Prosopis juliflora invasions and ecological dominance in the sacred groves of Western Haryana, India

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Abstract

The present study was conducted in the sacred groves of Haryana in the semi-arid regions. Prosopis juliflora is one of the most common invasive plant species and has varying degrees of ecological consequences. In Haryana, the vast semi-arid conditions has ideally favoured the invasion of P. juliflora including the sacred groves of the State. Therefore, the present study investigated the population structure of the P. juliflora in the two sacred groves of Haryana i.e. Daya (SG-I) and Kharkada (SG-II) with different degrees of invasion. The impact of the invasive tree on the native flora was also examined by the assessment of different ecological parameters like analytical characteristics of vegetation along with four diversity indices (Shannon-Weiner Index, Simpson Index, Pielou Index and Margalef Index).

The results of the study revealed that the sacred grove with low Prosopis invasion (SG-I) had high density and Basal area of native plant species as having significant values for the selected diversity indices and thus is better flourished in comparison to the highly invaded site (SG-II). It can be concluded that the native phytodiversity of the sacred groves of Haryana is in peril due to increasing P. juliflora invasion, thus efficient management strategies are required in this direction.

Keywords: Conservation, Invasion, Mesquite, Sacred groves.

Introduction

The areas of land or bodies of water that have a special spiritual importance to peoples are referred to as "Sacred Natural Sites" or "Sacred groves"[39]. Sacred groves are becoming more widely acknowledged as a traditional type of community-based conservation because of their significant cultural and religious significance to the local population[3,26]. Sacred groves can be found all across the world, but they are most prevalent in Africa and Asia[39]. But in the times of climate change and anthropogenic activities, sacred groves have not been immune to the current issue of global species invasion. Invasive species once enter into a natural ecosystem, then they take the advantage of opportunities and fill the gaps left by native species, further leading to their growth, establishment and change in community structure. *Prosopis juliflora*, also known as Mesquite (Family-Fabaceae), is a highly invasive species in alien habitats and is one of the top 100 invasive species around the world. It leads to alterations at the ecosystem level by forming monospecific stands and degrading the chemical as well as biophysical characteristics of the soil. *P. juliflora* proved beneficial for marginal, subsistence-based people in its natural habitat[6,40].

The tree was able to flourish in the kinds of harsh conditions and deficient soils. Every part of the tree might be used for a variety of things including medicine, food, fuel and cosmetics[37]. *P. juliflora* was introduced in more recent areas because of the popularity it had in its native habitat. Although several sources give different dates for the introduction of *P. juliflora* to India, it was unquestionably in the second half of the 19th century[11,40].

The primary goals were to employ *P. juliflora* as a prospective livestock feed and as a shade tree near homesteads. Numerous other uses of *P. juliflora* were discovered by farmers who were struggling financially. It may survive in a variety of geographical and environmental aspects. It may thrive on a variety of soil types including sandy, stony and heavy clay[20]. It can flourish in alkaline soils with salinities as high as those found in sea water[13]. However, *P. juliflora* soon started to occupy places it was not supposed to. It is also known that *P. juliflora* prevents nearby plants of other species from sprouting their seeds[32]. Additionally, it deters other plant species from growing close by. To accomplish this, it releases allelochemicals from its different parts like leaves, fruits and roots[25]. The invasion of *P. juliflora* species may have also changed the genetic makeup of native species, taxonomical diversity of plants, habitat structure and integrity, ecosystem productivity, tropic networks, nutrient cycling, soil nutrient properties, functional and phylogenetic diversity and ecosystem productivity throughout the world[15,49].

Haryana is an agrarian State in northern India with a very modest amount of forest cover, much of which is found in sacred groves and community forestry. But over time, human impact, ancient beliefs being lost and changing attitudes among people have degraded the sacred groves, allowing alien species like *P. juliflora* to flourish in these natural ecosystems.

Thereby, the present study investigated the population structure of the mesquite tree i.e. *P. juliflora* in two different sacred groves of Hisar district, Haryana. Our central research question examines the extent to which the perceived spread of this invasive tree species influences the native flora of these sacred groves.

