Richness and Impact of Invasive Alien Species Plant in Trees of Shivapuri Nagarjun National Park, Central Nepal

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Abstract

The effect of invasive species on biodiversity is a major issue of world. This study was conducted at the Shivapuri Nagarjun National Par. This study assessed the invasive species status factor associated with it and their impact on seedling and sapling of trees. Modified Whittaker Nested sampling stratifies was adopted for vegetation sampling. A total of 15 plots were taken with 195 subplots between 1409 m to 2140 m. altitudinal ranges. A total of 32 tree species and nine invasive species were recorded from the studied sites. The pine forest was having significantly ($W = 3$, $p = 0.03$) more coverage of invasive species than mixed forest, the coverage of invasive species was also significantly ($W = 50$, $p = 0.009$)more with more invasive species than plot with single invasive types. Beside this coverage was also affected by canopy cover, trampling and altitude but not significantly different. The invasive species have impact on numbers of seedling, sapling and their diversity species coverage. We recommend removing these invasive species.

Keywords: *Invasion, Native, Park, Plant, Trampling*

Introduction

An invasive species is a plant, fungus, or animal species that is not native to an exclusive area or location and has the propensity to cover a range that could cause damage to the environment, human economy, or human health (Colautti & MacIsaac, 2004). Invasive species can successively harm the natural resources in an ecosystem as well as threaten anthropogenic use of these resources (Fei, Phillips, & Shouse, 2014). They are a topic of controversy, as it is often confusing to understand whether they are a boon or a bane (Rai et al., 2012). Habitats high in native species richness often have high invasive species richness (Peng et al., 2019).

The introduction of invasive alien species (IAS) occurs through anthropogenic means

Whereas the dispersal of native invasive species may occur due to natural processes or human activities (Shrestha, 2016). After being introduced to an environment, the establishment and colonization of invasive species largely depend upon the availability of resources and human influence (Shrestha, 2016). An environment with unused resources makes the place more prone to invasion (Davis et al., 2000) and anthropogenic movement increases the propagule pressure of invasive species (Simberloff, 2009).

IAS is one of the crucial direct drivers of loss of biodiversity and change in ecosystem services (Brunel et al., 2013; Chaudhari et al., 2021). The extension of IAS is a topic of global concern since it could impoverish native biodiversity and impact ecosystems and their life forms and habitats from aquatic to wetlands, to grasslands, and forested areas as well. In recent times, the negative impacts of invasive species on resident communities are gaining more attention and also their mechanisms (Schirmel et al., 2016); (Wardle & Peltzer, 2017). The impacts of biological invasion in the context of ecology and evolution could eventually lead to the extinction of species, ecosystem process modification such as changes in nutrient cycling, fire regimes, and even alteration in hydrology (Evans et al., 2016). A strong linkage between invasion and various factors such as global warming and increment in the human population is predicted to increase the threats of IAS (Simberloff et al., 2013; Spear et al., 2013).

The problems of invasive species are common to the developed as well as developing countries. However, their impacts are seen to be greater in developing countries like Nepal because of inadequate resources and expertise for their management (Shrestha, 2016). In the context of Nepal, invasive and alien species are profoundly common and expanding rapidly in natural as well as anthropogenic landscape, and such systems even though are noted to be highly impacted economically, ecologically as well as evolutionarily, they have not been yet assessed elaborately. (Shrestha, 2016) A total of 26 species of naturalized plants are considered as invasive and most problematic species (Tiwari et al., 2005; Shrestha et al., 2017), introduced from South America, Mexico, and tropical America. Similarly, Shrestha (2016) studied IAPS like *Lantana camara*, *Chromolaena odorata*, *Ageratina. adenophora*, *Mikania micrantha*, *Hyptis suaveolens* and projected that these invasive plant species have severely impacted the lower Terai, Siwalik, and Mid Hill regions of Nepal with serious repercussions to growth and productivity of ecosystem diversity.

