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Spatial assessment of plant invasion across the urban protected area of Amchang Wildlife Sanctuary, Assam

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Abstract:
Spread across 78.84 km^2 towards the eastern fringe of Guwahati Smart City (26^{0}06'N-26^{0}13'N & 91^{0}50'E-91^{0}58'E) in Assam, Amchang Wildlife Sanctuary (AWLS) was notified in 2008 for conservation of Asian Elephant populations. The protected area faces anthropogenic pressure in the form of encroachment, NTFP collection, grazing and invasive alien plant (IAP) spread. Invasion pressure was assessed by undertaking field survey across 200m x 200m quadrats to map occurrence and spread of Ageratum conizoides, Chromolaena odorata, Lantana camara and Mikania micrantha. Spatial analyses with IAP severity as dependent variable and land use/cover, distance from road and distance from PA edge as independent variables yielded a strong and statistically significant positive correlation suggesting strong clustering and heavy localized invasion. Nearly 47% area was found to be invaded by IAPs, with 27% area being severely invaded, 9% highly invaded and 11% moderately invaded. Mikania micrantha was observed to be the most frequently occurring species. The occurrence of all the selected species was found to be positively correlated with canopy openness, being absent in pure patches of Very dense forest, pure Bamboo patches and Sal and Teak dominated areas along the periphery. The study thus identifies severely and highly invaded areas in urgent need of managing IAP populations to increase native fodder plant population, which may decrease instances of Elephant stray-outs. Further research on species specific biocontrol agents can be carried out along the periphery to initiate management of IAP spread along the sanctuary.

Keywords: Canopy density, Forest, Guwahati, Invasive species, LULC, Protected area.

1. Introduction:

Invasion by angiosperms in natural conditions across the globe has increased owing to the increased anthropogenic activities that affect species dispersal through travel and trade as well as habitat susceptibility through change in disturbance regimes (Pimentel et al., 2000). There is only a fraction of species that invade ecosystems, but the ones that do are serious threat to the natural biodiversity (Myers & Bazley, 2003).

Urbanization exacerbates invasions due to reduced competition and fragmented green spaces by creating disturbed habitats (Suarez et al., 2001) and habitat disturbance directly correlates with invasion success and fragmented habitats are more susceptible to invasions as edge effects increase light and nutrient availability (Alston & Richardson, 2006). Invasive species often exhibit traits that confer competitive advantages. Rapid reproductive rates enable invasive species to establish in uninvaded areas (Dorcas et al. 2012). Behavioral plasticity aids invasions by helping them adapt to diverse foods and habitats, enabling global spread (Koening, 2003).

Remote sensing technologies and GIS have become indispensable for mapping invasive species distribution and monitoring spread dynamics (Richardson et al., 2020). Systematic field surveys however, remain critical for ground-truthing remote sensing and invasion prediction outputs. Transect surveys in Kenyan savannas quantified the spread of invasive Opuntia stricta cactus, revealing a 15% annual increase in cover correlated with livestock-mediated seed dispersal (Witt and Luke, 2017). Quadrat sampling in U.S. forests documented that invasive earthworms (Lumbricus spp.) reduced native plant diversity by 30% within 5 years of establishment (Fisichelli et al., 2013).

Amchang Wildlife Sanctuary (AWLS), situated along the eastern fringe of Guwahati city, was notified in year 2008 to safeguard Asian Elephant population and is also home to other listed faunal species like Western Hoolock Gibbon, Chinese Pangolin, Slow loris etc. But, the urban expansion of Guwahati city as well as other infrastructure development around AWLS has been creating widespread pressure on the biological stock of the sanctuary (Kalita et al., 2014). Invasion by exotic species being a major driver of ecosystem degradation, a combined approach of grid-based survey and further spatial analysis of invasion severity was used to assess the spatial aspects of invasion across Amchang Wildlife Sanctaury.

2. Study area

Amchang Wildlife Sanctuary (AWLS) is situated towards the eastern fringe of Guwahati, the largest city and gateway of North-East India. Spread across an area of 78.64 km^2, it is located in the eastern fringe of Guwahati city, sharing the major geography, physiography and climatic factors with the city. It is spread between 26° 06’ - 26° 13’ N and 91° 50’ - 91° 58’ E. Erstwhile three reserve forests (RF): Amchang RF (53.18 km^2), Khanapara RF (09.96 km^2) and South Amchang RF (15.50 km^2), they were integrated in the form of this wildlife sanctuary on 19th June 2004 by the Government of Assam, published via the Assam Gazette No. 135 on 22nd June 2004.

