground exposure.
- Apply ecological restoration techniques such as reintroducing native grasses, bamboo, or shrubs that can suppress invasive regrowth. Evidence from various projects shows that integrating restoration immediately after mechanical weed removal is critical for preventing reinvasion.
- Sustained commitment from both the implementing agencies and funding organizations is essential.
- Support from Government agencies is essential, with the allocation of funds and personnel.

5.5 LAND-USE PLANNING AND INTEGRATED MANAGEMENT

In Asian elephant landscapes, land-use decisions often shape invasion dynamics. Preventing spread requires coordinated planning across jurisdictional and administrative boundaries.

- Integrate invasive species considerations into land-use plans, forest management plans, and wildlife corridor strategies.
- Establish buffer zones between agricultural lands and protected areas, using controlled vegetation or fencing to limit dispersal of weed seeds.
- Promote sustainable grazing and agriculture practices, as overgrazing, monoculture plantations, and soil disturbance often create opportunities for weed establishment.

- Incorporate invasive species management into climate adaptation and reforestation programs to ensure new projects do not inadvertently promote invasive spread.

5.6 COMMUNITY ENGAGEMENT AND AWARENESS

Sustainable prevention hinges on community involvement. Local communities are often the first to notice changes in vegetation patterns and can play a pivotal role in early detection and control.

- Develop education programs and outreach campaigns that help communities identify priority invasive species and understand their ecological impacts.
- Develop school-based education and youth engagement by integrating invasive species awareness into environmental curricula, establishing eco-clubs, and encouraging student-led monitoring projects in buffer zones.
- Encourage community-based monitoring groups, particularly in buffer zones and multi-use landscapes where human-elephant interactions are high.
- Provide incentives for prevention and early control, such as payment for ecosystem services, livelihood support through invasive biomass utilization (as in CAMPA's Lantana-based industries), or inclusion in eco-restoration employment schemes.
- Restoration efforts must continue beyond the initial planting phase, particularly in forested areas.

5.7 POLICY, GOVERNANCE, AND INSTITUTIONAL COORDINATION

A strong regulatory and institutional framework underpins prevention. The *Invasive Species Report* (Sandilyan 2019) emphasizes the need for cohesive governance across agencies and range countries.

- Develop national and regional biosecurity frameworks that regulate the import, movement, and management of invasive species.
- Encourage cross-sectoral coordination between forestry, agriculture, environment, and infrastructure departments at both Ministerial and Departmental levels as well as relevant National Development and Planning Offices which, in many countries operate separately.
- Promote data sharing and joint monitoring platforms across elephant range countries to identify and manage transboundary invasions.
- Incorporate invasive weed prevention into elephant conservation policies and national biodiversity action plans, ensuring alignment with the goals of the IUCN SSC AsESG and Convention on Biological Diversity (CBD) targets.
- Consultation with stakeholders and permission from the Government on time is important.

5.8 RESEARCH AND KNOWLEDGE EXCHANGE

Prevention strategies must evolve with new knowledge and technology.

- Encourage research on ecological thresholds, soil seed banks, and invasion dynamics in different Asian elephant habitats (forest, savannah, riparian).
- Support innovation in remote sensing, machine learning, and UAV-based mapping to enhance real-time monitoring.
- Facilitate exchange of best practices among Asian elephant range countries and conservation agencies through workshops, online platforms, and collaborative field trials.
- Promote the inclusion of invasive alien species awareness across environmental higher-education programs such as Agriculture, Conservation Biology, Ecology, and Forestry to ensure that future practitioners recognize the severity of invasive species threats. Integrating this topic into BSc and MSc curricula can motivate more students to pursue research on invasion biology and strengthen the long-term scientific capacity needed to address invasive species in Asian elephant habitats.

5.9 MANAGEMENT CASE STUDIES

Case study (1)

Partnership for restoring grasslands affected by *Chromolaena odorata*

Manas National Park in Assam, north-east India is one of the largest grasslands protected areas in India. The Manas landscape underwent civil unrest during 1989–2003, interrupting the grassland management system previously in place. This absence of grassland management resulted in significant habitat degradation, potentially affecting several grassland-dependent species, including elephants.

To address this critical issue, the National Park management and NGOs began working together in 2017, and a partnership to conserve the critical grassland habitats of Manas National Park was formally launched in November 2021. The conservation partners are jointly carrying out interventions using a common framework that includes mapping of invasive alien plants, especially *Chromolaena odorata* (native to the Americas), removal of invasive plant species, engaging the local community in restoration, knowledge dissemination and sharing of restoration experience with conservationists working in the Sub-Himalayan grasslands of Nepal and Bhutan.

As part of this partnership, the National Park authority has adopted a Grassland Management Action Plan. The Plan was finalized in November 2021 and all the major action points have been incorporated in the National Park's working plans, including the Tiger Conservation Plan. Thus, the broader grassland habitat restoration initiatives, which were initially started by conservation partners, have now been embedded by the Forest Department in their management process. This is a unique collaborative approach for the conservation of tall grassland and the model could be adopted for other protected areas in which habitat restoration is needed (Das, 2022).