The mid-hills of Nepal containing the temperate region (2000-3000m) is dominated by evergreen, broad-leaved, and mixed forests. Some of the species present in this region are *Persea duthiei, Phoebe lanceolata, Cinnamomum tamala, Lindera nacusua, Quercus lamellosa Quercus, Quercus semecarpifolia, Picea smithiana, Abies pindrow, Cupressus torulosa, Cedrus deodara*, deciduous species of *Aesculus-Juglans-Acer*, and

Magnolia-Acer-Osmanthus. (Tiwari et al., 2005) These forest ecosystems are being severely impacted by invasive species.

Aprerequisite for characterizing invasibility is dependent upon the level of the biodiversity and disturbances of the ecosystems (Catford et al., 2012). Therefore, ecosystems with a history of recurrent disturbances (such as trampling and grazing) should consist of species with adaptations to frequent disturbances (Souther et al., 2019). The impacts of invasive species on ecosystems and their services are also affected by interactions with disturbance indices such as fire, weather, trampling, and other disturbances. Disturbance and invasion could be negatively or positively correlated (Bulleri et al., 2016).

Invasive species vastly affect the forest ecosystem which could ultimately affect the economy and wellbeing of the local people. Biological Invasion is not only a malady to the environment, but in the anthropocentric views, it hampers the livelihood of the local people. Taking into account the fact that limited studies related to invasive species have been done at the Shivapuri Nagarjun National Park, this study had found the invasive species status factor associated with it and their impact on seedling and sapling of trees.

Materials and Methods

Study Area

Shivapuri Nagarjun National Park (SNNP) covers 159 sq. km and is located between 27°45' to 27°52' N and 85°15' to 85°30' E with two isolated island forests viz. Shivapuri and Nagarjun in the central part of Nepal. The Government of Nepal has declared the Shivapuri Watershed and Wildlife Reserve as a National Park in 2002 and the Nagarjun forest area has been annexed in 2009 AD (SNNP, 2010). The national park extends to Sindhupalchowk, Dhading, and Nuwakot districts (Bhuju, Sakya, Basnet, & Shrestha, 2007) and is the subject of interest because of its high biodiversity, species richness, along with invasive species affecting the native species in the national park (Shrestha S., 2014). The park stretches about 20-24 km from east to west and about 8-10 km from north to south. The park boundary is well demarcated with a 111 km long wall around the park. The boundary walls run along/between several villages (formerly Village Development Committees, VDCs) that include Talakhu, Chhap, Likhu, Samundra Devi, Sikre, Sunkhani, and Thanapati of Nuwakot district in the north and Bajrayogini, Baluwa, Chapali, Bhadrakali, Gagalphedi, Jhor Mahankal, Nayapati, Sangla, Sundarijal, and Bishnu Budhanilkantha of Kathmandu district in the south. It is a protected area that falls entirely within the middle mountain range of Nepal. The name of the park is also considered to derive from the ancient name Shiphuchd representing the holy peak of woods (ShNP Management Plan, 2004). SNNP is linked by four major road-networks from the valley (Kathmandu to Budhanilkantha, Tokha, Kakani, and Sundarijal) (SNNP, 2010). The study area (Figure 1) in this research started from the Sundarijal Entrance to Chisapani Village from an altitude of 1400 masl to 2140 m asl.

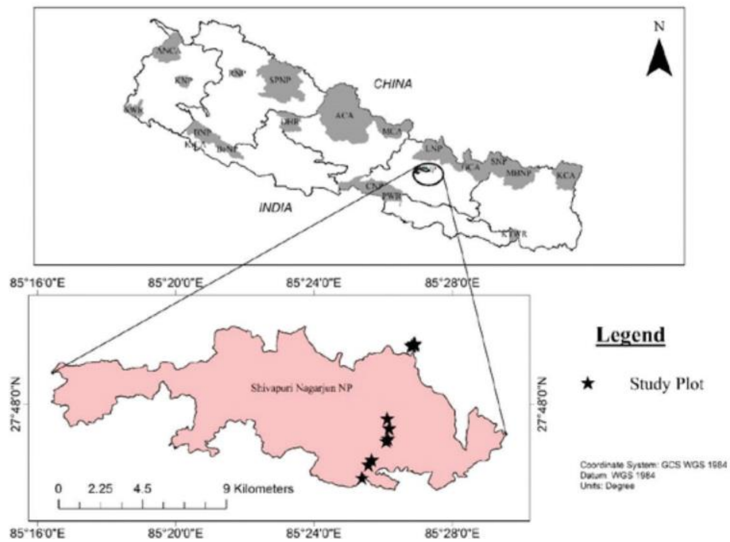

Figure 1: Study area map showing the Shivapuri Nagarjun National Park.