This sanctuary was notified for conserving small populations of Asian elephant (Elephas maximus) and is enriched with a fauna of 44 species of mammals and 250 species of birds. Due to sharing its boundary with Guwahati city, urbanization has a major role in shaping the landscape, including the Eco-sensitive zone and sanctuary area of AWLS. Being divided into 2 blocks, Block 1 (53.18 km^2) and Block 2 (25.46 km^2) are separated by land use features like settlement, agriculture, linear infrastructure, with area-perimeter ratios of 1.49 (Block 1) and 0.58 (Block 2) indicating compact patch of Block 1 but irregular patch of Block 2, making it more prone to disturbance.

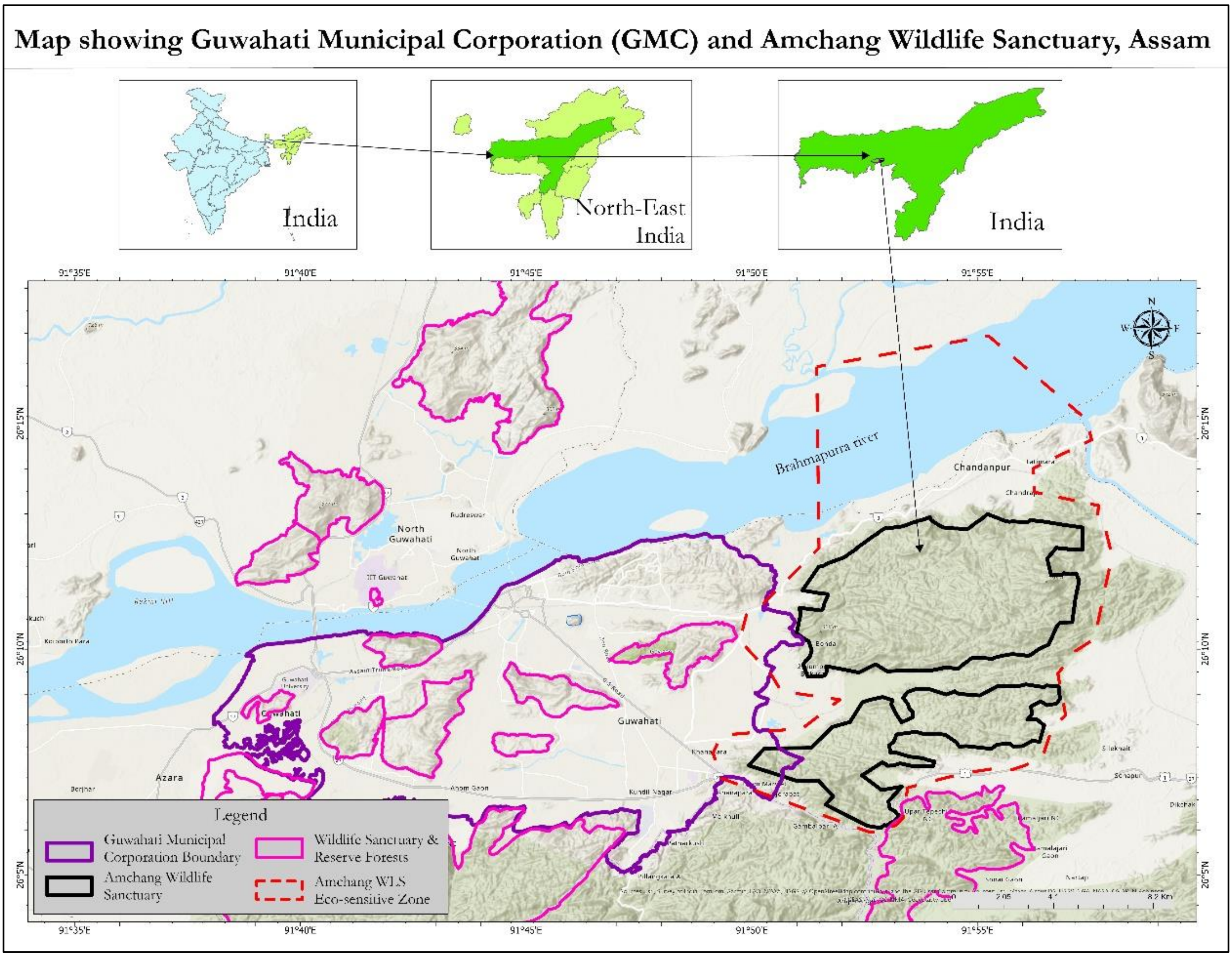

Figure 1 Study area map of Amchang Wildlife Sanctuary, Assam

3. Methodology

Based on secondary data on local dominance (Kar et al., 2015; Sarma et al., 2019), information from PA staff and global invasiveness (Global Invasive Species Database, 2025), 4 terrestrial invasive species - Ageratum conizoides, Chromolaena odorata, Lantana camara and Mikania micrantha were selected for this study. To assess the spatial distribution of selected invasive alien plant species (IAPs), a grid-based presence/absence survey across uniformly sized grids of 200m by 200m (Fig. 1), overlaid using ArcGIS Pro 3.4 software was performed to record the occurrence of selected species.

Presence was noted if at least one individual of a species was observed within the grid. Conversely, absence was recorded when a species was not detected despite thorough scanning of representative microhabitats within the grid. Each grid was surveyed by traversing it along transects or accessible paths to ensure comprehensive coverage. Species identification was carried out in situ using Kanjilal et al., (1938), and cross-verified with herbarium specimens. Data were recorded in binary format (1 = presence; 0 = absence) for each species in each grid. Presence/absence data for each invasive species was mapped across the study area using a uniform grid framework.

Invasion severity was computed by summing presence values across all invasive species per grid. These results were normalized by using a Scaled Severity Index (Archer et al., 2012) (1) to classify invasive species richness within surveyed grids. The index scales between 0 and 1 with areas where invasive species have not been detected as 0 and presence of multiple species being represented by higher values. All spatial analyses were performed using ArcGIS Pro 3.4.

$$\text{Scaled Severity Index (SSI)} = \frac{\text{Observed grid richness} - \text{Minimum grid richness}}{\text{Maximum grid richness} - \text{Minimum grid richness}} \quad (1)$$

