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Invasive alien plants, insect pests and pathogens in Planted and Natural forests in Nepal: Key lessons from an online survey on distribution and impacts

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Abstract

Owing to its diverse climatic and topographic condition, Nepal hosts diverse forests and rich biodiversity which provide a variety of ecosystem goods and services. Spread of invasive alien plants, insect pests and pathogens (IAS) has been contributing to degrading forest ecosystem services in Nepal. This study outlined the status, distribution and impact of IAS on forest ecosystem using an online survey among forest officers and forest technicians across Nepal. Invasion and management of pests and diseases is quite limited and under-reported, while the management measures on IAPs are growing. Raising awareness at individual and community levels and capacity building among three levels of government (local, provincial and federal) aids sustainable management of IAS and supports continuous delivery of forest goods and services.

Keywords: IAS, biological invasions, severity of damages, control measures, forest health

Introduction, scope and main objectives

Biological invasion has been an emerging problem worldwide, with the magnification of impact of rapidly changing climate and altered human activities (Giometto et al., 2014). The mismatch in species distribution pattern coupled with increased human disturbance in natural ecosystems has caused the emergence of insects and pests causing the huge impact on biodiversity of Nepal. The spread of invasive alien plants, insect pests and pathogens (IAS) is one of the biggest threats across the globe causing negative impacts on local livelihoods, ecosystem health, food security and biodiversity (Rai and Singh 2020). Significant efforts from the local to global scale have been made in research, assessment, and management of IAS. While developed countries in the North have formulated necessary regulations for prevention, early detection and eradication and management of invasive species, developing countries in the South are facing challenges to formulate relevant policies and programs (GoN/MoFSC, 2014; McGeoch et al., 2016) due to lack of baseline data on species introduction across geographic regions.

Nepal is considered as one of the countries with the greatest threat (ranked 3 out of 124 countries for the agriculture sector) from biological invasions (Paini et al., 2016) and relatively low national capacities to address this problem (Early et al., 2016). Located in the centre of the Himalayan biodiversity hotspot, Nepal has a large elevation gradient with extreme variations in topography and climate along that gradient. Forests and other

wooded land together covers 44.74 percentage of the total area of the country, however mean stem volume per hectare was found to be less in Forest Resource Assessment (FRA) 2010-2014 (165 m^3ha^{-1}) than in National Forest Inventory (NFI) 1987-1998 (178 m^3ha^{-1}) (MoFSC, 2015).The biological invasions have emerged as a significant threat to biodiversity and ecosystem services in Nepal and its severity and extent is consistently growing (MoFSC, 2014). MoFE (2010) has identified invasion of IAS as one of the 9 drivers of deforestation and forest degradation in Nepal and included in REDD+ Readiness Plan (R-PP). A total of 182 non-native plant species are naturalized in Nepal (Shrestha and Shrestha 2021; Kunwar and Acharya 2013) among them 27 are invasive. Four of them (*Chromolaena odorata, Pontederia crassipes, Lantana camara* and *Mikania micrantha*,) are among the 100 of the world's worst invasive alien species (Lowe et al., 2000).

The distribution of invasive alien plant species (IAPs) is higher in Tarai, Siwalik and Mid-hills of central and eastern Nepal (GoN/MoFSC, 2014). Despite the increasing invasion, less attention has been given in understanding the knowledge, awareness and perceptions relating to IAS and their impacts on forest ecosystems. Considering vital role of forest, Government of Nepal has focused on the effective management of forest resources under various management regimes to maximize benefits from the forest (Malla and Pokharel, 2018). However, the large numbers of community forest user groups do not have any strategy for invasive species management (Shrestha et al., 2019). The management of IAS is still not a national priority; the existing legal instruments are not effectively implemented; the commitments made have not been fulfilled (Siwakoti and Shrestha, 2014). This study, therefore, is a pursuit of increasing knowledge of IAS. Knowledge and perception among local government officers and forest managers on distribution of IAS and their potential risks and damages across Nepal were assessed.