The following activities should be done as part of engaging the community and participatory management:

- Sensitize local communities about the impact of invasive alien plants (IAP) on elephant habitat and how it can lead to an increase in human-elephant conflicts (HEC) and affect people's well-being.
- Communities living near elephant habitats often send their livestock into forest and grassland areas. However, livestock grazing is a significant factor in the spread of invasive species. To address this issue, we should incentivize alternative livelihood activities that reduce livestock grazing. Additionally, promoting the adoption of high-yielding livestock can help lessen the pressure on these natural habitats.
- Communities residing alongside elephant habitats thrive on non-timber forest products (NTFP) and often encounter elephants while gathering NTFP. However, unsustainable extraction can contribute to the spread of invasive alien plants. By empowering these communities with conservation-focused livelihood initiatives, we can help them forge a brighter future and lessen their reliance on elephant habitats.
- Local community members can also be trained in monitoring techniques so that they came become trainers and ambassadors within their community. If local people are only engaged in menial work rather than in research work, they are less likely to feel engaged in the way needed.
- Many successful livelihood business models in elephant range countries to utilize invasive alien plants (IAP) and to create products such as *Lantana* elephant, handmade paper from water hyacinth, and natural dye from *Chromolaena odorata*. These and other initiatives can be promoted among local communities in sustainable ways.

Case study (2)

Grassland restoration in Manas National Park, India

Grassland habitats in Manas National Park are crucial for the survival of many threatened and faunal species, including elephants. Manas NP is severely affected by invasive species, particularly *Mikania micrantha* and *Chromolaena odorata*. These plants threaten natural habitats by outcompeting native flora. The grasslands face significant risks from uncontrolled burning, invasive species, and livestock grazing, with over 30% of the area impacted by *C. odorata* and *M. micrantha*.

Aaranyak, in collaboration with the Assam Forest Department, began a grassland restoration project in 2013 to understand the distribution of Invasive Alien Plants (IAPs) and the efficacy of different management methods for controlling them. Aaranyak investigated the distribution pattern of *Chromolaena odorata* and *Mikania micrantha* and factors governing their spread in the grassland of Manas

The National Park carried out extensive field sampling and modeled the distribution of invasives using a suite of algorithms. Model predictions differed with respect to Area Under the Curve (AUC), sensitivity, specificity and True Skill Statistic (TSS) range, largely in classification performance. Final risk maps were produced averaging the model outputs of Random Forest and MaxEnt for both the species. Subsequently, we also emphasized that the niche/Species Distribution Modelling (SDM) studies should instigate by testing a suite of algorithms for predictive ability under the specific conditions of the study since no single optimization approach would be best under all circumstances. Proximity to the road and human settlement, elevation, fire occurrence and precipitation of driest quarter were the key predictors for both the invasive.

The potential area invaded by *C. odorata* was 74.87 sq. km and *M. micarantha* 81.82 sq. km, and a high degree of overlap found between the distributions of both the species. Invasion risk maps can be used as an early detection tool for the management of invasive species, which could help in minimizing the ecological significance and economic cost of invasions (Nath et al 2019).

From 2014 to 2016, three different treatments: manual removal of IAPs, cutting, and cutting & burning of IAPs in three different 1-ha plots were experimented with for three consecutive years. This successfully demonstrated that manually uprooting the IAPs is an ecologically-effective strategy to restore grassland habitat. Management methods to control invasion and promote grassland recovery is poorly studied, particularly of *C. odorata*. Based on experiment it was found that the species richness, density and cover of native grasses increased significantly by the third year (t2) in the manually uprooted treatment site compared to other two treatments; while the density and cover of *C. odorata* decreased. The data highlights the efficacy of the manual uprooting treatment in reviving the grassland habitat. It is an ecologically-effective strategy as it can restore the entire native grass-community if maintained and monitored for at least three to five years. However, there is need to caution that manually uprooting the *C. odorata* and reviving natural grass-communities requires long-term investment of resources and time (Sinha *et. al.* 2022).

After the successful demonstration of grassland restoration, a "Habitat Management Workshop" was organized jointly with the Field Director, Manas Tiger Reserve, WWF-India, Aaranyak, WTI, Durrell Wildlife Conservation Trust on 2-3 November 2017 for sharing the study outcome. Protected Area (PA) managers from Nepal and Bhutan also attended. To follow up on the workshop, a core committee was formed and developed a partnership to restore the grassland. Each organisation was assigned to continue the restoration work at different grassland habitats that were heavily invaded (Das, 2022).

With this tried-and-tested management method, conservation partners have been working together to reduce invasions by approximately 95% in the selected prime grassland habitat, covering approximately 5 km^2, in the central and eastern ranges of the Park in subsequent years.

5.10 ESTABLISHING MONITORING AND EVALUATION FRAMEWORKS

Development of baseline data: mapping invasive weed distribution and assessing impact on Asian elephant habitats

Baseline data of at least three kinds are required: 1) the identification of species as being an invasive or potentially invasive species, 2) the presence and abundance of invasive species across time, and 3) the impact of invasive species on Asian elephants and other species that can affect habitat characteristics and ecosystem functioning.