Severity index	Level of severity	Summary
0	None	No invasion presence at the grid
0.01-0.20	Moderate	One selected IAP present
0.201-0.60	High	2-3 selected IAP present
>0.60	Severe	4-5 selected IAP present

Table 1. Summary of the Scaled Severity Index (SSI) used for mapping invasion severity

Spatial patterns of IAP occurrence were overlaid on land use/cover data of 2021 and assessed using Moran's I Global Spatial Autocorrelation. Spatial autocorrelation refers to the degree to which IAP occurrence and their associated data values tend to be clustered together (positive autocorrelation), dispersed (negative autocorrelation), or randomly distributed in space (Griffith, 2003). Ordinary Least Square and Geographically Weighted Regression spatial models were used to analyze the impact of land use/cover, proximity to road and forest edge on severity of invasion.

4. Results

Within the study area, a total of 2112 grids with 200m x 200m grid size were selected for mapping occurrence of selected IAPs, viz. Ageratum conizoides L., Chromolaena odorata (L.) R.M.King & H.Rob., Lantana camara L., Mikania micrantha Kunth across different land use/covers of the PA. 67.52% grids were found to be occupied by the selected IAPs. Across these surveyed grids, M. micrantha was found to be the most frequent, occurring in 55.26% grids, followed by L. camara in 27.84% grids, A. conizoides in 23.67% grids, and C. odorata in 17.42% grids.

Ageratum conizoides: The species was found present in 500 grids out of 2112 surveyed grids and was found across all the terrestrial land cover classes of this PA, with maximum spread of 91.2% in MDF, followed by 3.6% in OF, 2% in Scrub and in VDF, 1% in Settlement, 0.2% in Agriculture.

Chromolaena odorata: The species was found present in 368 grids out of 2112 surveyed grids, being absent in 1744 grids. It was found across all the land cover classes of this PA as well as in agricultural areas, with maximum spread of 87.23% in MDF, followed by 5.98% in OF, 3.53% in Scrub, 2.72% in VDF, and 0.54% in Settlement.

Lantana camara: The species was found present in 597 grids out of 2143 surveyed grids, being absent in 1546 grids. It was found across all the land cover classes of this PA, with maximum spread of 87.59% in MDF, 5.27% in OF, followed by 3.91% in Scrub, 2.04% in VDF, 1.02% in Settlement and 0.17% in Agriculture.

Mikania micrantha: The species was found present in 1432 grids out of 2143 surveyed grids, being absent in 711 grids. The maximum spread of 89.97% was found in MDF, followed by 5.74% in VDF, 2.74% in OF, 0.94% in Scrub and 0.60% in Agricultural area.