Field Sampling

We applied the modified Whittaker nested vegetation sampling method for the study. The Modified-Whittaker plot design is a vegetation sampling design that can be used for assessing plant communities at multiple scales (Stohlgren et al., 1995). A total of 15 plots were taken with 195 subplots. Sampling was carried out between the altitudinal ranges of 1409m to 2140m. Each plot was measured 20m by 50m (1000m^2) and contained nested subplots of three different sizes. A 5m by 20m (100 m^2) subplot was placed in the plot's center, and two 2m by 5m (10 m^2) subplots were placed in opposite corners of the plot. There were a total of ten 0.5m by 2m (1 m^2) subplots. Six were arranged systematically inside and adjacent to the 1,000 m^2 plot perimeter and four were arranged systematically outside and adjacent to the 100 m^2 subplot perimeter. At each ground sampling point, a Modified-Whittaker nested vegetation sampling plot was established. In the 1000m^2 plot, the number of individuals of each species in the tree stage was counted and the diameter at breast height (DBH, measured at 137cm above the ground) was measured. Individuals of tree species were divided into three growth stages: trees (DBH>9 inches), saplings (DBH= 1-4.9 inches), and seedling (DBH< 1inch) (Interior West Forest Inventory and Analysis (IWFIA Program, 2001). Species diversity of each plot was calculated. The sapling count was recorded in the 100-m^2 subplot to determine the sapling diversity for each plot. Likewise, in the two 10-m^2 subplots, coverage of the invasive species and invasive species richness was recorded.

Trampling type disturbance

The trampling percentage was visually estimated, the method adapted from Marques et al. (2001). The disturbance index value was classified according to the class of trampling intensity.

Table 1 Disturbance Index Values for Trampling

SN	Trampling (%)	Disturbance index value	Disturbance intensity
1	0	0	Low
2	0-30	1	Medium
3	>31	2	High

Data Analysis

Species Diversity Index (H')

The Shannon index Shannon & Weaver (1949) was employed for the estimation of species diversity; seedling and sapling diversity.

Where,

H' = Species Diversity Index
Pi = proportion of the species; Pi
N = total number of individuals of species
ni = importance value of each species

Percentage coverage of Invasive Species

The percentage coverage of invasive species was calculated by using a direct estimate of cover (Daubenmire, 1959) which is given by the following formula:We made boxplot and did statistical test using R core 2018. To see the invasive species coverage relationship with forest type, invasive species richness, and altitudinal range Wilcox test was performed. For invasive species coverage with extent of trampling (low, medium and high) and canopy cover classes Kruskal wallis test was performed.

Results and Discussion

Invasive Species

We recorded nine invasive species, Eupatorium *adenophora* L. *(72.05%), Galinsoga parviflora* Ruiz & Pav. *(8.06%), Xanthium strumarium* L. *(7.87%), Lantana camara* L. *(7.73%), Oxalis latifolia Kunth (1.88%), Amaranthus spinosus* L. *(0.93). Solanum* *viarum (1.16%)*, *Ageratum conyzoides* L. (0.31%) and *Bidens Pilosa* L. (0.02%) (Figure 2), along with 32 tree species; the dominated tree species were *Pinus roxburghii*, *Schima wallichii*, *Fraxinus floribunda*, *Juniperus* sp. and *Pyrus pashia.*