Currently, problematic plant and pest risk assessment protocols, such as the Environmental Protection Agency (EPA) and Intergovernmental Panel on Climate Change (IPCC) standards, Alien Plant Ranking System (which uses life-history traits, ecology, and management feasibility of control; Hiebert and Stubbendieck 1993), NatureServ’s I-ranks system (which uses biogeographical information; Morse et al. 2004), Massachusetts Invasive Plant Advisory Group (MIPAG) criteria, etc., are already available to categorise species’ intrinsic likelihood of invasion. For instance, the Massachusetts Invasive Plant Advisory Group (MIPAG) uses the following criteria to identify invasives:

1. being nonindigenous,
2. having biological potential for rapid and widespread dispersal and establishment in minimally managed habitats,
3. having biological potential for dispersing over spatial gaps away from the site of introduction,
4. having biological potential for existing in high numbers away from managed artificial habitats,
5. be naturalized,
6. be widespread or at least common in a region or habitat type,
7. have high occurrences of numerous individuals, forming dense stands in minimal managed habitats,
8. be able to out-compete other species in the natural community, and
9. have the potential for rapid growth, high seed or propagule production and dissemination, and establishment in natural plant communities.

Likely invasive species meet only the first five criteria. Species can be placed in ordinal categories based on their invasion risk. However, the community needs to decide which, if any, of the existing standards should be adopted or whether new protocols should be used to categorise species along the scale of invasiveness.

One of the problems with identifying invasive species is that they are often difficult to identify as being invasive until the invasion has occurred. Understanding and identifying functional traits correlating with invasion (biological potential for rapid dispersal and other traits) are useful in this context. The definition of invasive species needs to be consistent. Richardson *et al*. (2000) proposed distance criteria that introduced plants should produce reproductive offspring in areas away from where they were introduced and those invasive species that change the character or nature of ecosystems over large areas could be termed 'transformers'. It would be useful to look for such changes caused by invasive species so that transformers can be identified early in ecosystems in order to accord some priority of management/removal of such species. Thus both 1) and 3) require studies to understand the functioning of invasive species in the ecosystem and long-term monitoring plots where experiments can be carried out.

Prevention of introduction and spread of alien species is the best way to deal with invasives, failing which, eradication via early detection and rapid response is important as it becomes increasingly difficult to control invasive species at each successive stage of invasion (McNeely 2001). Therefore, effective surveillance is required to detect potential invasives and the spread of existing invasives. At the time of Prasad and Williams' (2010) report, there had been no systematic studies of invasive species in protected areas in Asian elephant habitat or studies quantifying the threats posed by invasive species to elephants as well as other native fauna and flora. However, in the time since, there have been multiple studies focusing on these aspects.

Some baseline data on invasive plant species presence are currently available from many range countries. A survey of ten national parks (including Cat Tien, where elephants are found) across Vietnam found 134 weeds, of which 25 were classified as invasive species (Tan et al. 2012, *Forests*).

An issue to consider is that the baseline data are heterogeneous in the sense of them being collected in different ways. For example, transects were set up along roads, trails, tracks, and ditch sides in Vietnam (Tan et al. 2012). In Nagarahole, southern India, cover of invasive species was estimated in 5-m x 5-m plots along randomly placed transects in part of the national park (Thanikodi et al. 2024).

Tan *et al*. (2012) used the methodology proposed by the National Parks Service, USA (Youang *et. al*. 2007). This monitoring protocol has been updated by Kull et al. (2022), which recommended the following: a) creating watchlists of problematic species and potential problematic species in the areas of interest and updating them, b) carrying out early detection monitoring for all the problematic species on the watchlists, c) sampling at least 0.75%-40% of the reference frames (area to be monitored; for parks with reference frames smaller than 142 ha, use three equidistant passes through polygons ~0.8 ha in size, and for larger parks, use 200-m or 400-m line transects) in each park for problematic species, d) estimating their abundance (with a ranking based on the cover of the species) and frequency in each park, and e) identifying temporal changes in distribution and abundance (by revisiting every four years).

The timing of sampling needs to be consistent in order to get valid changes in distribution, if any. Depending on the species, detection may or may not vary based on season. The level of change that can be detected will depend on the extent of spread of the invasive (changes in species with low abundance will be difficult to detect), the intensiveness of sampling, detection probability, and errors associated with sampling. These need to be taken into consideration in order to make inferences about change.

It is desirable to develop statistically rigorous methods to obtain the extents of invasive species distributions (see Elzinga et al. 2001). This can be combined with landscape modelling to extrapolate the likelihood of occurrence or spread of invasives (for example, Campbell et al. 2002, Rew et al. 2005, Barnett et al. 2007). Remote sensing can also be used in some cases (for example, Lass et al. 1996, Lawrence et al. 2006).

It would be useful to have online databases, populated with the available information from published literature and government and other reports on the extent and density of invasive species. This could have information at different spatial scales, eventually combined into maps of risk. Attention needs to be given to data handling, creation of metadata (such as that meeting ISO standards), database design (for abundance/ecological and spatial data), data entry, verification, and validation.

Studies of the impact of invasive species on Asian elephant habitat and ecosystem functioning are much required. While mapping the presence of invasives is done more commonly, understanding the impact on function often requires experimental manipulation. However, under natural conditions, the density of elephants in areas with different extents of invasive species cover may be used to infer negative effects of invasive species. Wilson et al. (2013) showed negative effects of *Lantana camara* on the use of dry deciduous forest (but not the entire reserve that included other habitat types) of Mudumalai Tiger Reserve, India, by elephants.

As mentioned above, Wilson *et al*. (2014) clearly showed that feeding rate of elephants was negative associated with the *Lantana camara* invasion and stepping rates were negatively associated with grass cover and positively associated with browse density. Thanikodi et al. (2024) showed within Nagarahole Tiger Reserve, southern India, that there was a negative correlation between the prevalence of *Lantana* and the use of the area by elephants. Both studies used dung as a proxy for elephant habitat use. Thanikodi et al. (2024) also found an increase in the prevalence of *Lantana* over a decade by quantifying cover.

