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Climate change and plant invasions in Himalaya

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Abstract:
Himalaya occupies an outstanding position, ecologically, economically, socio-culturally and politically. They are one of the rugged territories on the planet, hosting the sky kissing grey peaks and are an abode to the largest fresh water sources in the sub-continent. In India they cover an area of 5 lakh Km² (about 16.2% of country's total geographical area) and seal the northern boundary of the country. Extended between 26°20' and 35°40' North latitudes and 74°50'and 95°40' East longitudes, they are spread over 10 states (administrative areas) in the country. Over the years biological invasions have increased substantially across world that is causing biotic homogenization, thereby posing a potent threat to the biological diversity and ecological integrity of native habitats and ecosystems. Climate change is likely to favour invasion to new areas, while simultaneously increasing the adaptability in natural communities by disturbing the dynamic equilibrium maintaining them.
Key words: Climate change, Himalaya, Invasions, Biodiversity

Introduction

India, situated between 8˚ 4'to 37˚ 6' N latitude and from 68˚ 7' to 97˚ 25' E, is the seventh largest country in World and the second largest in Asia in terms of its geographic area. This mega diversity country hosts varied climate types and supports huge variety and variability of life forms with high degree of endemism. The two major biodiversity hotspots of this country include the Western Ghats and the Himalaya. Being the second largest country in terms of human population, the anthropogenic impact on biodiversity and ecosystems is obviously immense. One of the manifestations of great deal of habitat destabilization is burgeoning plant invasion and this country with a colonal history, is presently under a severe threat of invasion by the exotic species. A large number of plant species have already established in various climatic zones of the country and are becoming a serious threat to the established ecosystems. Aided by the habitat disruption, the alien species establish swiftly in both the preoccupied habitats by other species and also the virgin sites created more frequently by human interference.

Out of the major biogeographic zones in India, the Himalaya occupies an outstanding position, ecologically, economically, socio-culturally and politically.

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They are one of the rugged territories on the planet, hosting the sky kissing grey peaks and are an abode to the largest fresh water sources in the sub-continent. In India they cover an area of 5 lakh Km² (about 16.2% of country's total geographical area) and seal the northern boundary of the country. Extended between 26°20' and 35°40' North latitudes and 74°50'and 95°40' East longitudes, they are spread over 10 states (administrative areas) in the country(Figure 1). The Himalaya is home to an estimated 25,000 species of flora (equivalent to 10% of the world's total), 75,000 species of insects (10% of world's total), and 1,200 species of birds (13% of world's total). The Himalaya also has high endemism: in the Chinese Himalaya, there are 40 angiosperm genera and 28 fish genera endemic to Yunnan; at least 3,165 species of flowering plants, 27 species of birds and 17 species of mammals are reportedly endemic to the Indian Himalaya; at least 500 plant species are endemic to Nepal and 750 to Bhutan.

Kashmir Himalaya occupies a pivotal position in representing a unique biospheric unit in the North Western Himalayas (Rodgers and Panwar 1988). The region has an area of about 15,948 km², with nearly 64% of the total area being mountainous. The region lies between 32°20' to 34°50' North latitude and 73°55' to 75°35' East longitude (Hussain 2002). The Western Himalaya harbours a rich flora and fauna where some rare and endemic biota flourishes. Declared as one of the hot spots of biological diversity it hosts heterogonous climate zones ranging from sub-tropical, sub- Mediterranean to the cold- arid zones. Habitat heterogeneity is considered to be the primary reason of hosting such diverse flora in both aquatic and terrestrial habitats. Beginning from sub-tropical, the floristic diversity ranges through sub-alpine to the upper reaches of alpine meadows. There are round 2,312 plant species which have been recorded from the region (Dar and Christensen 1999), grouped under 842 genera and 189 families.