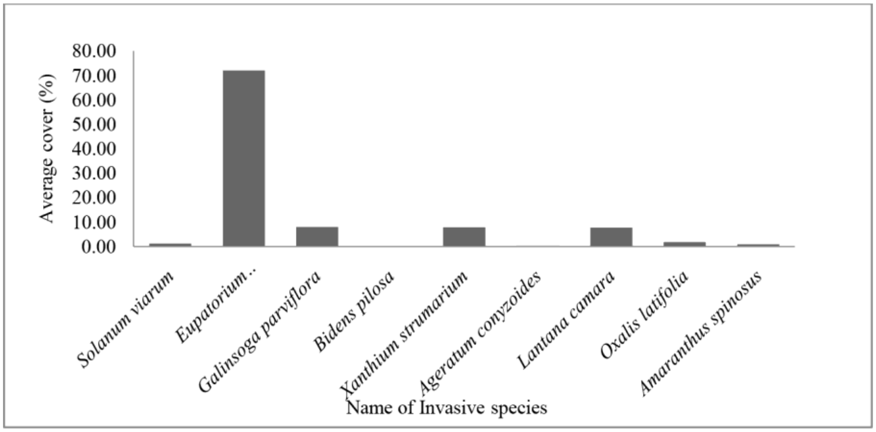

Figure 2: Invasive plant species coverage in SNP.

Invasive species Cover and Covariant

The invasive species coverage was dependent on different covariant (Figure 3). The mean invasive species cover was 6.67± 1.77 (S.E) with the range 0 to 22.604. The pine had significantly (W = 3, p= 0.03) more coverage of invasive plant species than mixed forest. The plots with a single type of invasive species had significantly (W = 50, p = 0.009) low coverage of invasive species than more type of invasive species (2 to 6). High trampling was supporting invasive species but not significantly (χ^2= 4.381, df = 2, p= 0.112) different, with the canopy cover 40-50 the median invasive species coverage was more but not significantly (χ^2 = 2.2552, df = 2, p = 0.323) different with canopy coverage classes. The invasive coverage was also not significantly different (W = 31, p= 0.778) at above and below 2000m altitude although the invasive species was more above 2000m.