Methodology/approach

We employed online survey using Survey Monkey platform to collect the data. The survey was conducted between July and October 2020 to evaluate knowledge towards invasive alien species effects, control and management practices among the local government forest officers/forest technicians. A set of questionnaires was designed in a participatory manner with inputs from the IAS Working Group and Forest Research and Training Centre, Ministry of Forests and Environment. The survey included questionnaires both in English and Nepali language aiming to make it easy and convenient to understand the key essence of the questions. To increase the understanding about IAS, the survey online link was supplemented by additional documentation of identifying invasive plants, insect pest and pathogens. The survey had been divided into four sections and included 24 questions. First three sections were focused on technical aspects for instance: i) invasive alien plants; ii) insect pests and iii) forest disease. Each section had included the questions asking infestation in natural and plantation forests types, 21 dominant tree species (Table 1) (Poudyal et al., 2019), their growth stages and body parts; symptoms and season of damages; forest ownership and functions and severity of impacts. The questionnaires were designed with options of binary or multiple choices, and in Likert scale (Joshi et al., 2015).

Table 1. Sample tree species for assessment of infestation of IAS

Local Name	Botanical name	Type	Local Name	Botanical name	Type
Thingre Salla	*Abies spectabilis*	Natural	Khote Salla	*Pinus roxburghii*	Planted
Khayar	*Acacia catechu*	Natural/Planted	Gobre Salla	*Pinus wallichiana*	Natural
Utis	*Alnus nepalensis*	Natural/Planted	Poplar	*Populus deltoids*	Planted
Bhoj patra	*Betula utilis*	Natural	Oak	*Quercua lamellose*	Natural
Simal	*Bombax ceiba*	Natural	Guras	*Rhododendron arboretum*	Natural
Katus	*Castanopsis indica*	Natural	Chilaune	*Schima walichii*	Natural
Sissoo	*Dalbergia sissoo*	Natural/Planted	Sal	*Shorea robusta*	Natural
Masala	*Eucalyptus camaldulensis*	Planted	Teak	*Tectona grandis*	Planted
Botdhairo	*Lagerstroemia parviflora*	Natural/Planted	Saj/Asna	*Terminalia alata*	Natural
Champ	*Magnolia champaca*	Natural/Planted	Himali Salla	*Tsuga dumosa*	Natural
Patle Salla	*Pinus patula*	Planted			

Three questions were open ended especially related to affected area and the area of interventions (policy and practices). The link of Monkey Survey with list of 24 questionnaires was sent via email to 84 divisional forest offices and 23 protected areas across Nepal. The participation of local level government offices or forest officers/forest technicians in the survey was voluntary however the purpose of the study, utility of data, anonymity and confidentiality clause was clearly highlighted for respondents before filling up the questionnaire. In total, we received 45 responses (34 through online platform and 11 in a personal email). The information was analyzed simply using descriptive statistics and results were presented in tabular form, charts and figures with descriptions.

Results

A total of 45 divisional and sub-divisional forest offices from 29 districts representing Tarai (low land) to mountain ecological region and eastern to western Nepal shared their experience and views on the impact of invasive plants, insect pests and pathogens in forest ecosystems in Nepal. Among them, 93% of the respondents were from local forest and watershed management offices and rest from the protected areas. By gender, 91% of the respondents were male and having age in between 24 and 60 years with bachelor degree to PhD in natural resource management sector. Most of the respondents had studied forest protection that includes forest insect pest and diseases in their academic courses however their practical experience on IAS management was not much noted.

Perception regarding IAS impacts on forest types and species

Insect pest was considered as a major threat affecting tree species during different growth forms and forest categories followed by forest pathogens, reported by 95% respondents. We made a comparison among different forest types in terms of insect pests and forest pathogens infestation (Figure 1). It was observed that higher impact of insects and pests and forest pathogens found on plantation forests whereas the least on natural forests. On the contrary, IAPs were considered as a major threat in natural forests. Interestingly, 56%, 38%, 22%, 20% and 11% of the respondents observed high impact of IAS on government managed forests, protected areas,

private forests, protection forests and community managed forests, respectively. Rest of them indicated low and medium impact. This result suggests that community-based forest management had low impact of IAS.

