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Assessment on the distribution and spread of invasive alien plant species: the case of Zone 1 and 3 of the Afar region, Ethiopia

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ABSTRACT

The study was conducted with the aim of assessing the distribution and abundance of invasive alien plant species (IAPS) in two administrative Zones (1 and 3) of the Afar region. Data were collected using systematic sampling technique and regular intervals of 10 km were used during the field survey. The following weeds *Calotropis procera*, *Cryptostegia grandiflora, Jatropha curcas, Lantana camara, Opuntia stricta, Parkinsonia aculeata, Parthenium hysterophorus, Prosopis juliflora*, *Senna occidentalis,* and *Solanum incanum* were recorded in this study. *Prosopis* was found in 38% of the 91 sample waypoints in the altitude range of 347-1005 meters above sea level whereas *C. procera* was recorded in 28% of the interceptions between 347 m and 1010 meters above sea level. *P. hysterophorus* occurred in 15 % of the waypoints in the altitudes ranged from 603 to 1005 meters above sea level. *C. grandiflora* and *P. aculeata* were observed respectively in 3% and 6% of the interceptions while *L. camara* and *O. stricta* were recorded only at a single waypoint. Higher abundance levels were observed for *P. juliflora* and *C. procera*. The majority of the IAPS were found infesting diversified habitats such as road sides, cropland, grazing land, riversides, forest and habitation areas. Awash Fentale district had the highest IAPS richness by possessing all the recorded species. The detailed distribution maps of the identified IAPS were developed and prioritization and ranking of invasive species was made based on abundance levels. The results of this study can be used in invasive weed management or extension programs that aim to tackle major IAPS problems in the region.

Introduction

Invasive alien species are any organisms that are introduced deliberately or non-deliberately into a new habitat and consequently establish themselves, invade and overtake the native fauna resulting in negative impacts on human livelihood and local biodiversity (Witt, 2010). Ethiopia is one of the countries where invasive alien plant species (IAPS) are heavily threatening the diverse

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agro-ecological systems; thus, the problem has recently become widespread across the country (Shiferaw et al. 2018). There are over 22 invasive plant species in Ethiopia among which *Eichhornia crassipes*, *Euphorbia stricta, Lantana camara, Parthenium hysterophorus* and *Prosopis juliflora* are indentified as causing major problems in this country (Etana, 2013). IAPS are causing huge economic and ecological losses by spreading at an alarming rate to national parks, rivers, lakes, power dams, and urban green areas (Hailu et al. 2004, Taye et al. 2009). The ever growing human population is also exerting pressure on natural resources of the country causing significant changes in land use patterns leading to conversion of a large mass of land to agriculture, mining, construction and other uses (Taye, 2007). These situations in part create ideal conditions for IAPS to take over the environment and further expand their geographical range as the natural ecosystem increasingly becomes unsuitable to support the native biodiversity (Taye, 2007; Taye et al. 2009).

Particularly in the Afar Region, people are mainly pastoralists surviving on livestock rearing or combining crop cultivation (agro-pastoralism) but the invasion of invasive plants along with periodic droughts has been creating menaces to the subsistence livelihood of the Afar community (Etana, 2013). The negative impacts of *Prosopis juliflora* invasion in particular have been posing serious threats on their food security, livelihoods as well as the environment; and there have also been considerable declines in livestock production and productivity due to the loss of dry season forage species (Dubale, 2006). Reduction in availability of palatable indigenous pasture species such as *Chrysopogon plumulosus*, *Cenchrus ciliaris* and *Setaria acromelaena* was observed in the region; indigenous trees such as *Acacia tortilis*, *Acacia senegal* and *Acacia nilotica* have also declined in the rangelands due to the invasion. Pods and branches of these trees were the main dry season feed sources for livestock (Dubale, 2006). Implementation of urgent measures to slowdown and control invasive plant species is a vital step towards ensuring the reduction of ecological and socio-economic threats of IAPS in the Afar region. Hence, understanding the extent of invasion, distribution and abundance is very essential for effective implementation of control measures. Precise information on large scale abundance and distribution of the invasive plants would be very important for designing future mitigation measures to tackle the negative impacts of IAPS. The present study was conducted to assess the distribution and spread of invasive plants in two administrative Zones (1 and 3) of the Afar region, Ethiopia.