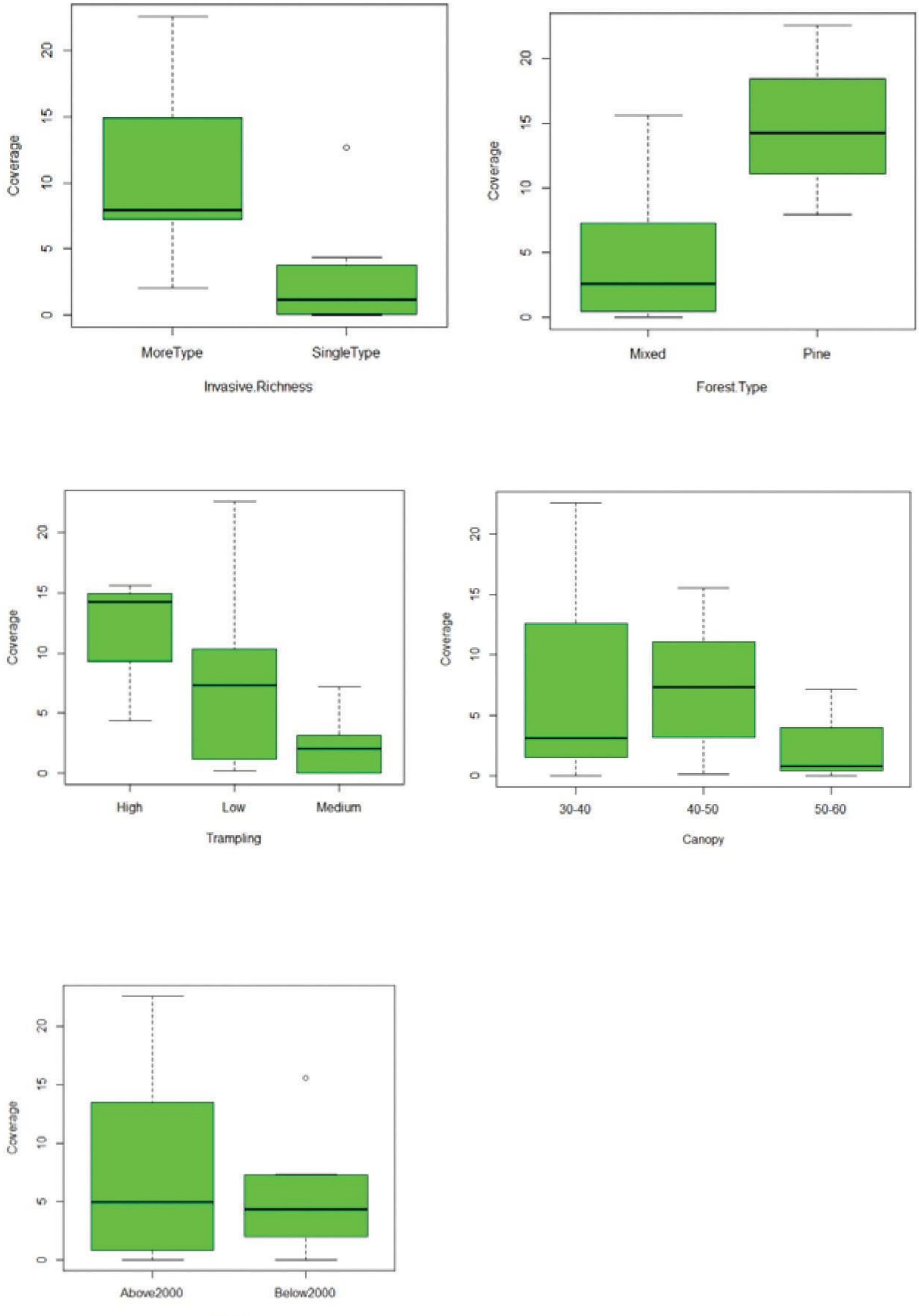

Figure 3: Invasive species coverage with different covariant.

Seedling, Sapling, and Invasive species Cover

The number of seedlings, sapling and their diversity were different with the extent of invasive species coverage (Figure 4). The number of seedling presence was significantly (W = 42, p= 0.009) different from invasive species coverage. The seedling number was more in 0-10% invasive species coverage plot in comparison to above 10% coverage plots. Likewise, the presence of saplings was also significantly (W = 39, p = 0.029) different from invasive species cover. Sapling was more in 0-10% coverage. The diversity of seedling and sapling also significantly different (W = 36, p-value = 0.055) and W = 38, p = 0.032 respectively with the invasive species coverage percentage.

