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Climate change and *Prosopis juliflora* invasion in India

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Abstract
Invasive species have been of interest to ecologists around the world because of their negative effects on the native environment. Invasive species are recognized as one of the important causes of biodiversity loss and degradation of natural ecosystems and services due to their rapid growth and expansion. On the other hand, climate change is a primary environmental issue for humanity in the 21st century which also causes many other environmental problems. Conservation of biodiversity is critical to achieve the Sustainable Development Goals (SDGs). Therefore, we need to look at the relationship between climate change and invasive species to design appropriate containment management strategies. Various studies suggest that developing countries will face a new group of invasive species in the future when natural ecosystems are disturbed due to climate change. This study seeks to explore possible links between climate change and the invasion of *Prosopis juliflora* in India in the near future. Various research papers and reports are thoroughly reviewed to observe the possible link between plant invasion and their expansion due to climate change. This study can be used as a tool to explore the interrelationship between climate change and plant invasion.

Keywords: invasive species, biological invasion, climate change, *Prosopis juliflora*, sustainable development goals (SDGs)

Introduction

Biological invasions are one of the main drivers of biodiversity loss. Biological invasion is the second biggest threat to biodiversity in context of the recipient ecosystem after habitat destruction (Wilcove *et al.*, 1998) [1]. They have been linked to the extinction of about 60% of species during the last century (Bellard *et al*., 2018) [2]. Biological invasion may have effects at population, community and/or ecosystem level (Mack *et al* 2000) [3]. Invasive plant species are recognized as one of the major threats to the functioning of ecosystems, biodiversity and economies worldwide (Kueffer, 2017) [4]. Ecologists had long been interested in finding out the factors that make a habitat invasible (Alpert *et al*., 2000.). One attribute, key to invasion success that has been found common amongst successful invaders is the ability to outgrow the competition (Biswas *et al* 2011) [6]. Future climate change is expected to expand the climate-appropriate range for invasive plant species (Adhikari *et al*., 2019) [7]. Planning for the management of these species requires the identification of existing invasions and the potential expansion of invasive plant species. The problem caused by biological invasions is expected to increase as a result of climate change and habitat fragmentation. (Beaury *et al*., 2020) [8]. Climate change can facilitate the introduction, establishment and spread of invasive species (Diez *et al*., 2012). As a result, invasive species are shifting their geographic distribution to higher altitudes as a result of climate change (Shrestha *et al*., 2018) [10]. It is important to look at the relationship between climate change and invasive species in order to design appropriate management strategies. In addition, Information is needed to design effective invasive species management by taking climate change into account.

Prosopis juliflora is one of the serious invaders posing a problem to natural biodiversity and has expanded its range from arid, semi-arid to saline regions of India (FAO, 2006) [11]. Thus, it is imperative to investigate the potential invasion dynamics of *Prosopis juliflora* under climate change scenarios to better influence decision-making processes on the management of this invasive species. Progress in sustainable management strategies based on the ecological causes of the invasion over a period of time can contribute towards management efforts to control the spread of the invasion.

Biological invasion studies based on ecological modeling have predicted that developing countries will face more threats in the future than developed countries. According to studies, developing countries should be prepared for a new set of invasive species as ecosystems will be disturbed due to climate change (Early *et al*., 2016) [12].

Invasive plants are foreign plant species that are accidentally or intentionally introduced into new environments or habitats and adversely affect the native plant diversity. Biological invasions are having a major impact on Earth's ecosystems (Vitousek *et al.* 1997) [41]. Invasive species are second only to habitat destruction when it comes to posing a threat to biodiversity (Wilcove *et al*., 1998) [1]. The United Nation's (UN) Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) estimated that nearly one-fifth of the Earth's surface, including global biodiversity hotspots, are at risk from biological invaders (IPBES, 2019) [22]. Invasive plant species have a greater tendency to shift their niche expeditiously than native species and are more likely to adapt to the new environment. (Shrestha and Shrestha 2019) [15].