Changes in the prevalence of invasives, which could potentially lead to differences in habitat use, have also been estimated more qualitatively in other cases (Vidya et al. 2024). At the landscape level, Baskaran et al. (2024) found decreasing crop damage due to HEC when grass biomass in the area was higher and anthropogenic activity was lower. Since anthropogenic activity also increases the spread of invasive species (Baskaran et al. 2012), it may indirectly affect grass biomass and thereby affect elephant foraging.

Action points:

- Set up a committee to decide on systems/standards to use for ranking invasive species and methodology and spatial and temporal scales (for instance, grid size, sampling frequency, replication, consistency in timing of sampling) of sampling that can be as similar as possible across countries and regions.
- Field guides of invasive species should be prepared so that forest staff who patrol routinely can identify and quantify.
- Vegetation plots be set up on a large scale to obtain wide coverage of the presence of invasive species in Asian elephant habitats. This is already being done in some countries like India, wherein the National Tiger Conservation Authority (NTCA) collects information on invasive species, although only in Tiger Reserves.
- Dedicated trained statisticians are required to deal with data. Often large amounts of data are available but the concerned authorities and/or ecologists do not have the capacity to analyse adequately or correctly. There could also be complex relationships and confounding variables that make effects difficult to tease apart. These are often not simple problems that can be solved by short-term capacity building exercises.

6. RECOMMENDATIONS FOR ASIAN ELEPHANT RANGE COUNTRY GOVERNMENTS

6.1. POLICY FRAMEWORKS, COORDINATION AND TRANSBOUNDARY COOPERATION FOR INVASIVE SPECIES MANAGEMENT

Effective management of invasive weeds in elephant habitats must be supported by strong policy and governance frameworks. Across Asian elephant range countries, protected area legislation and wildlife management laws typically mandate the maintenance of ecological integrity and explicitly empower management authorities to address threats to wildlife habitats, including invasive alien plant species. It is imperative that current policies and legislation be strengthened to empower enforcement agencies to implement them effectively. Furthermore, it is essential to meticulously monitor all potential pathways by which invasive alien species (IAS) may enter elephant habitats, thereby facilitating early detection and prevention efforts.

Many commercial ventures, such as tea gardens and agricultural activities near elephant habitats, utilize certain plants for nitrogen fixation, which can also be invasive alien species (IAS). These IAS have started invading elephant habitats due to floods and wind. For example, *Mimosa diplotricha C. Wright*, also known as *Mimosa invisa*, was used by a tea garden near Kaziranga National Park, India, in the mid-nineties. Since then, it has spread across the park, and management efforts have been on-going. Additionally, the plant has entered Orang National Park, located downstream, through floodwaters. Therefore, there should be legislation to control the use of such invasive species.

- **Planting wrong/non-native species**- It has been noted that following the removal of invasive alien species (IAS) in certain elephant habitats, management practices sometimes involve the planting of inappropriate species. Specifically, this includes the introduction of livestock fodder grass species, such as *Cumbu Napier grass* (CO-4/CO-5), or the establishment of plantation trees in grassland areas. It is imperative to adhere to the principles of ecological restoration when selecting plant species to ensure effective habitat recovery and biodiversity conservation.
- **Setting a quick fix by managers**- It has been observed that practitioners often use techniques such as harrowing in Asian elephant habitat, especially in grassland, to remove IAS on a large scale, or cut trees to stop woody invasion from grassland. The harrowing facilitates and exposes the seeds of IAS (*Chromolaena odorata, Lantana*), which then grow more vigorously. Further, if someone cuts above the growth of the species *Bombax ceiba* to stop woody invasion in the grassland, the next year, coppice appears.

In many jurisdictions, invasive alien species are defined as non-native species whose introduction or spread may threaten wildlife or its habitat. Within this context, regulating the introduction, trade, and movement of invasive species is recognized as the most effective preventive measure. Where prevention fails, early detection, monitoring, and rapid eradication are emphasized as critical tools for limiting ecological damage and long-term management costs.

Protected area management planning frameworks increasingly include dedicated provisions for invasive species management. These provisions require that invasive plant control and eradication be explicitly addressed within approved management plans, supported by clear prescriptions for monitoring, control methods, and post-removal restoration. Management authorities are also empowered to undertake habitat improvement measures where invasive species have degraded ecosystem function or wildlife use.

These policy frameworks provide important precedents for Asian elephant range countries, demonstrating how invasive weed management can be institutionalized within existing conservation mandates rather than treated as an ad hoc activity. Embedding invasive species prevention and control within legally mandated planning and management processes strengthens accountability, facilitates coordinated action across agencies, and ensures that invasive weed management is aligned with broader elephant conservation and biodiversity objectives.

6.2 CAPACITY BUILDING AND TRAINING FOR CONSERVATION PRACTITIONERS

The successful implementation of these management strategies depends on the skills, resources, and institutional capacity of conservation practitioners working in elephant landscapes. Effective management of invasive weeds in Asian elephant habitats depends not only on sound policies and technical guidance, but also on the capacity of conservation practitioners to implement these measures consistently and at scale. Across Asian elephant range countries, practitioners often operate in complex, resource-limited environments where invasive species management competes with multiple conservation priorities. Targeted capacity building and training are therefore essential to translate strategies into sustained on-the-ground action.