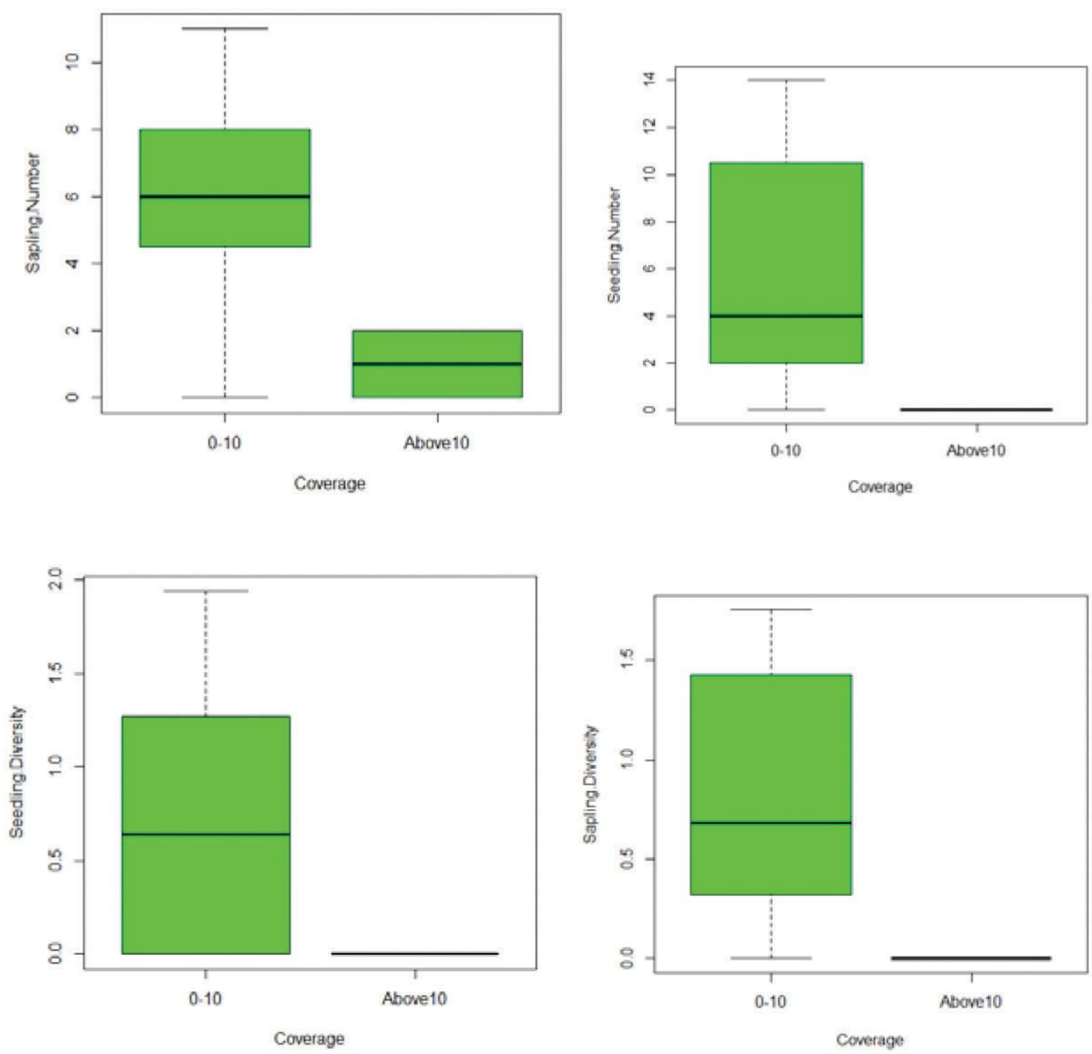

Figure 4: Seedling and sapling number and diversity with invasive species coverage

Invasive species Cover and Covariant

In the case of the pine forest, the invasive species coverage was higher similar to other studies (Dyderski & Jagodzinski, 2020). Additionally, *Eupatorium adenophora*was found to have the highest coverage in the study plots. It has been observed that invasive species, particularly, *Eupatorium adenophora,*are able to employ their adaptive mechanisms to form dominant coverage in the Pine forest (Callaway & Ridenour, 2005). Similarly, invasive species are even able to escape the negative reaction sent out by the native pine species and increase their coverage in the forest (Dyola, et al., 2020). On the contrary, high species diversity in mixed forest regions contributes to the moderation of prevalent invasive species resulting in decreased invasion coverage (Haas et al., 2011).

The invasive species coverage in the study plots was found to be significantly higher where more than 2 types of invasive species were prevalent. Hejda et al. (2009) also found similar results when analyzing native species richness in the invaded communities. The higher the invasive species richness, the higher becomes the invasion coverage because the prevalence of more invasive species within an area accounts for reduced regeneration rate of the native plants (Chaudhary et al., 2020). The plots the study area nearer to villages within the trekking trail had higher invasive species richness with the prevalence of species such as *Eupatorium adenophora, Bidens pilosa, Galinsoga parviflora,* and *Ageratum conyzoides*. With more human movement and involved disturbances such as trampling, there also occurs dispersion of invasive species seeds resulting in an increase in their coverage area (Hobbs & Huenneke, 1992).

High invasive species coverage was recorded in the area that had high and low trampling. Similar case was encountered by Winkle (2014) in their study regarding spread of invasive species in urban natural areas. Disturbance such as trampling or soil movement could act primarily as a source of invasion as they provided a rougher surface on which seeds are embedded, as a result of which disturbance provided safer space for seeds of invasive species to grow (Hobbs & Atkins, 1988). It can be predicted that intermediate disturbance was needed for management of invasion which was supported by the Intermediate Disturbance Hypothesis by Wilkinson (1999), which thus, suggested that at intermediate levels of disturbance, diversity was maximized because species that thrived at both early and late successional stages coexisted, as a result, species diversity can be maintained while managing as well as controlling invasion.

The coverage of the invasive species was found to be decreasing with increasing canopy cover. This result was in line with the research done by Khania and Shrestha (2020) and Sharma et al. (2019). This is because invasive species are understory shrubs in the forest ecosystem and are unable to compete with trees for lights, thus, their coverage decreases in areas with higher canopy cover (Sharma, et al., 2019). Additionally, most of the invasive species-area abundant in areas that are open with plenty of light availability, which is hindered in forest areas with higher canopy cover (Mavimbela et al., 2018).