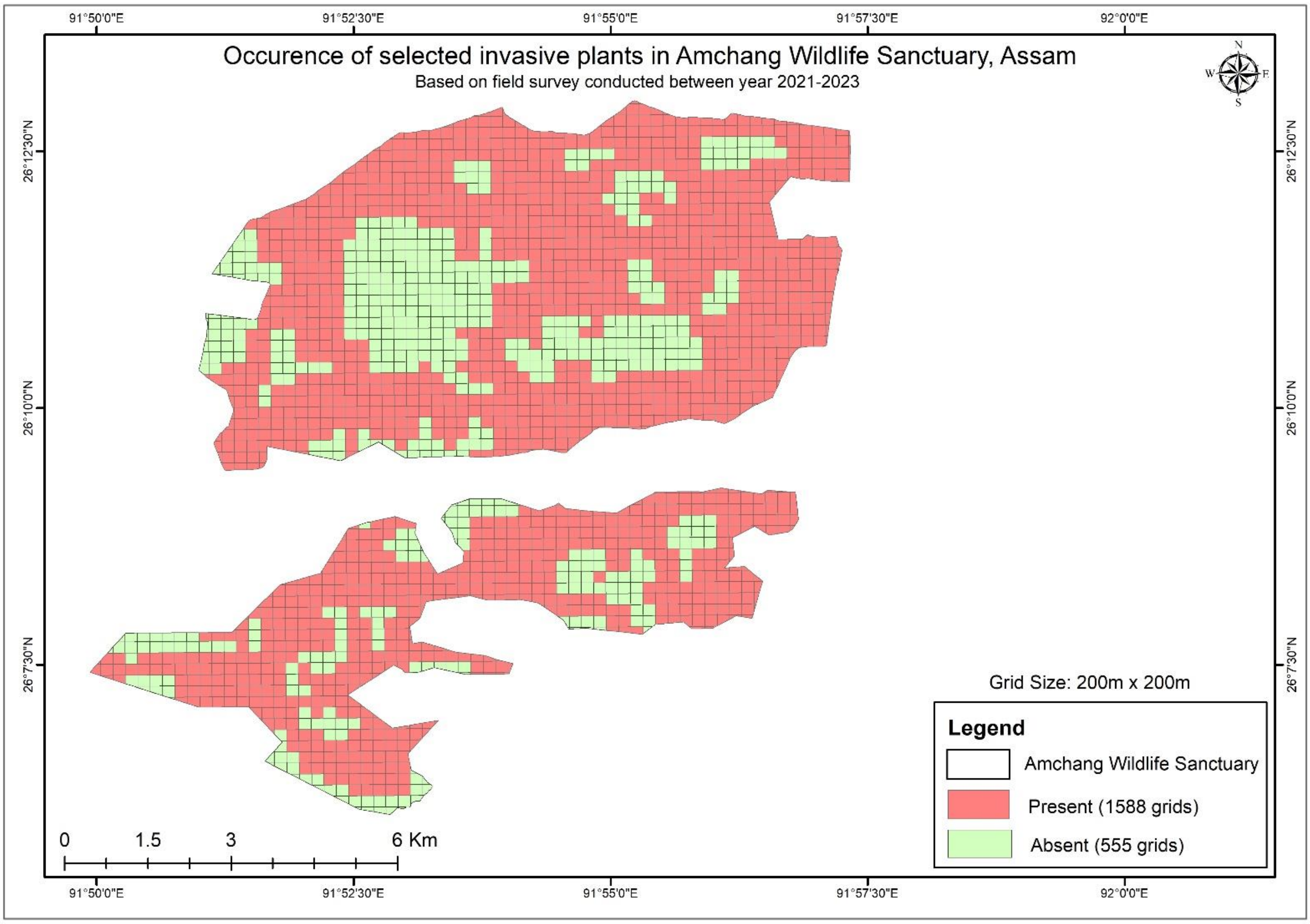

Figure 2 Occurrence of the selected species across Amchang Wildlife Sanctuary, Assam

Moran's I analysis was performed to assess the spatial autocorrelation in the presence/absence data of invasive alien plant species (IAPs). The result yielded a Moran's I value of 0.651 in case of L. camara, 0.585 in case of A. conizoides, 0.592 in case of M. micrantha, 0.622 in case of C. odorata with p-value < 0.001 in all cases, indicating a strong and statistically significant positive spatial autocorrelation for these species. This suggests that IAP presence in the study area is spatially clustered, likely influenced by shared environmental or anthropogenic factors across adjacent grids. The results indicate that the selected species tend to occur near each other spatially. Lantana camara has the highest Moran's I (0.651), suggesting strongest clustering and heavy localized invasion.