Beyond in-service training, it is essential to strengthen the education pipeline by institutionalizing invasive species management within university curricula. Universities offering botany, conservation biology, forest biology, protected area management, ecology, and environmental science should introduce a core module on invasive species ecology and management at both undergraduate and graduate levels. This module should integrate theory and applied field skills—covering invasion pathways, risk assessment, prioritization tools, early detection and rapid response, seasonal and habitat-specific identification, safe mechanical and chemical control techniques, restoration ecology, and ecological monitoring using

GPS-enabled tools. **Embedding a mandatory invasive-species module into relevant university programs will ensure that new recruits entering conservation departments already possess essential competencies in invasive species prevention, detection, control, and habitat restoration.** Such upstream investments reduce induction time, improve consistency in field practice, and enhance the long-term scalability of invasive weed management within elephant landscapes.

Capacity building efforts should focus on strengthening both **technical skills** and **institutional understanding**. Practitioners require practical training in invasive species identification, including the ability to distinguish priority invasive weeds from native or non-invasive species across different habitat types and seasons. This is particularly important in elephant landscapes, where early-stage invasions may occur in remote forest interiors, riparian corridors, grasslands, and human–wildlife interface zones.

Training programs should also emphasize **early detection and rapid response (EDRR)** protocols. Conservation staff, forest guards, and field technicians need clear guidance on how to document new infestations, assess invasion risk, and initiate timely control actions before invasive weeds become established. Standardized monitoring methods—such as plot-based surveys, transects, and the use of GPS-enabled data collection tools—should be incorporated to support consistent reporting and data sharing across sites and institutions.

In addition to detection and monitoring, practitioners require hands-on training in **control and restoration techniques**. This includes instruction in safe and effective mechanical removal methods (such as cut root-stock techniques), appropriate use of chemical controls where permitted, and post-removal restoration practices using native grasses, shrubs, bamboo, or tree species relevant to local Asian elephant habitats. Emphasis should be placed on adaptive management, enabling practitioners to adjust control strategies based on site conditions, regrowth patterns, and observed ecological responses.

Capacity building should extend beyond field-level skills to include **planning, coordination, and governance awareness**. Training modules can help practitioners understand how invasive weed management fits within protected area management plans, wildlife legislation, and landscape-scale conservation strategies. Strengthening this institutional awareness ensures that invasive species management is embedded within routine management activities rather than treated as a short-term or external intervention.

Peer learning and knowledge exchange are also critical components of effective capacity building. Workshops, cross-site exchanges, and practitioner networks can facilitate the sharing of lessons learned, innovations, and locally adapted solutions across elephant range countries. Drawing on successful models from large-scale initiatives, such as national invasive species programs and protected area management frameworks, can accelerate learning and reduce duplication of effort.

Finally, capacity building initiatives should recognize the role of **local communities and frontline staff** who interact daily with Asian elephant habitats. Training programs that include community members, eco-development committees, and local restoration crews can enhance early detection, improve compliance with prevention measures, and foster long-term stewardship of restored habitats. Where appropriate, linking training to livelihood opportunities—such as restoration employment or invasive biomass utilization—can further strengthen sustained engagement.

By investing in comprehensive, practical, and context-specific capacity building, this AsESG Working Group aims to support conservation practitioners who are equipped to prevent, detect, and manage invasive weeds effectively. Strengthened capacity at individual, institutional, and network levels will be essential for ensuring that invasive species management contributes meaningfully to the long-term resilience of elephant habitats across range countries.

6.3 FUNDING MECHANISMS TO SUPPORT INVASIVE SPECIES CONTROL PROGRAMS

Effective control of invasive weeds in Asian elephant habitats requires sustained, predictable funding that matches the long-term nature of invasion management. Because invasive species control typically involves repeated interventions—prevention, early detection, removal, restoration, and monitoring—funding mechanisms must extend beyond short-term project cycles and support continuity over multiple years.

A foundational mechanism is the **integration of invasive species management into core conservation and protected area budgets**. Embedding invasive weed control within routine operational funding ensures that these activities are treated as essential habitat management functions rather than discretionary or externally funded add-ons. This approach supports staffing stability, consistent monitoring, and adaptive management, all of which are critical for success.

Government-led conservation, restoration, and climate adaptation programs represent an important funding pathway. Invasive species management directly contributes to biodiversity conservation, ecosystem resilience, fire risk reduction, and climate adaptation objectives. Aligning invasive weed control with national biodiversity strategies, forest restoration initiatives, and wildlife recovery programs can unlock existing funding streams while reinforcing policy coherence.

International donor and multilateral funding mechanisms play a complementary role, particularly in elephant range countries with limited domestic resources. These funds can support capacity building, pilot interventions, cross-border collaboration, and the development of standardized tools and best-practice guidelines. Strategic use of donor funding is especially valuable for demonstrating scalable models that can later be absorbed into national budgets.

In some contexts, **livelihood-linked financing mechanisms** may help offset management costs. Carefully regulated utilization of invasive biomass—for example through restoration employment, bioenergy, or small-scale local enterprises—can provide economic incentives for sustained control while supporting community engagement. Such approaches must be designed with clear ecological safeguards to avoid creating incentives for maintaining invasive species.

Emerging **payment for ecosystem services (PES)** and nature-based solutions financing also offer opportunities to support invasive weed management. By recognizing the role of invasive species control in improving habitat quality, water regulation, carbon storage, and biodiversity outcomes, these mechanisms can help channel funding toward preventative and restorative actions in key Asian elephant landscapes.