The invasive species coverage was found slightly higher in the study plots above 2000m (until 2140m), however, the increment was not that significant. The plots taken during the study, that is, 1400m to 2140 is within the distribution range of the invasive species prevalent in the study area, thus altitudinal difference was not found to be statistically significant (Shrestha, 2016).

Seedling and Sapling Presence and Invasive Species Coverage

The seedling and sapling numbers were significantly low with the coverage of invasive species above 10% in comparison to 0-10% coverage which might have suppressed due to invasive species activities through disruptive belowground mutualisms and secretion of inhibitory chemicals (Stinson, et al., 2006). Similar case was encountered by Chaudhary et al. (2020) and Dyderski and Jagodzinski (2020). The invasive species produce allele chemicals which create an unfavorable environment for the growth and development of native plant seedlings and saplings (Seastedt et al., 2008). Likewise, as seedlings and saplings are particularly vulnerable to competition with the understory of the forest ecosystem, over light availability and nutrition, higher invasive species coverage slows down seedling and sapling presence (Dyderski & Jagodzinski, 2019).

The seedling and sapling diversity were found to be higher in the plots with less than 10% invasive species coverage similar to Ekanayake et al., (2020) which might be due to interaction with the invasive species including the coverage of the invasive species. Similar result was obtained by Chaudhary (2015). Likewise, as invasive species coverage increases with its richness, with the increase in the coverage of the invasive species, there also occurs an increase in the invasive species richness (Chaudhary, 2015). As a result, it can affect the species diversity and richness of other native vegetation due to the secretion of high amounts of allelopathic and phytotoxic chemicals. Likewise, in native forests, invasive plant species were able to dictate the stratification, which suppressed the growth of saplings and eventually species diversity (Keely, 2006). Therefore, we recommend suppressing the presence of invasive species in the study area which might be done by the involvement of the local community and park authorities.

Conclusion

This study has found invasive species and impact of invasive species on trees in Shivapuri Nagarjun National Park, Central Nepal. A total of nine invasive specieswere investigated and recorded. *Eupatorium adenophora* was the most dominant invasive species recorded in this park.The invasive species coverage was significantly depending on types of forestand invasive species richness.The number of seedlings, sapling and their diversity were significantly different with the extent of invasive species coverage.The park and local people should work together and form effective plan and implement it to lower the number of invasive species and their impact on trees.

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References

- Brunel S, Fernández-Galiano E, Genovesi P et al (2013) Invasive alien species: a growing but neglected threat? In: Late lessons from early warning: science, precaution, innovation. Lessons for preventing harm. EEA report 1/2013, Copenhagen, pp 518–540

- Callaway, R. M., & Ridenour, W. M. (2005). Novel weapons: Invasive success and the evolution of increased competitive ability. *Biological Sciences Faculty Publications*, 223.

- Chaudhari, S. K., Rajbanshi, P., Karki, R., & Dahal, D. (2021) Distribution of Invasive Plant Species along Elevation Gradient in Eastern Nepal. *Integrating Biological Resources for Prosperity*.

- Chaudhary, R., Shrestha, B. B., Thapa, H., & Siwakoti, M. (2020). Status and impacts of invasive alien plant species in Parsa National Park, central Nepal. *Banko Janakari*, 30(1), 21-31. https://doi.org/10.3126/banko.v30i1.29179

- Davis, M.A., Grime, J.P. and Thompson, K. 2000. Fluctuating resources in plant communities: a general theory of invisibility. Journal of Ecology 88: 528-534.

- Dyderski, M. K., & Jagodzinski, A. M. (2019). Similar impacts of alien and native tree species on understory light availability in a temperate forest. *Forests*, 10 (11), 951. https://doi.org/10.3390/f10110951

- Dyola, N., Bhuju, D. R., Kharal, D. K., Aryal, S., Gaire, N. P., & Hitler, L. (2020). Growth pattern of Pinus roxburghii under different regimes of invasive species in Panchase, Nepal Himalayas. *Pakistan Journal of Botany*, 52(1). http://dx.doi.org/10.30848/PJB2020-1(33)