Material and Methods

Study Area: Two sacred groves (SG), designated SG-I (Daya) and SG-II (Kharkada) in the Hisar district of Haryana, which are situated in semi-arid areas of the State and are impacted by the regional steppe climate, were chosen for the current study. A small amount of rain falls each year in Hisar amounting to roughly 459 mm and the average temperature is 25.1°C. The selected sacred groves are natural ecosystems and deep alluvial plains having significant biodiversity.

During the present study, the quadrat method was employed to assess the population structure of *P. juliflora* and to understand its impact on the native flora in the two sacred groves. A total of 15 quadrats on each sacred grove were plotted for the current investigation for vegetation sampling[5]. By gauging the trees' circumference at 1.37 m above the ground and subsequently classifying them according to their girth, the population structure of trees, or Girth-class Distribution (GCD), was examined for the two sites. Along with this, the density (D), basal area (B.A.) and important value index (IVI) of the flora were examined following Phillips[27] and Misra[21].

Subsequently, various species diversity indices were calculated following Shannon and Wiener index for diversity[33]; Simpson index for the concentration of dominance[34], Pielou index for species evenness[28] and Margalef index for species richness[19].

Results

During the present investigation, the two sacred groves were seen to exhibit different levels of *Prosopis juliflora* invasion as per the analytical characteristics obtained during the study. SG-II had almost ten times more density and basal area of *P. juliflora* in comparison to SG-I (Table 1). Other than this, the IVI value of the invasive tree was also very high on SG-II than SG-I, clearly indicating that SG-II is way more highly invaded by *P. juliflora* than SG-I.

Other than this, on the two sacred groves taken under study, the overall population of *P. juliflora* showed a positively skewed distribution with a significant fluctuation in the juvenile and large tree girth classes as shown in figure 2. The shape of the GCD of *P. juliflora* also differed between the two sacred groves. Although both the sites had their GCDs dominated by smaller trees in comparison to large trees. But, SG-I there was lower water availability showed an absence of large trees in higher girth classes, however in SG II with comparatively higher water availability. The individual trees in larger size classes were also present along with the smaller ones. In addition to this, there were 53% of juvenile plants in the entire population of Prosopis, indicating excellent recruitment rates.

While studying the impact of *P. juliflora* invasion on the native flora, no large difference could be observed in the number of native plant species (trees, shrubs, herbs and climbers) on the two sites. But their analytical characteristics varied significantly due to differences in the level of *P. juliflora* invasion (Table 1). The density of native trees was reported to be 250 Ind./ha on SG-I while on SG-II it was seen to be very low i.e. 75 Ind./ha. For shrubs, herbs and climbers, the density was calculated as 2325, 35935 and 962.5 Ind./ha on SG-I while 1037.5, 2820 and 30 Ind./ha on SG-II respectively (Table 2).