It was observed that among 21 tree species higher impact of invasive insects pests and pathogens was observed on planted tree populations of Sissoo (*Dalbergia sissoo)*followedby natural-planted Sal (*Shorea robusta)*, planted Teak (*Tectona grandis)* and Masala (*Eucalyptus* spp) in Tarai (low land); and Khote Salla (*Pinus roxburghii)* and Chilaune *(Schima wallichii)*trees in the hills; planted-natural Utis (*Alnus nepalensis)* followed by Gobre Salla (*Pinus wallichiana)* and Khasru (*Quercus* spp.) forests in the mountains (Figure 1). These results showed that both natural and planted forests have been affected though planted population was more vulnerable to insect pest and pathogens.

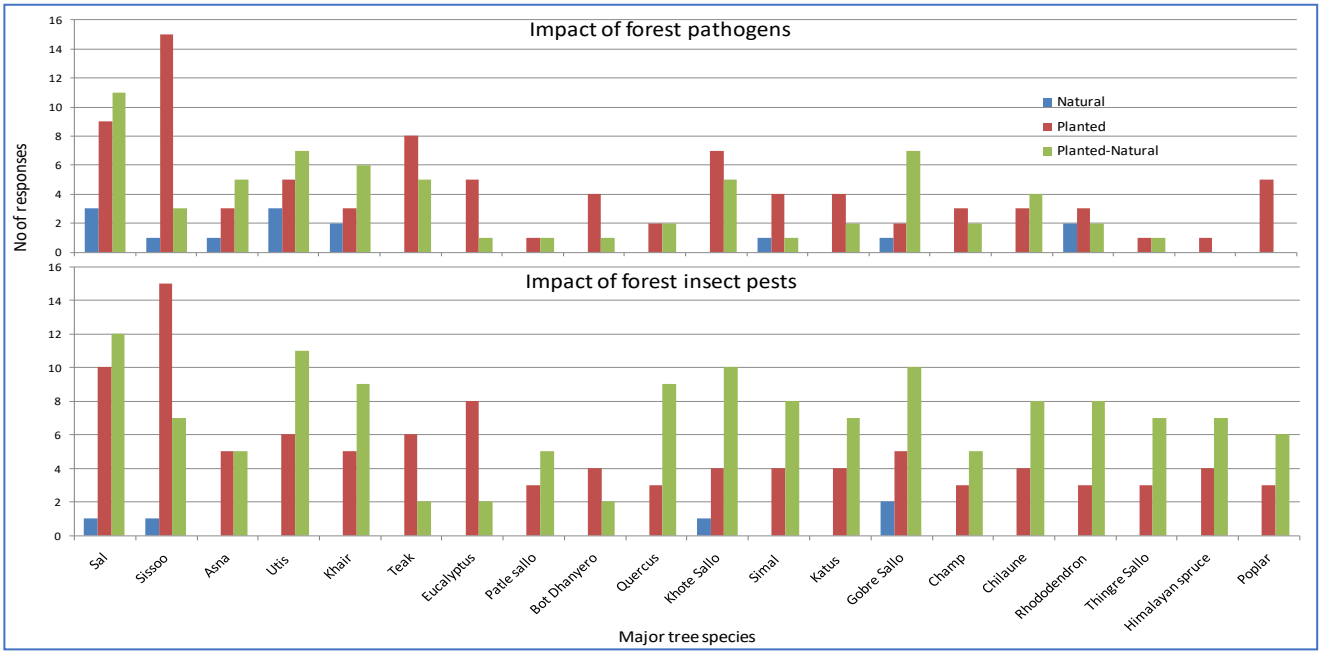

Figure 1: Impact of insect pests and pathogens on key host tree species

Infestation of IAS varied with the growth forms of tree species. Highest infestation was found on seedling stage of all tree species followed by dead and dying trees of Sal and Teak infested by insects and pests. There is a great heterogeneity among plant parts that have been impacted by insects pests and pathogens; however stems, leaf foliage and twigs of *Shorea robusta*, *Dalbergia sissoo*, *Tectona grandis*, *Schima wallichii*, *Pinus roxburghii*, *Pinus wallichiana* and *Alnus nepalensis* were highly infested. The maximum impact on tree growth was reported in *S. robusta* followed by *D. sissoo*, *B. utilis* and *A. catechu*. These results showed that Sal and Sissoo are the most vulnerable species infected by forest insect pest and pathogens.