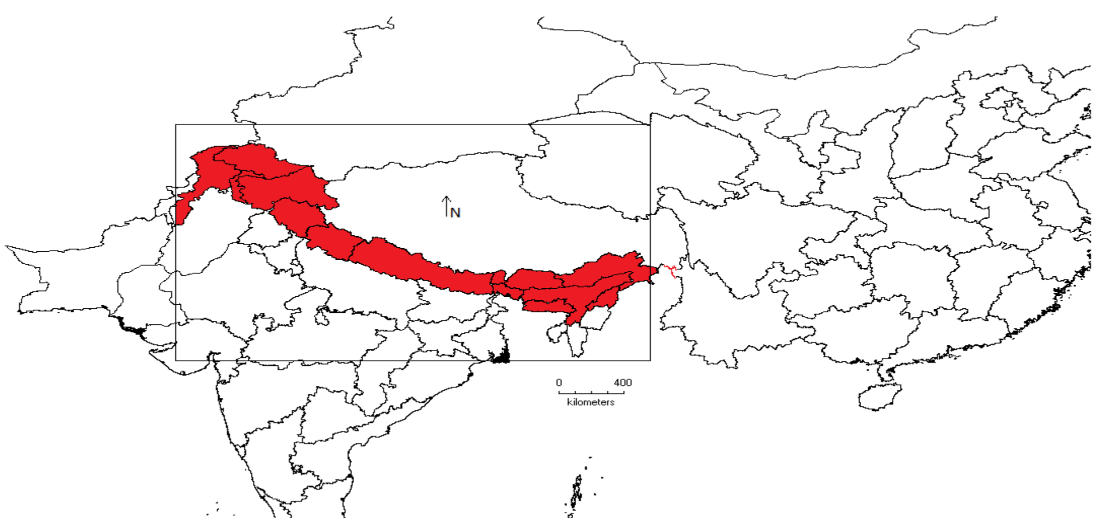

Figure 1: Map showing extent of Himalayan region

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Plant invasion in India: an overview

Over the years biological invasions have increased substantially across world that are causing biotic homogenization, thereby posing a potent threat to the biological diversity and ecological integrity of native habitats and ecosystems (Booth et al. 2003, Hulme 2003). In fact, after habitat loss, plant invasion is considered as the second major threat to the biological diversity. Exotic invasive species affect indigenous species diversity, soil nutrient composition and alter forest fire cycles and lead to loss of productivity of invading ecosystems. Moreover, these species seriously threaten rare and endangered species (Pimentel et al. 2005).

India, the second most populous country in the world, has become a new home for a huge number of invasive species native to various regions of the world. According to Third National Report, 40% of the Indian flora is alien, out of which 21% is invasive. Biogeographically, more than one-third (35%) of the alien flora in India has its native range in South America, followed by Asia (21%), Africa (20%), Europe (11%), Australia (8%), North America (4%); and cryptogenic (1%). In fact among the 36 plant species belonging to the ‘‘world’s worst invasive alien species’’, 17 species occur in India. Reddy (2008) reported a total of 173 invasive alien species belonging to 117 genera under 44 families. Most of the species (almost 80%) came from neo tropics with Tropical America (74%) and Tropical Africa (11%) contributing maximum proportion o the invasive alien flora of India. Habit wise analysis showed herbaceous species share 151 species, followed by shrubs (14), climbers (5) and trees (Reddy 2008). Khuroo et al. (2011) recorded 1,599 alien species in India with Asteraceae (134 spp.), Papilionaceae (114 spp.) and Poaceae (106 spp.) being the most dominant families. Recently, Shah and Reshi (2012) documented 223 alien aquatic plant species from India, representing 116 genera from 60 families, mostly natives to Eurasia (Table 1). Cyperaceae the largest family (30 spp.), followed by Asteraceae and Polygonaceae (13 spp. each) and Potamogetonaceae and Poaceae (11 and 10 spp., respectively). Brassicaceae and Lemnaceae (8 spp. each) were the next largest families, followed by Amaranthaceae, Hydrocharitaceae and Lamiaceae (7 spp. each). Most of the alien aquatic species in Indian waters are native to either Europe or Asia followed by Africa and Australia.