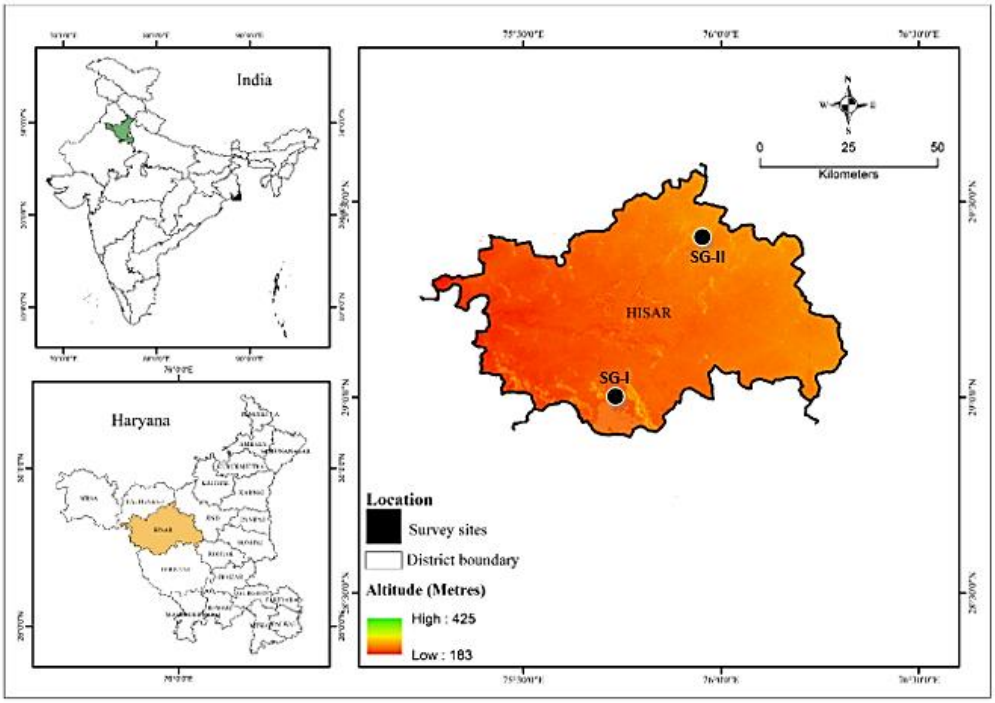

Fig. 1: Map of the selected study sites, showing the location of Sacred groves in Hisar, Haryana with respect to India.

Vegetation Sampling

Table 1
Analytical characteristics of *P. juliflora* representing the level of invasion on the selected sacred groves

S.N.	Parameter	SG-I	SG-II
1	D (Ind./ha)	57.5	567.5
2	B.A. (m^2/ha)	0.1483	1.5464
3	IVI	34.28	155.57
Abbreviations: D (Ind./ha)- Density (Individuals/hectare), B.A. (m^2/ha)- Basal area (m^2/hectare), IVI- Important Value Index.			

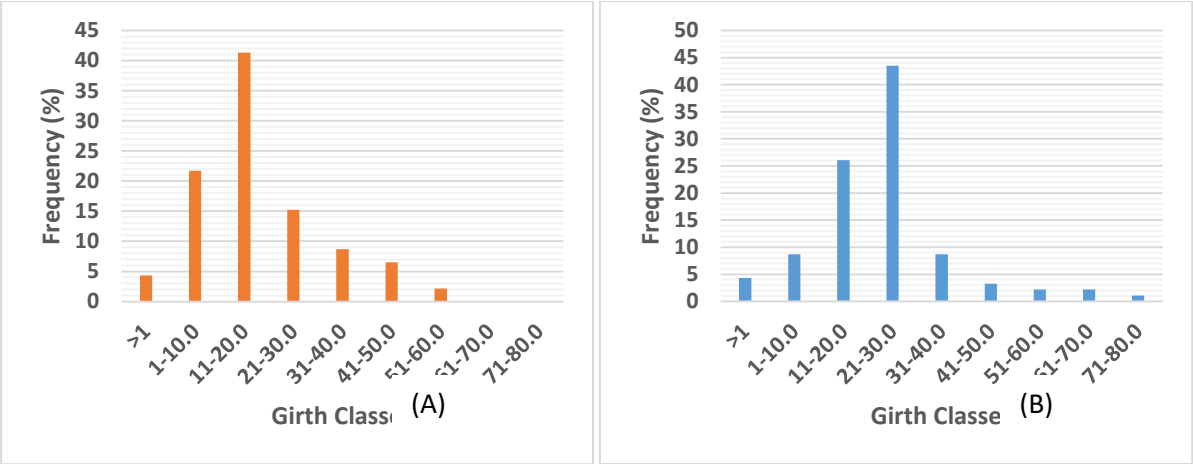

Fig. 2: Girth-class distributions of *Prosopis juliflora* in the sacred groves under study (A) SG-I and (B) SG-II.