Both natural forests and tree plantations of Nepal are invaded by 14 Invasive Alien Plant Species (IAPs), including some of the globally worst species such as *Chromolaena odorata, Lantana camara* and *Mikania micrantha. C. odorata* and *Ageratina adenophora* were the most frequent IAPs in forests and tree plantations in Nepal. The respondents prioritized 14 invasive plants based on their abundance and impacts on forest ecosystems of their areas. *Mikania micrantha, Lantana camera, Chromolaena odorata* were prioritized as top three species which

are abundant and demonstrated high impact on different ecosystems and habitats followed by *Ageratum conyzoides*, *Ageratina adenophora*, *Parthenium hysterophorus*, *Mimosa diplotricha*, *Eichhornia crassipes*, *Mesosphaerum sauveolens*, *Xanthium strumarium*, *Argemone mexicana* and *Senna tora (Figure 2)*. These species are rampantly expanding in different habitats resulting in invasion by IAPs of tropical origin such as *Mikania, Ageratina* and *Partheniumto* ecosystems in mountain districts: Bhaktapur, Kaski, Lamjung, Manang, Kalikot, Gorkha, Pachthar, and Terathum.

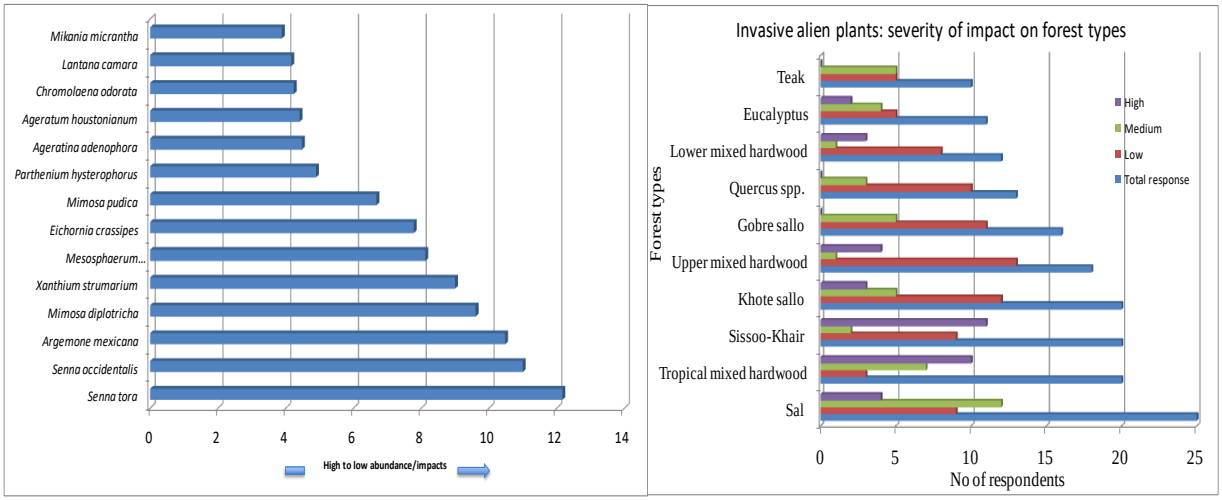

Figure 2: Prioritized invasive plants (left) and perceived impact of IAPs on major 10 forest types (right)

The impacts of IAPs were observed high on Sal (*Shorea robusta)* forest followed by tropical mixed hardwood (Sal, Saaj - *Terminalia alata*, Simal - *Bombax ceiba*) forests, Sissoo-Khair, Khote Salla, Gobre Salla, *Quercus* spp., upper mixed forest (*Aesculus-Juglans-Acer species*) lower mixed hardwood forest (*Persea-Litsea-Neolitsea* species), and Eucalyptus and Teak planted forests (Figure 3). However, the severity of impact was intense on Sissoo-Khair Forest followed by tropical mixed hardwood, Sal forests and Teak-Eucalyptus plantation forests at low land; and Khote Salla and lower mixed hardwood forests at mid-hills. Quercus, Gobre Salla and upper mixed hard wood forests were also observed as infested forest type by IAPs at middle mountains.