Species	Moran's Index	z-score	p-value
Ageratum conizoides	0.585	36.69	<0.001
Chromolaena odorata	0.622	39.06	<0.001
Lantana camara	0.651	40.83	<0.001
Mikania micrantha	0.592	37.11	<0.001

Table 2. Spatial autocorrelation of selected species across Amchang WLS using Moran's index

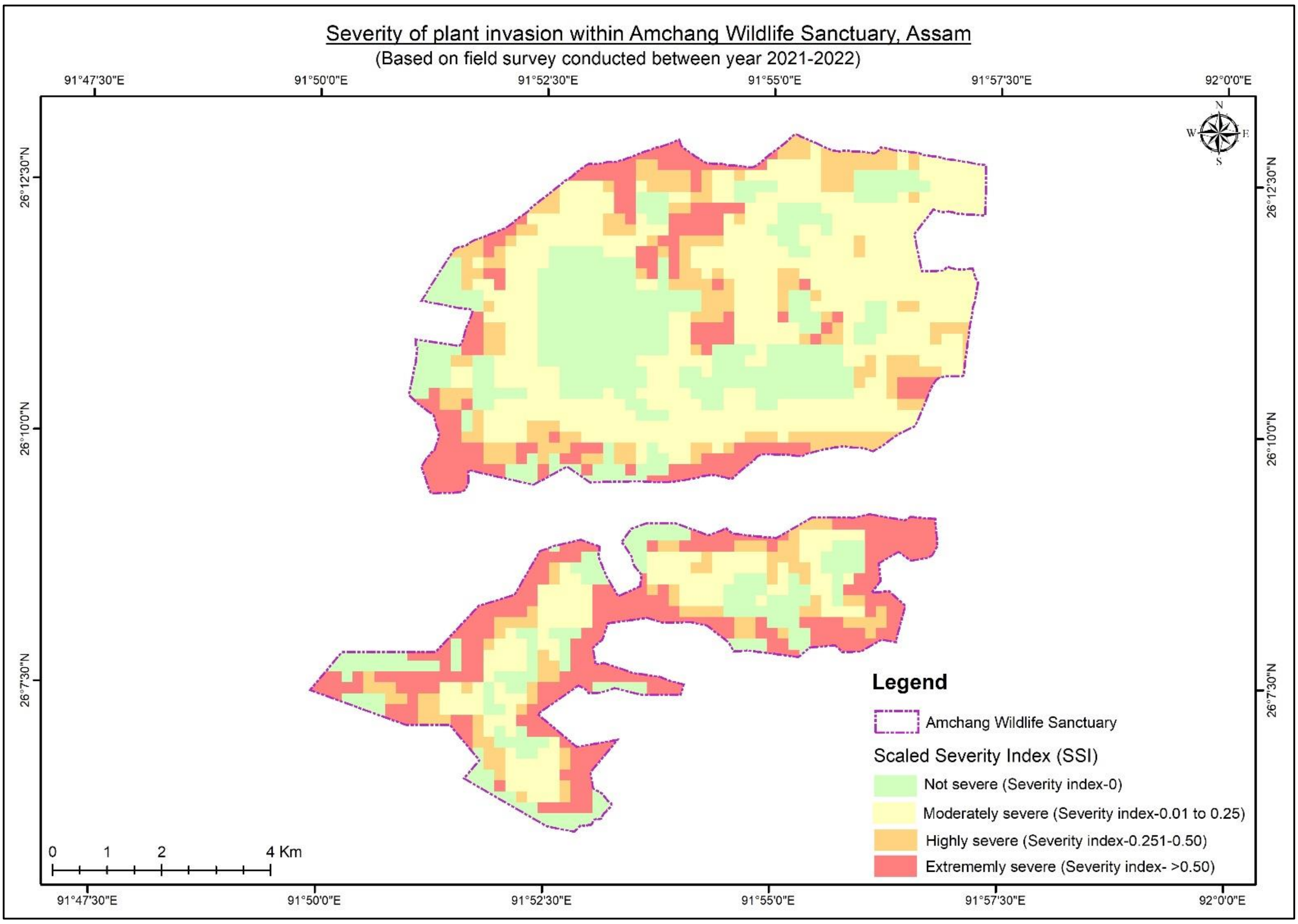

Figure 3 Severity of selected invasive species across Amchang Wildlife Sanctuary

With p-value < 0.001, there is less than 0.1% chance that the clustering of selected IAPs occurred randomly. Spearman rank correlation test was applied to identify the correlation between different canopy densities and spread of the selected IAS. Positive correlation was observed between the spread of A. conizoides (0.069), C. odorata (0.203), L. camara (0.139) and M. micrantha (0.166) and canopy openness across the study area.