Table 2
Analytical characteristics of native plant species under *P. juliflora* invasion on the selected sacred groves

S.N.	Habit	Parameter	SG-I	SG-II
1	Trees	Species number	7	9
		D (Ind./ha)	250	75
		B.A. (m^2/ha)	25.1729	3.01361
2	Shrubs	Species number	10	9
		D (Ind./ha)	2325	1037.5
		B.A. (m^2/ha)	4.74495	3.7837
3	Herbs	Species number	33	28
		D (Ind./ha)	35935	2820
		B.A. (m^2/ha)	0.34993	0.01229
4	Climbers	Species number	4	4
		D (Ind./ha)	962.5	30
		B.A. (m^2/ha)	0.02902	0.00012
Abbreviations: D (Ind./ha)- Density (Individuals/hectare), B.A. (m^2/ha)- Basal area (m^2/hectare).				

Table 3
Diversity indices calculated for the native plant species under *P. juliflora* invasion on the selected sacred groves

S.N.	Habit	Site	H'	CD	E	d
1	Trees	SG-I	1.951	0.15057	0.93826	1.221
		SG-II	1.671	0.30350	0.72589	1.342
2	Shrubs	SG-I	1.592	0.27784	0.69139	1.161
		SG-II	1.392	0.40993	0.63383	1.151
3	Herbs	SG-I	2.935	0.13569	0.85962	2.278
		SG-II	2.766	0.18146	0.80931	2.405
4	Climbers	SG-I	1.412	0.26878	0.85248	0.869
		SG-II	1.338	0.37339	0.81193	0.832

Similarly, the value of B.A. of native plant species was also found to be low in the sacred grove with the *P. juliflora* dominance. It was observed as 25.1729, 4.74495, 0.34993 and 0.02902 m^2/ha on SG-I and 3.01361, 3.7837, 0.01229 and 0.00012 m^2/ha on SG-II for trees, shrubs, herbs and climber species respectively. The SG-II also had a low value for the diversity indices like H', E and d in comparison to SG-I in the different strata (Table 2). But the value of CD was found to be higher in SG-II than in SG-I representing a high concentration of dominance comparatively (Table 3).

Statistical analysis: To understand the impact of *P. juliflora* invasion more clearly on the native flora of the selected sacred groves, Principal Component Analysis and Pearson Correlation were carried out on the data using R Studio (Figure 3). To visualize Eigen values, a scree plot was prepared, showing the percentage of variances explained by each principal component (Figure 3a).

The statistical analysis of the current data showed that D, B.A. and IVI of *P. juliflora* are positively correlated to each other but negatively correlated to most of the parameters of native flora i.e. D, B.A., H' and E but negatively correlated with CD and represented almost neutral correlation with d of native plant species. This can be visualized in figure 3b that the variables that are positively correlated, point to the same side of the graph while the variables that are negatively correlated, point to the opposite sides of the plot. Similarly, this can be understood from the heat map with colour gradients (Figure 3c).

Discussion

The sacred virgin forests or sacred groves are thought to have existed thousands of years ago during a time when human society was at its most rudimentary. The locals conserve sacred groves because they believe that they are home to the Gods, according to their cultural and religious beliefs and because they were kept untouched by the locals and contain vast amounts of biodiversity. The sacred groves' historical origins can be traced to the hunting, pre-agricultural and gathering phase of cultures[14].

As a result, it is thought that the origin of these virgin forests was pre-Vedic. The sacred groves have significant biodiversity that have enormous ecological significance; thus, they are crucial to the conservation of the natural world's biodiversity and vegetation.