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Table1. Gist of alien invasive plant species (Terrestrial and Aquatic) in India and Kashmir Himalaya.

Plant category	No. of Families	No. of Genera	No. of Species	Dominant Life Form	Major source region	Source
India	161	842	1,599	Herbaceous	South America, Europe, North America, Africa & Austrailia.	Khuroo et al. (2011)
India (Aquatic)	60	116	223	Emergents	Eurasia	Shah & Reshi (2012)
Kashmir Himalaya	104	352	571	Herbaceous	Europe, Asia & Africa	Khuroo et al. (2006)
Kashmir Himalaya (Aquatic)	42	68	129	Emergents	Europe, North America & Asia	Shah & Reshi(2014)

Scenario of plant invasion in Kashmir Himalaya

Kashmir, popularly known as paradise on Earth, hosts a rich diversity of flora and fauna. However, in the recent years the region is witnessing a severe threat to its biodiversity due to invasion of large number of alien plant species both in terrestrial and aquatic habitats. Most of these species have emerged as worst invaders in the human intervened sites at the plains and high altitudes in the Kashmir Himalaya causing a substantial threat to the local flora by depleting the nutrient availability in the soils and starving them of other important resources, thereby leading to the cryptic extinction of the more important indigenous species. Equipped with novel traits, these species consistently expand their ranges and have been witnessed at upper elevated zones as well for example; Stewart, 1978 has witnessed *Anthemis cotula* at an altitude of 2800m asl in Kashmir Himalaya. As per Khuroo et al. (2006) the alien flora of Kashmir comprised of 571 plant species belonging to 352 genera and 104 families. Dicotyledons (425) of alien plant species distributed in 261 genera and 74 families; whereas monocotyledons share 133 plant species grouped under 81 genera and 23families. Gymnosperms are represented by 11 plant species belonging to 8 genera and 5 families. Recently Shah and Reshi (2014) reported 127 alien aquatic species belonging to 68 genera in 43 families from different Kashmir Himalayan water bodies. Largest families being Cyperaceae and Potamogetonaceae constituting 21 and 10 species, respectively followed by Polygonaceae and Lemnaceae with 8 and 7 species each and next by Brassicaceae and Labiateae with 6 species each. While estimating the contribution of source floras to the aliens of Kashmir Himalaya, European flora contributes maximum percentage of species (38%) followed by Asia (excluding South Asia), Africa, North America, South America and Australia which contribute 27, 15, 10, 8 and 2% to the total alien flora, respectively.(Table 1).

Climate change and its implications in the Himalayan Context

Most of the studies on the plant invasions throughout the world have been carried out in low lying areas. Not with standing that the high altitude ecosystems are relatively more stable and less likely to be prone to exotic species invasions (Millenium Ecosystem Assessment 2003, Humphries et al. 1991), still at low magnitude, evidences shows that plant invasions do occur and the invasion in these regions is not insignificant (Rouget et al. 2003, Baret et al. 2006, Pouchard et al. 2009). With ever increasing intra and inter-continental human movements, in concert with changing climatic regimes, species have also evolved novel ways to migrate, establish and spread in new regions and novel habitats where they never occurred earlier (NAS 2002).

Global climate change is an issue of great concern in both the developing and developed societies. Since the advent of industrial revolution there has been continuous and progressive accumulation of green house gases in the atmosphere which has lead to the phenomenal rise in the global surface temperatures in deviating from the norm of fifteen degree centigrade (global average). The negative impact of this global, complex phenomenon is being debated keeping the political, economic, ecological and social concerns in consideration. This in turn has put in dawn many ecological issues like species migration, plant shifts, diversity decline, etc. Most of the countries at this point of time face to be or not to be situation; on the one hand they want to sustain their rapid economic progresses and on the other they want to conserve their natural resources. Climate change and species invasions are the two important drivers of ecological changes in the twenty first century, posing a serious threat to native biodiversity and ecosystem functioning (Vitousek et al. 1996, Thomas et al. 2004). Global climate change is expected to further expand the risk of plant invasion through ecosystem disturbance and enhanced competitiveness due to elevated CO_2 (Dukes and Mooney 1999; Weltzin et al. 2003; Thuiller et al. 2007). A direct effect of recent climate change on biodiversity is cryptic and difficult to measure, but the processes are global and practically irreversible. With ever increasing human

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intervened landscapes, invasive species are going to expand their ranges to such sites where they have never been located earlier.