5. Discussion

Ageratum conizoides L., Chromolaena odorata (L.) R.M.King & H.Rob., Lantana camara L., Mikania micrantha Kunth. are reported to be invasive in India (GISD, 2025). The spread of these selected IAPs across 2112 grids of 200m x 200m was observed, with their presence in 1426 grids, while the selected species were found to be absent in 686 grids.

Among the selected species, M. micrantha, native to South America, was found to be the most frequent. Its occurrence was observed to be highly spatially clustered, supporting its property as prolific disperser with the help of wind-dispersed seeds to outcompete native flora as described by Sankaran et al. (2014) in humid tropics of Kerala. The possibility of rapid propagation by vegetative means as well might be the reason behind clustered occurrence with wind and other propagation methods helping it to travel long distances as well (Banerjee et al., 2017).

L. camara was found to have the highest spatial clustering and heavy localized invasion due to the inherent property of this species in interruption of other species regeneration, and can be a precursor to differential depletion of native species including trees (Sharma and Raghubanshi, 2007). The seeds of L. camara follow endozoochory (dispersal by frugivorous birds and animals) as well as dispersal through water and fire (Sharma et al., 2005), which supports its occurrence along the forest edges used for grazing by domesticated cows, buffaloes and goats. There are several instances of controlled fire in these areas, which may also be the reason behind its spread. Relatively high spatial clustering was observed in case of C. odorata as well and was found frequently along forest edges, especially areas with grazing pressure. The occurrence of A. conizoides was observed with clustered occurrence due to its dominance in moist uplands and forest edges (Kaur et al., 2012). Seeds of A. conizoides follow anemochory (wind dispersal) as well, each plant being producer of about 95,000 seeds that have been reported to maintain 50% germination rate (Kaur et al., 2012). This property of the species is the reason behind its success across the study area, with occurrence along edges of VDF as well in addition to dominating OF and Scrub/Grass areas.

The results of correlation analysis between IAP spread and different forest covers indicate that all the selected species were found to show correlation with canopy openness. These findings suggest that canopy density plays a critical role in limiting the establishment and proliferation of terrestrial IAS, as denser forest canopies reduce light availability at the forest floor, thereby limiting the growth of light-demanding invasive species (Sharma and Raghubanshi, 2009). In contrast, lower canopy density provides ecological opportunities for invasion, particularly in disturbed or fragmented forests (Richardson et al., 2000). Lantana camara, Chromolaena odorata, Ageratum conyzoides, and Mikania micrantha are known to thrive in disturbed, open, or degraded forest edges due to their ability to grow rapidly and outcompete native flora (Dogra et al., 2010; Joshi et al., 2006). The weak negative correlation for M. micrantha ($\rho = -0.069$) may be attributed to its climber habit, allowing it to spread even in moderately shaded areas by using existing vegetation for support (Tripathi et al., 2012).

6. Conclusion

The protected area is located adjacent to Guwahati Metropolitan, resulting in high anthropogenic pressure along the western boundary. Eviction drive was conducted in year 2017 by the state forest department along the south-western border, yet, the sanctuary is still highly encroached, in addition to grazing pressure as well as NTFP collection. Such disturbance regimes impact the natural ecology of the protected area and is increasing the pressure of plant invasion. Forest degradation in the form of invasion by exotic species can be a precursor to habitat fragmentation and result in canopy openness.

Moran’s I analysis indicated a strong and statistically significant positive spatial autocorrelation for these species, which suggested that IAP presence in the study area is spatially clustered, likely influenced by shared environmental or anthropogenic factors across adjacent grids. This trend of disturbance, if unchecked, will degrade the quality of forest ecosystem, and as a result impact foremost the local climatic regime and increase the instances of human-wildlife (majorly elephant) conflicts. Considering the legal protection of a wildlife sanctuary, to decrease the pressure from invasion, manual removal is the most ethical way, even though it is highly labor intensive. The forest edges and canopy breaks can be planted with native fruit trees preferred by Asian elephants.

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