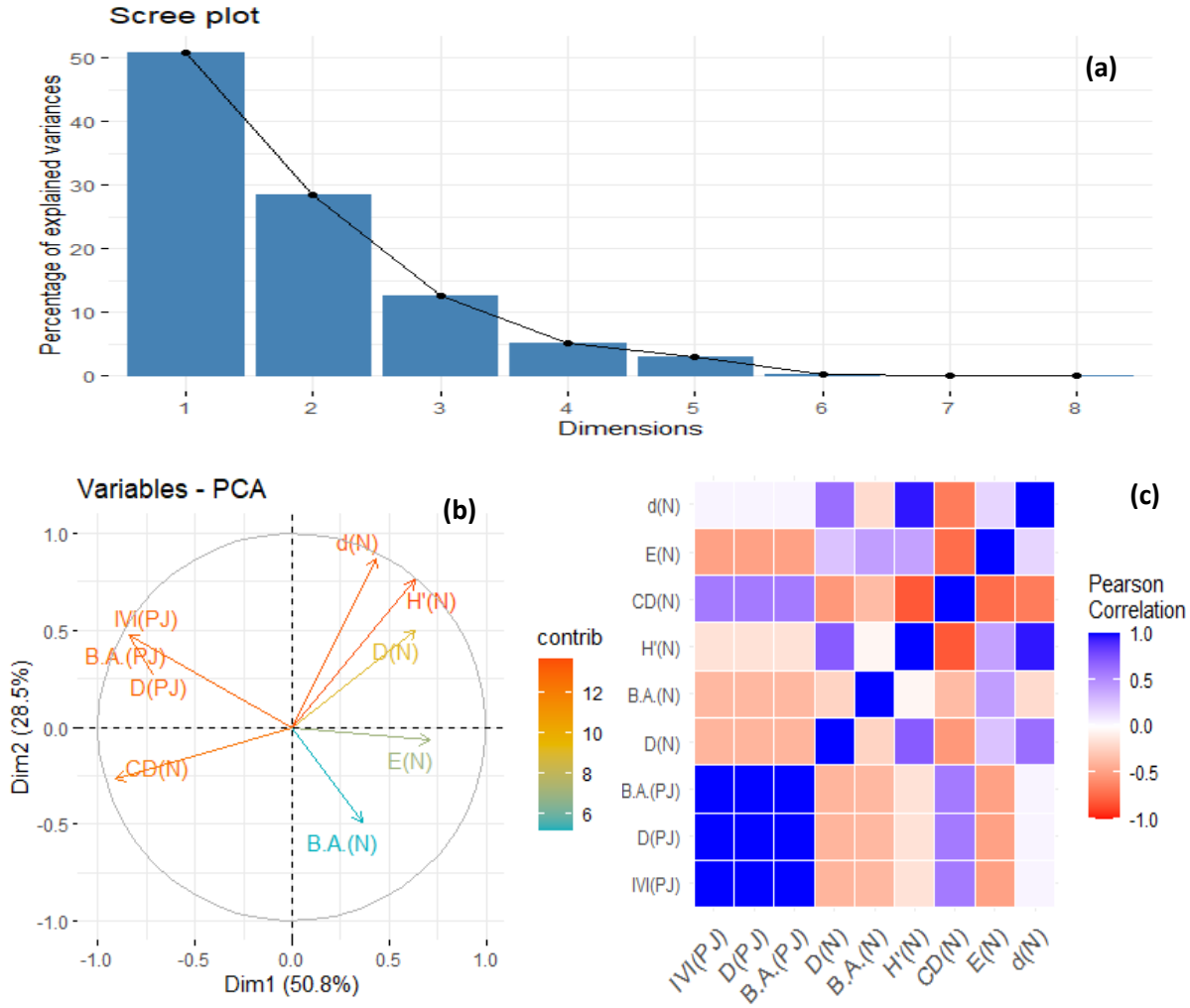

Fig. 3: Statistical analysis of the data- (a) Scree plot, (b) Principal Component Analysis variables graph and (c) Pearson Correlation heatmap (PJ- Prosopis juliflora and N- Native plant species).

It has been observed that spiritual beliefs or taboos that were essential to the preservation of sacred groves are eroding over time for a variety of reasons, making their current situation fairly problematic. Numerous sacred groves across the nation are under threat from various anthropogenic pressures brought on by urbanization, resource exploitation and population growth. A research on the condition of several sacred groves in the Himalayan region found that the traditional communities are being influenced by economic factors to forgo the groves' community-oriented protection and as a result, they are being exploited now[30,35].