Overall, diversified and well-aligned funding mechanisms are essential to ensure that invasive species control programs are financially viable, scalable, and resilient. Stable funding enables conservation practitioners to move from reactive, short-term responses to proactive and sustained management of invasive weeds in Asian elephant habitats.

6.4 INTERNATIONAL COLLABORATION AND KNOWLEDGE-SHARING PLATFORMS

Invasive weed management in Asian elephant habitats is inherently a transboundary challenge, as elephant ranges span political borders and invasive species spread through shared ecological and human-mediated pathways. International collaboration is therefore essential to ensure that management approaches are coordinated, evidence-based, and scalable across regions.

Collaboration among Asian elephant range countries enables the sharing of technical expertise, management experiences, and lessons learned from both successful and unsuccessful interventions. Knowledge-sharing platforms can support the exchange of standardized methodologies for invasive species mapping, monitoring, early detection, control, and restoration, reducing duplication of effort and improving consistency across landscapes. Such platforms are particularly valuable for disseminating practical field-based techniques, adaptive management approaches, and monitoring protocols suited to different ecological contexts.

Regional and global networks—such as species specialist groups, conservation consortia, and research partnerships—provide important mechanisms for sustained collaboration. These networks facilitate joint workshops, technical working groups, and cross-site learning exchanges, allowing practitioners to learn directly from comparable elephant landscapes. Digital platforms, including shared databases, online training modules, and collaborative mapping tools, further enhance accessibility and long-term knowledge retention.

International collaboration also supports **transboundary landscape management**, where coordinated invasive species control can improve habitat connectivity and reduce reinvasion risks along borders. Aligning management priorities, monitoring indicators, and reporting frameworks across countries strengthens collective responses and contributes to regional conservation goals. Through structured collaboration and open knowledge exchange, invasive weed management efforts can be accelerated and continuously improved across elephant range states.

6.5 IDENTIFICATION OF FUNDING SOURCES: GOVERNMENT GRANTS, INTERNATIONAL AID, AND PRIVATE SECTOR PARTNERSHIPS

Identifying and mobilizing diverse funding sources is critical to sustaining invasive species control programs in Asian elephant habitats. A mixed funding portfolio reduces reliance on any single source and increases resilience to shifting political or economic conditions.

Government grants remain a primary funding source for invasive species management, particularly through protected area budgets, forestry and wildlife departments, and national biodiversity or restoration programs. Invasive weed control can be supported through allocations tied to habitat management, climate adaptation, fire management, and ecosystem restoration, especially where invasive species are recognized as a driver of habitat degradation.

International aid and multilateral funding mechanisms provide essential support in many Asian elephant range countries. Funding from bilateral development agencies, global biodiversity funds, and international conservation organizations can support capacity building, pilot projects, cross-border initiatives, and the development of regional guidelines and tools. These funding sources are particularly important for addressing large-scale or transboundary invasions and for supporting innovation and knowledge transfer.

Private sector partnerships offer additional opportunities to support invasive species control, particularly where activities align with corporate sustainability, biodiversity offsetting, or environmental, social, and governance (ESG) commitments. Partnerships may involve direct financial support, co-funding of restoration activities, technical expertise, or investment in responsible biomass utilization and restoration supply chains. Clear governance arrangements and ecological safeguards are essential to ensure that private sector involvement supports conservation outcomes.

Together, government funding, international aid, and private sector partnerships form a complementary financing landscape. Strategic identification and alignment of these funding sources can support sustained, effective invasive weed management while reinforcing broader conservation and sustainability objectives in Asian elephant habitats.

7. CONCLUSION

Addressing invasive weeds in Asian elephant habitats is both an ecological necessity and a practical conservation challenge. Through coordinated action, shared knowledge, and sustained investment, this AsESG Working Group aims to support range countries in safeguarding elephant habitats while strengthening broader ecosystem resilience.

7.1. SUMMARY OF KEY FINDINGS AND RECOMMENDATIONS

Invasive weeds pose one of the most significant and rapidly intensifying threats to Asian elephant habitats across their range. The document's findings demonstrate that species such as *Lantana camara, Chromolaena odorata, Mikania micrantha*, and *Parthenium hysterophorus* extensively degrade native vegetation, reduce forage availability, fragment habitat connectivity, alter fire regimes, and disrupt access to critical resources such as water and mineral licks. These ecological impacts cascade into elephant behaviour—forcing longer travel distances, reducing feeding efficiency, and pushing elephants into farmlands—thus increasing HEC.

Case studies, particularly from Manas National Park and the Nilgiri Biosphere Reserve in India, highlight both the severity of the problem and the clear potential for ecological recovery when targeted management is implemented. Manual uprooting, habitat restoration, mapping and modelling tools, community engagement, and multi-year monitoring were shown to substantially reduce invasive cover and restore native grasslands critical for elephants and other wildlife.

The report recommends a coordinated suite of approaches: Early Detection and Rapid Response, pathway prevention, ecological restoration, integrated land-use planning, capacity building, community-based monitoring, and strengthened policy frameworks. Long-term funding, cohesive governance, and transboundary collaboration are essential to ensure that these interventions become routine components of habitat management rather than isolated projects.