Sutherst *et al*., (2000) [16] suggest that climate change may influence the entire invasion process by affecting three significant constraints: sources of invasive species, pathways of dispersal, and the invasion process in host ecosystems. Recent studies have concluded that climate change will greatly affect the distribution of invasive

species by causing expansion, change or contraction in species ranges (Corlett and Westcott, 2013) [17]. Climate change facilitates and creates opportunities for the establishment and spread of invasive species and also reduces the resilience capacity of native species (Hellmann *et al*., 2008) [18]. They alter the dynamics of plant communities and threaten the stability and functioning of ecosystems by affecting the nutrient cycle, increasing soil acidity, competing with indigenous flora, and inhibiting their regeneration. (Bradley *et al*. 2010) [19].

Presently in India, of all the species in existence, 40 % are exotics of which 25% have turned invasive (Raghubanshi *et al*., 2005) [20] Much of India's degraded ecosystems are due to invasion by these alien flora. Some of the worst exotic invaders in the subcontinent are *Prosopis juliflora, Chromolaena odorata, Mikania micrantha, Ageratina adenophora, Lantana Camara,* and *Parthenium hysterophorus* (Raghubanshi *et al*., 2005) [20]. *Prosopis* genus involves 44 species, belongs to the family Fabaceae and sub-family Mimosoideae (burkart, 1976) [21]. It is very well resistant to drought and thrives in the semi-arid conditions of the Indian ecosystem. In addition, it is a cheap source of fuel wood. It was deliberately introduced to gain benefits in the Indian subcontinent. There are only 4 species of genus *Prosopis* that are invasive, namely- *P. glandulosa*, *P. velutina*, that are serious weeds in Australia and some African countries whereas *P. juliflora* and *P. pallida* are neo-tropical species and serious weeds in Kenya, Sudan, Ethiopia, the Middle East, and the Indian subcontinent (Pasiecznik *et al.,* 2001) [22]

Prosopis juliflora is native to Mexico, Northern South America, Central America and the Caribbean Islands (Pasiecznik *et al.,* 2001) [22]. In 1877, it was first introduced in India (Pasiecznik *et al*., 2001) [22] then it was repeatedly introduced. It spread rapidly in Rajasthan, Gujarat, Haryana, Madhya Pradesh, Andhra Pradesh, Maharashtra, Karnataka, Orissa, Punjab and Delhi (FAO, 2006) [11]. It is found in a wide variety of habitats including forests, agricultural land, wastelands, watersheds, coastal dunes and along roadsides and railway tracks. It forms an open and closed type of thickener. Its habit varies from a shrub to a tree. It is extremely aggressive in its introduced ranges and can make an almost pure stand.

Climate variables are known to affect the presence, absence, distribution, reproductive success and survival of both native and non-native species. Environmental selection for traits that enhance reproduction in warm climates would enable the expansion of some invasive species. Furthermore, the availability of "empty" niches in the natural range, migration from natural enemies, and the ability to adapt to new habitats can enhance an invader's ability to respond positively to climate change (Jarnevich *et al*. 2014) [23]. Changes in the climate and atmosphere are provoking a wide variety of responses from invasive plants (Leishman and Gallagher 2016) [24]. The effectiveness of techniques for managing some invasive plant species may be affected by climate and atmospheric changes (Ziska and Dukes 2011) [25, 26]. As climate disruption increases, management of invasive plant species may change (Dukes 2011) [25, 26].

Conclusion

Invasive species are more flexible in their response to greater availability of resources when compared to native species; however, this flexibility is generally related to the benefit of fitness. Interestingly, natives maintain greater homeostasis when compared to growth between low and average resources availability (Davidson *et al*., 2011) [27]. The ecosystem's metabolic functions and disturbance regimes can be influenced by biological invasion (Vitousek, 1990) [30]. There may be significant feedback of biological invasions with regional and global climate (Field *et al.,* 2007*)* *[31]* In addition, invasive plant species benefit from atmospheric carbon dioxide enrichment and global warming more than native plant species (Liu *et al*., 2017) [28]. Although numerous studies have discussed potential threats to ecosystems from climate change and invasive plants in isolation, only a few studies have considered the interactive and potentially synergistic effects of these two factors on ecosystems (Thuiller *et al*., 2008) [29]. Therefore, an integrative study of climate change and biological invasion is required for the long-term management of invasive plant species.

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