The present study examined the invasion of *P. juliflora* and its impact on native phytodiversity in the two sacred groves of western Haryana. According to the analytical characteristics discovered throughout the analysis, the two sacred groves were found to have varying degrees of *P. juliflora* invasion. It was nearly ten times as abundant and had a larger basal area in SG-II than it did in SG-I (Table 1). In addition, the IVI value of the invasive tree was significantly higher on SG-II than SG-I, demonstrating that SG-II has been more heavily colonized by *P. juliflora* than SG-I.

The data also imply that populations of *P. juliflora* are not self-thinning and that intraspecific competition prevents greater size classes of trees by dominating the selected study sites. This results in a population structure that is significantly positively skewed and devoid of larger trees. The invading Prosopis stands in Kenya were also devoid of self-thinning[22].

Between the two sites, there were differences in the GCD of *P. juliflora* as well despite the fact that smaller trees as opposed to large trees predominated in the GCDs of both sites. However, SG-I, where there was less water availability, indicated a paucity of larger trees in higher girth classes, whereas SG II, where there was considerably more water availability, showed the presence of larger trees alongside the smaller ones. This can be supported by the study of Shackleton et al[31]. The absence of large trees in Prosopis population has also been reported during research carried out in South Africa but demonstrates good population structures with reverse J-shape.

There was little difference between the two areas in terms of the number of native plant species (trees, shrubs, herbs and climbers) while examining how the *P. juliflora* invasion affected the local flora. The extent of *P. juliflora* invasion, however, caused a considerable difference in their analytical characteristics (Table 1). On SG-I, native plant species' density was found higher, however on SG-II, it was seen to be very low.

Similar to this, it was discovered that native plants had a low value of B.A. in the sacred grove where *P. juliflora* predominated. In comparison to SG-I, the SG-II likewise scored poorly on diversity indexes like H', E and d in the various strata (Table 2). However, it was discovered that SG-II's CD value was larger than SG-I, indicating a significant concentration of dominance in comparison (Table 3).

This indicates that the invasive tree is highly influencing the community organization of native plants by controlling their growth. The decrease in diversity of native woody species correspondingly with an increase in *P. juliflora* spread can be supported by Gunarathne and Perera[17], Mworia et al[24] and Rembold et al[29].

A large number of researchers stated that *P. juliflora* leaves comprise water-soluble allelochemicals that are washed to the ground when rainwater falls on them, resulting in definite allelopathy[1,2,4,16,18,25]. The invasions of *P. juliflora* have also been seen to decrease the native seedling growth rates in half and increase native woody plant seedling mortality during a study carried out in Brazil[9].

P. juliflora's canopies discourage other growth, especially annuals[12]. The harmful consequences that this invading tree has on phytodiversity, demonstrate how seriously it threatens native plants[7,36]. The antimicrobial activity of the leaf litter harms the soil's cellulolytic and symbiotic nitrogen-fixing bacteria, imperilling phytodiversity and agricultural productivity[42].

In addition, the *Prosopis* population as a whole contained 53% of juvenile plants, indicating outstanding recruitment rates. According to the *Prosopis* population structures encountered during the present study, there are more juveniles[38] which indicate higher recruitment rates, but are equivalent to invasive populations observed by Muturi et al[23] and de Oliveira et al[8].

So, according to the present study's findings, the original above-ground vegetation of sacred groves is significantly impacted by the *Prosopis juliflora* in the semi-arid regions in western Haryana, leading to a loss of biodiversity. This may also affect other species such as birds due to lack of adequate nesting sites and food sources[10]. The *Prosopis* invasion has an impact on the local human populations also, which depend on many particular natural resources from local plant species such as fuelwood, fodder and medicines etc. It is to be managed effectively.

Conclusion

A national strategy is required for managing the invasive populations of *Prosopis* in the natural forest ecosystems including sacred groves. This will be made easier if people are aware of *Prosopis* population dynamics and how invasions affect local plant species. The present study suggested that invasions of *P. juliflora* are reducing the phytodiversity of the native species in sacred groves of Haryana. The native plant species are crucial for maintaining variety of ecosystem services, so *Prosopis* invasions must be controlled to prevent the loss of these functions.

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