7.2 CALL TO ACTION FOR RANGE COUNTRY GOVERNMENTS AND CONSERVATION ORGANIZATIONS

Given the scale, speed, and ecological cost of invasive weed expansion, immediate and sustained action by Asian elephant range countries is critical. Governments must fully embed invasive species management into protected area operations, forest management plans, and national biodiversity strategies. This includes regulating high-risk pathways (e.g., soil movement, nursery trade, post-disturbance colonization), improving early detection networks, and mandating restoration following invasive removal.

Conservation organizations, Universities, research institutions, and NGOs have a central role in developing tools, building capacity, generating strong scientific evidence, and supporting community-based restoration initiatives. The report's case studies show that collaborative frameworks—where park authorities, NGOs, and local communities work together—are not only effective but essential for scaling interventions across large landscapes. Government agencies and conservation groups must also work jointly to reduce human–elephant conflict by improving habitat quality, supporting alternative livelihoods, and ensuring community participation in monitoring and restoration.

Critically, transboundary coordination is required. Many elephant populations move across borders, and invasive species disperse along shared ecological corridors. Regional cooperation—through shared monitoring systems, common biosecurity standards, and joint training programs—will greatly strengthen the ability of range countries to respond effectively and prevent reinvasion.

Across Asian elephant range countries, many frontline staff, field assistants, community members, and even mid-level government officers do not routinely work in English. This presents a significant barrier to the adoption of technical guidance on invasive species management. To ensure that this report leads to practical implementation, **official translations into the primary working languages of each range country** should be arranged. While in India and Sri Lanka the need may be less urgent—given the wide use of English in government and conservation sectors—in countries such as Thailand, Myanmar, Cambodia, Laos, Vietnam, Indonesia, and Nepal, translation is essential for uptake.

Local AsESG members, in collaboration with government wildlife authorities and conservation NGOs, should play a lead role in coordinating high-quality translations, ensuring both technical accuracy and cultural relevance. Making the document accessible in local languages will significantly increase the likelihood that recommended management actions are understood, accepted, and integrated into operational protocols.

Effective invasive species management depends on the ability of field personnel—and often community participants—to **recognize invasive weeds quickly and confidently in the field**. Many practitioners, including experienced researchers, may not realize that commonly seen species are in fact invasive. To address this gap, AsESG and national partners should develop **laminated, waterproof field guides** in relevant local languages.

These guides should include clear photographs of priority invasive weeds, brief identification tips, notes on ecological impacts, and concise instructions for recommended removal techniques (e.g., cut-root-stock method, recommended equipment, safety notes, and what *not* to do). Compact field guides can be distributed to forest guards, protected area staff, restoration workers, community eco-development committees, and NGO field teams, significantly improving early detection accuracy and consistency of management responses.

7.3. FUTURE DIRECTIONS FOR RESEARCH AND IMPLEMENTATION

To safeguard elephant habitats over the coming decades, future work must integrate rigorous scientific research with scalable on-ground implementation. More long-term, experimental studies are needed to understand ecosystem-level impacts of specific invasive species, thresholds of ecological change, and optimal restoration strategies under varying conditions such as rainfall, soil type, and fire regimes. Additionally, innovations in remote sensing, hyperspectral mapping, machine learning, and UAV-based monitoring can greatly improve detection accuracy and allow for near real-time mapping of invasion dynamics.

Implementation must also evolve to address persistent capacity gaps. This includes training practitioners in identification, rapid response, ecological restoration, and adaptive management. Establishing standardized monitoring protocols, shared databases, and learning platforms will help build institutional memory and improve consistency across elephant range countries.

Finally, the future of invasive species management depends on ensuring durable funding mechanisms. Governments, donors, and private-sector partners should jointly invest in multi-year programs that integrate invasive control with habitat restoration, climate adaptation, community resilience, and biodiversity conservation. The long-term sustainability of elephant landscapes—and the wellbeing of the communities that share them—will depend on a unified, proactive, and well-funded approach that recognizes invasive species management as a core pillar of elephant conservation.

REFERENCES

Arandhara, S., Sathishkumar, S., Gupta, S., Sharma, S. K., & Venkatesh, A. (2021). Influence of invasive *Prosopis juliflora* on the distribution and ecology of native blackbuck in protected areas of Tamil Nadu, India. *European Journal of Wildlife Research, 67*, 48.

Barnett, D. T., Stohlgren, T. J., Jarnevich, C. S., Chong, G. W., Ericson, J. A., Davern, T. R., & Simonson, S. E. (2007). The art and science of weed mapping. *Environmental Monitoring and Assessment, 132*, 235–252.

Baskaran, N., Anbarasan, U., & Agoramoorthy, G. (2012). India's biodiversity hotspot under anthropogenic pressure: A case study of Nilgiri Biosphere Reserve. *Journal of Nature Conservation, 20*, 56–61.

Baskaran, N., Balasubramanian, M., Swaminathan, S., & Desai, A. A. (2010). Feeding ecology of Asian elephant (*Elephas maximus* Linn.) in tropical forests of Nilgiri Biosphere Reserve, southern India. *Journal of the Bombay Natural History Society, 107*(1), 3–13.

Baskaran, N., Sathishkumar, S., Vanitha, V., Arjun, M., Keerthi, P., Bandhala, N. G., & Anbarasan, U. (2024). Unveiling the hidden causes: Identifying the drivers of human–elephant conflict in Nilgiri Biosphere Reserve, Western Ghats, southern India. *Animals, 14*, 3193.