The Western Himalayan region has a characteristically different climate type in comparison to the other biogeographic zones of the country. Most of the parts here witness severe winters with moderate to heavy snowfall in and a comparatively less warm summers. Global warming is believed to make a profound effect on the temperature regimes and the precipitation pattern in the region during the 21stcentury and the latter abiotic factors have always been the primary participants in designing the biota of a particular region. The various assessment reports brought out since 1990s by Inter governmental Panel on Climate Change (IPCC) have brought out various assessment reports and have tracked the building up of knowledge and understanding of the climate change at both global and regional levels. The mean annual temperature in the Himalayas is projected to increase from 0.9±0.6℃ to 2.6±0.7℃ in the 2030s. The net increase in temperature ranges from 1.7℃ to 2.2℃ with respect to the 1970s. Temperatures also show a rise in all seasons. The annual rainfall in the Himalayan region is likely to vary between 1268 ± 225.2 and 1604 ± 175.2 mm in 2030s. The projected precipitation is likely to increase by 5% to 13% in 2030s with respect to 1970s (INCCA 2010). These elevated temperature and precipitation levels may have an incredible influence on the distribution pattern of the invasive plants in the region and the invasive plants may shift their range of expansion to the high altitude zones to disturb the niches of the inhabitants and subsequently the homogenization.

Climate change as a driver for invasion: prediction of invasive range expansion under climate change

Climate change is likely to favour invasion to new areas, while simultaneously increasing the adaptability in natural communities by disturbing the dynamic equilibrium maintaining them. As per Intergovernmental Panel on Climate Change (IPCC) the recent worldwide warming will result in pole ward and altitudinal shifts in plant ranges and many ecosystems will become vulnerable to biological invasions as climatic barriers are removed. The IPCC concludes that an increase of greater than 1.5°C–2.5°C in the global average temperature will cause dramatic changes in species distribution and ecosystem function, resulting in overwhelmingly negative consequences for ecosystem sustainability The Himalayan region deserves special attentions because high mountain regions are extremely sensitive to climate change and further of their biological, as well as socio-economic significance. In response to the rising temperatures, it is likely that ecological zones, species ranges will also shift upwards. Plants found in high

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mountain regions are generally long-lived species, but long-term changes in the climate are likely to affect their distribution and survival.