Discussion

One of the most important steps in assessing invasion of IAS is developing knowledge on the occurrence, impacts and interventions (Herborg et al., 2007). From the survey, it was found that both plantation and natural forests were affected however planted forests and species were more vulnerable to IAS infestation. The planted forests are not well adapted in the given habitat hence the insects and forest pathogens find them as a new host for infestation. This suggests that the conservation of natural forests is highly important for minimizing the impacts of insect and pest and pathogens in the ecosystems.

Community based forest management regime was less affected in comparison to government managed forests, protection forests and protected areas and this could be attributed to a periodic silvicultural operation in community-managed forests and easy access. The periodic silviculture (weeding, cleaning, bush clearing, thinning, pruning, etc.) helps remove unnecessary and weed species that effectively control IAPs.

Degraded and open canopy forests are converted into closed-canopy forests after handover which was attributed by the regular and close scrutiny of local communities towards weeds control (Shrestha et al., 2018). Shade-intolerant IAPs such as *C. odorata* has declined locally in forests due to closure of forest gaps and increase in canopy density (Joshi et al. 2006; Khaniya and Shrestha, 2020). The government managed forests and protected areas are highly affected from IAS indicates that frequent and regular surveillance and weeding practices substantially abate the IAS invasion.

Sal, Sissoo-Khair, Teak and Eucalyptus in Tarai; Khote Salla, Chilaune in the mid hill; and Gobre Salla, Utis, Poplar and Quercus in the mountains are the key species that have been mainly affected from IAS. The higher impact in tree growth is related to higher leaf nutrient content in these tree species. Mostly insects and pathogens relating to the leaves and stems have affected majority of the species and growth forms. Likewise, invasive plants have really affected natural regeneration and overall productivity of forest, shrubland and grass land ecosystems. There are a limited number of studies evaluating the impacts of IAS.

IAP species *Mikania micrantha* has highly affected particularly in moist habitats along forest edges, riverine forests (Sissoo-Khair) and grasslands (Sapkota, 2009). Malla and Pokharel (2018), reported that Sal, Teak, Eucalyptus in Tarai region of Nepal have been affected from forest pest and diseases; consistent with the present study findings. Sissoo was severely affected by *Fusarium solani* and *Ganoderma lucidum* causing the serious problem of dieback and root rot across the country (Timilsina et al., 2020) and Sal has been severely affected by heartwood borer in Tarai Nepal (Chhetri et al., 2021). Shrestha (2016) reported that *Lantana camara, Chromolaena odorata, Ageratina adenophora, Mikania micrantha, Mesophaerum sauveolens* have severely invaded rangelands of Tarai, Siwalik and Mid-hills of Nepal with obvious negative impacts to productivity and biodiversity of this ecosystem (Timsina et al., 2011).

Majority of them showed similarity with and supported our results. For instance, This article has alerted that some very important forests types Khote Salla, Chilaune in the mid hill; and Gobre Salla, Utis, Poplar and Quercus in the hills and mountains have been affected by IAS which is not very often reported and considered yet to its previous research. This situation has alarmed clearly to prepare long-term strategy for tackling with invasion of invasive alien plants, insect pest and pathogens across Nepal.

Conclusions/ wider implications of findings

Forests have become an integral component of the livelihood of majority of people particularly living in rural area. This online survey has clearly showed, IAS as an important driver of altering and degrading forest ecosystems. As majority of the respondents have reported that forest, shrub land, grassland and wetland ecosystems are affected from IAS; observed symptoms of insect and pathogens attack and direct effect of invasive alien plants in different growth stages and parts of economically important tree species, i.e. Sal, Sisoo, Khair, Teak, Masalaat low land, Khote Salla, Chilaune atmid-hills; and Gobre Salla, Khasru, and Utis in the mountains of the country. However, it seems hard to prevent, control and eradicate until and unless we have no appropriate policies, mechanisms, long-term systematic and science-based IAS management in forest ecosystems, which is truly urgent to prevent, control and eradicate IAS in Nepal. In this context, online survey

was found as a useful tool to assess perceptions of forestry officers/practitioners and forest managers and can provide amazing facts and observations on IAS distribution and their impacts on forest ecosystems. Likewise, the study indicated the technical information of pests and diseases is rather challenging. Knowledge of impacts of IAS and key measures among forest officers, other stakeholders including forest managers can be useful to bridge policy and practices and to kick off the prevent, control and eradication of existing IAS in different forest ecosystems at local level.

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