Campbell, G. S., Blackwell, P. G., & Woodward, F. I. (2002). Can landscape-scale characteristics be used to predict plant invasions along rivers? *Journal of Biogeography, 29*, 535–543.

Das, D., Lahkar, B. P., & Dutta, D. K. (2022). Partnership for conserving the Sub-Himalayan grasslands of India. *Oryx, 56*(4), 492–493.

Elzinga, C. L., Salzer, D. W., Willoughby, J. W., & Gibbs, J. P. (2001). *Monitoring plant and animal populations*. Blackwell Science.

ICFRE, 2020. A Handbook on Invasive Species. Indian Council of Forestry Research and Education, Dehradun, India.

Kishore, B. S. P. C., Kumar, A., Saikia, P., Lele, N., Srivastava, P., Pulla, S.,

Kull, K. A., Young, C. C., Haack-Gaynor, J. L., Morrison, L. W., & DeBacker, M. D. (2022). *Problematic plant monitoring protocol for the Heartland Inventory and Monitoring Network* (Version 2.0). National Park Service.

Lass, L. W., Carson, H. W., & Callihan, R. H. (1996). Detection of yellow starthistle (*Centaurea solstitialis*) and common St. Johnswort (*Hypericum perforatum*) with multispectral digital imagery. *Weed Technology, 10*, 466–474.

Lawrence, R. L., Wood, S. D., & Sheley, R. L. (2006). Mapping invasive plants using hyperspectral imagery and Breiman–Cutler classifications (Random Forest). *Remote Sensing of Environment, 100*, 356–362.

Massachusetts Invasive Plant Advisory Group. (2005). *Final report: The evaluation of non-native plant species for invasiveness in Massachusetts*.

McNeely, J. A. (2001). Invasive species: A costly catastrophe for native biodiversity. *Land Use and Water Resources Research, 2*, 1–10.

Molvar, E.M., R. Rosentreter, D. Mansfield, and G.M. Anderson. 2024. Cheatgrass invasions: History, causes, consequences, and solutions. Hailey, ID: Western Watersheds Project, 128 pp.

Nath, A., Sinha, A., Lahkar, B. P., & Brahma, N. (2019). In search of aliens: Factors influencing the distribution of *Chromolaena odorata* L. and *Mikania micrantha* Kunth in the Terai grasslands of Manas National Park, India. *Ecological Engineering, 131*, 16–26.

National Authority CAMPA, Ministry of Environment, Forest and Climate Change. (2022, December 15). *Mapping, monitoring and management of Lantana camara through utilization for improving livelihood of people in forest fringe villages of India: A collaborative revised project proposal submitted under CAMPA*.

Prasad, S., & Williams, A. C. (2010). *Extent and distribution of some invasive plant species in Asian elephant habitats: Report from preliminary online survey*.

Rew, L. J., Maxwell, B. D., Dougher, F. L., & Aspinall, R. (2006). Searching for a needle in a haystack: Evaluating survey methods for non-indigenous plants. *Biological Invasions, 8*, 523–539.

Sandilyan, S. (2019). *Strategies for control and management of some selective invasive alien plant species endangering Indian biodiversity*. National Biodiversity Authority.

Sinha, A., Nath, A., Lahkar, B. P., Brahma, N., Sarma, H. K., & Swargowari, A. (2022). Understanding the efficacy of different techniques to manage *Chromolaena odorata* L., an invasive alien plant in the Sub-Himalayan tall grasslands: Toward grassland recovery. *Ecological Engineering, 179*, 106618.

Suresh, H., Bhattacharya, B. K., Khan, M. L., & Sukumar, R. (2024). Mapping of understorey invasive plant species clusters of *Lantana camara* and *Chromolaena* *odorata* using airborne hyperspectral remote sensing. *Advances in Space Research, 73*, 1379–1396.

Tan, D. T., Thu, P. Q., & Dell, B. (2012). Invasive plant species in the national parks of Vietnam. *Forests, 3*(4), 997–1016.

Thanikodi, M., Gautam, H., & Vidya, T. N. C. (2024). Invasive species in Nagarhole National Park and use of the area by Asian elephants. In *Proceedings of the International Conference on Human–Elephant Conflict Management* (pp. 37–42). Karnataka Forest Department.

Vidya, T. N. C., Thanikodi, M., Jabili, C., Anvitha, S., Sanyal, A., Choudhary, D., Mohanty, S., & Athira, T. K. (2024). *Sub-shrubs and herbs, including weeds, at the Kabini backwaters* [Technical report]. Jawaharlal Nehru Centre for Advanced Scientific Research.

Wilson, G., Desai, A. A., Sim, D. A., & Linklater, W. L. (2013). The influence of the invasive weed *Lantana camara* on elephant habitat use in Mudumalai Tiger Reserve, southern India. *Journal of Tropical Ecology, 29*(3), 199–207.

Wilson, G., Gruber, M. A. M., & Lester, P. J. (2014). Foraging relationships between elephants and *Lantana camara* invasion in Mudumalai Tiger Reserve, India. *Biotropica, 46*(2), 194–201.

Wilson, G., Gruber, M. A. M., Lester, P. J., Desai, A. A., & Sim, D. (2014). The association between invasive *Lantana camara* and seedlings/saplings of a plant community in Mudumalai Tiger Reserve, India. *Journal of Tropical Ecology, 30*(6), 551–563.