To predict the range expansion of alien invasives under climate change influences is an open but important question? To address them is more complicated? And to make insteps in this complex phenomenon is not impossible. This has become possible through one of the recent advents in the field of Bio- informatics**,** Biogeography, Ecology and Conservation Biology called Ecological Niche Modelling/ Species Distribution Modelling/ Bioclimatic Envelop Modelling. In the last two decades, a number of efforts have been made to predict the ecological niche of a species using several modeling tools, such as BIOCLIM (Busby 1991), GARP (Stockwell and Noble 1991), DOMAIN (Carpenter et al. 1993), that make it possible to identify specific habitats where a species can thrive best. Using these tools Uma Shanker et al. (2013) and Kannan et al. (2013) modelled the ecological niche of *Lantana camara* from its "native" habitat in Mexico and showed that it is possible to predict the possible sites and habitats around the world where *Lantana* could invade. Species Distribution Modelling (SDM) has become over the years a pivotal tool to address the issues of species distribution in their native and non-native habitats, to identify the areas of potential distribution and to predict the future distribution of species under climate change scenarios, particularly with respect to the global elevated CO_2, the ever increasing global temperature and the changing course of precipitation. Several modelling approaches have be employed to predict the distribution and spread of invasive species in Western Himalayas under climate change scenarios thus alarming in advance, how detrimental the invasion is going to be. Priyanka and Joshi (2013) modelled the invasive range of *Lantana camara* using various climate change scenarios and data from various centers by a modelling algorithm, Maxent. Their resuts showed that under climate change, *Lantana camara* will expand its niche and that most of the southern and western regions of the Western Himalaya may become infested with *Lantana* by 2080. Vikrant et al. (2013) modelled the potential distribution of *Sapium sebiferum*, an invasive tree species in Western Himalaya and predicted its potential to occupy 11,920 sq. km area in the Western Himalaya. Kathiresan (2006 b) showed that under upland conditions, increasing temperature above 35°C favored the germination and establishment of *Trianthema portulacastrum* L, an invasive weed. Germination of noxious carrot grass *Parthenium hysterophorus* L was found to be triggered by a combination of higher temperature and moderate available soil moisture. With increasing temperature and fluctuating precipitation, the weed may pose a severe threat assisted by globalized trade and agriculture. Similarly, the rate of increase in root bio-mass of invasive alien weed *Prosopis julijlora* Swartz (DC) under increasing temperatures is observed to be higher, thereby increasing its persistence potential and invasive behavior. Using different

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climate change scenarios and suitable environmental variables, Adhikari et al. (2012) modelled the invasive weed *Chromolina odorata* and showed that under future climate change *Chromolina* is most likely going to invade most parts of the Eastern as well as the Wetern Himalayas including Jammu and Kashmir.

Future Directions

Western Himalaya, home to diverse unique and economically valuable floristic elements, despite being vulnerable to challenges such as climate change and biological invasions, remains largely neglected for studies in this area in an integrated framework. Notwithstanding that the invasive species in the aquatic and terrestrial habitats of the region are well documented (Shah and Reshi, 2014, Khuroo et al. 2006), yet the studies on expansion patterns of these species in the climate change context are lacking. The global climate change is influencing the distribution pattern of invasive plants worldwide and there are cases where the invasive species have expanded their ranges to the new ecologically sensitive zones. Therefore, the need of the hour is to develop predictive models for the likely range expansion by the invasive species, especially to alpine habitats. The species distribution modelling finds is an effective tool to assess the range expansion of the invasive plants, using future climate and physiographic data on the regional scale. This will give us beforehand identification of areas where the invasive species are going to recruit in future and one could evaluate the negative impact of invasion much before the process initiates and put in place suitable management strategies. Moreover, the Himalaya as a whole is expected to act as refugia for expectedly large chunk of species in the scenarios of climate change. In this context, questions pertaining to the ranges of alpine species in Himalaya during the Last Glacial Maximum and the history of alpine plants in this region attain importance.

Conclusion

Being an abode to rich floristic diversity and endemic species, the Western Himalaya is one of the captivating landscapes on the globe. For centuries it has attracted the attention of plant explorers, natural scientists and culturists for aesthetic and other reasons. However, the region over the years has witnessed rapid invasion by non-native species posing a significant threat to the native flora. The ever increasing network of surfaced roads, especially to pristine alpine habitats, has facilitated the huge tourist influx to alpine sites, thereby leading to significant habitat disturbance in the region. This has been one of potential means of facilitating the opportunistic invasive species. The upward shift and unpredictable expansion of these species in the context of climate change is becoming a challenging issue for biodiversity managers. Fortunaltely, a galaxy of Species distribution models has emerged recently to access the current and future distribution of invasive species under climate change patterns. Such modelling

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approaches in various mountainous zones around the globe have successfully predicted the frequent emergence and establishment of number of invasive species in high elevation zones. We call for large-scale climatic modelling studies in the Himalayan region to predict well in time the potential invasions in the climate change scenario for putting in place effective management strategies.

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