- Ekanayake, E., Cirella, G. T., & Xie, Y. (2020). Impacts of community forestry on forest condition: Evidence from Sri Lanka's intermediate zone. *Journal of Sustainable Forestry*, 15(9), e0239405. https://doi.org/10.1371/journal.pone.0239405

- Haas, S. E., Hooten, M. B., Rizzo, D. M., & Meentemeyer, R. K. (2011). Forest species diversity reduces disease risk in a generalist plant pathogen invasion. *Ecology Letters*, 14(11), 1108-1116. https://doi.org/10.1111/j.1461-0248.2011.01679.x
- Hejda, M., Pysek, P., & Jarosik, V. (2009). Impact of invasive plants on the species richness, diversity and composition of invaded communities. *Journal of Ecology*, 97(3). https://doi.org/10.1111/j.1365-2745.2009.01480.
- Hobbs, R. J., & Atkins, L. (1988). Effect of disturbance and nutrient addition on native and introduced annuals in plant communities in the western Australian wheatbelt. *Australian Journal of Ecology*, 13(2), 171-179. https://doi. org/10.1111/j.1442-9993.1988.tb00966.x
- Hobbs, R. J., & Huenneke, L. F. (1992). Disturbance, diversity and invasion: Implications for conservation. *Conservation Biology*, 6(3), 324-337.
- Keely, J. (2006). Fire Management Impacts on Invasive Plants in the Western United States. *Conservation Biology*, 20(2), 375-384. https://doi.org/10.1111/ j.1523-1739.2006.00339.x
- Khania, L., & Shrestha, B. B. (2020). Forest regrowth reduces richness and abundance of invasive alien plant species in community managed Shorea robusta forests of central Nepal. *Journal of Ecology and Environment*, 44(1), 12. https:// doi.org/10.1186/s41610-020-00158-7
- Mavimbela, L. Z., Sieben, E. J., & Proches, S. (2018). Invasive alien plant species, fragmentation and scale effects on urban forest community composition in Durban, South Africa. *New Zealand Journal of Forestry Science*, 48(1), 19. https://doi. org/10.1186/s40490-018-0124-8
- Seastedt, T. R., Callaway, R. M., Pollock, J. L., & Kaur, J. (2008). Allelopathy and plant invasions: Traditional, congeneric and bio-geographical approaches. *Biological Invasions*, 10, 875-890. https://doi.org/10.1007/s10530-008-9239-9
- Sharma, L. N., Adhikari, B., Watson, M. F., Karna, B., Paudel, E., Shrestha, B. B., & Rijal, D. P. (2019). Forest canopy resists plant invasions: a case study of Chromolaena odorata in sub-tropical Sal (Shorea robusta) forests of Nepal. *bioRxiv*, 747287. https://doi.org/10.1101/747287
- Shrestha, B. B. (2016). *Invasive alien plant species in Nepal*. Frontiers of Botany.
- Simberloff D, Martin JL, Genovesi P et al (2013). Impacts of biological invasions: What's what and the way forward?*Trends Ecology Evolution* 28, 58–66

- Simberloff, D. (2009). The role of propagule pressure in biological invasion. Annual Review of Ecology, *Evolution and Systematics* 40, 81-102.
- Spear D, Foxcroft LC, Bezuidenhout H et al (2013). Human population density explains alien species richness in protected areas. Biol Conserv 159:137–147
- Stinson, K. A., Campbell, S. A., Powell, J. R., Wolfe, B. E., Callaway, R. M., Thelen, G. C., . . . Klironomos, J. N. (2006). Invasive plant species suppresses the growth of native tree seedlings by disrupting belowground mutualisms. *Plos Biology*, 4(5), e140. https://doi.org/10.1371/journal.pbio.0040140
- Tiwari, S., Siwakoti M., Adhikari, B., & Subedi, K. (2005). An Inventory and Assessment of Invasive Alien Plant Species of Nepal. IUCN- The World Conservation Union, Nepal
- Wilkinson, D. M. (1999). The disturbing history of intermediate disturbance. In *Oikos* (pp. 145-147).
- Winkle, J. E. (2014). *Informal trails and the spread of invasive species in urban natural areas: 'Spatial analysis of informal trails and their effects on understory plant communities in Forest Park, Portland, Oregon.* Portland State University.