Materials and Methods

Study area

The data were collected in 2010 growing season in the administrative zones (Zone 1 and 3) of the Afar region, Ethiopia. Zone 1 has seven districts namely: Elid’ar, Dubti, Asayita, Afambo, Mille, Chifra and Ade'ar, which are further divided into 95 sub-districts covering a total area of 2,179,188 ha. Its average annual temperature is 34.58 °C with mean annual rainfall of 95.06 ml. The Zone's soil aggregation is estimated to be 53.32% loamy, 35.96% sandy, 9.29% clay and 1.43% black soil. The Zone has permanent rivers that serve for different purposes such as Awash, Elid'ar, Dobi and Bure (PARDB, 2009). Zone 3 is comprised of six districts namely: Awash Fentale, Argoba, Amibara, Buremudayitu, Dulecha and Gewane, which included 71 sub-districts covering a total area of 840,943 ha (PARDB, 2009). The average annual temperature is 29.33 °C with mean annual rainfall 572.5 ml. About 45.33% of the Zone's soil aggregation is estimated to be loamy while 33.83% and 20.83% are sandy and clay soil, respectively. Permanent rivers such as Awash, Bulga, Filwuha, Koka, Aware, Ghacheni and Flambo flow through Zone 3. Crops like maize, sesame, tomato, sugarcane, onion etc. are also cultivated in this Zone. Over 513,267 ha of land is covered with grazing land whereas, about 267,777 ha of land is estimated to be relevant to irrigation and rain driven agriculture (PARDB, 2009).

Sampling techniques for IAPS distribution and abundance

The study was conducted in spring, winter and autumn seasons starting from October until mid-April. The survey was carried out by traveling with vehicles along all accessible roads across the two Zones. Interceptions were made at every 10 km intervals and the altitude, distribution, abundance, habitat, landform and other remarks were recorded for all respective interceptions or waypoints. The coordinates of the geographical locations and the altitudes were recorded using hand held GPS (Garmin 60™).

Data analysis and mapping

The gathered data were analyzed using Arc GIS 9.1 software and the abundance and distribution maps for the major IAPS were developed. Infestation levels for each sample waypoint were plotted on each map for each IAPS recorded. The abundance levels for every IAPS at each sample point were determined by visual estimation based on five scoring rates and these were decided according to expert's judgment as described in Wittenberg (2004). The relative abundance level scoring rates used were: 0- 5%= Present, 5-15%=Rare; 15-30%=Occasional; 30-50%=Frequent; 50-75%=Abundant; 75-100%=Very abundant. The relative rating percentages used in these scoring schemes were indicators of relative coverage of the targeted IAPS on the land on which they were found as compared to the local vegetation. The relative frequency of each IAPS over altitudinal variation and different land use or habitat types was analyzed using Microsoft Excel® 2007 program.

Results and Discussion

A total of 91 waypoints or interceptions were made at 10 km intervals during the field survey and a total of ten invasive species were found and recorded. These were *Calotropis procera*, *Cryptostegia grandiflora, Jatropha curcas, Lantana camara, Opuntia stricta, Parkinsonia aculeata, Parthenium hysterophorus, Prosopis juliflora*, *Senna occidentalis,* and *Solanum incanum*. Among these IAPS, three of them (*C. procera, P. hysterophorus* and *P. juliflora*) were already well established in the survey area whereas score of others were observed to be at their early phases of invasion.

Distribution and abundance of Prosopis juliflora

From the overall 91 waypoints or interceptions made during the field survey, *Prosopis juliflora* was found on 52 sites and it was absent from the remaining 39 samples. Most of its occurrence (29 waypoints) was observed in Zone 3. Even though it was not recorded in Elid'ar and Chifra districts, high infestations were observed in Amibara district. Generally, it was more or less evenly distributed over many sites (Figure 1). The plant had been frequently abundant (30-50%) on about 13 interceptions. It had very abundant (75-100%) and abundant (50-75%) infestation levels respectively at Amibara and Dubti districts (Figure 2). The altitude within which *Prosopis* was recorded ranged from 347 m to 1005 m a.s.l. with the mean altitude of 620 m a.s.l. (Figure 1). The frequency analysis showed that most of *P. juliflora* occurrence (26.92%) was observed in the altitude range of 300-400 m a.s.l. and the least (1.92%) was found between 1000 m and 1100 m a.s.l (Figure 3). This result might suggest that the species is more adaptable to areas of lower altitudes. However, some evidence from other countries showed that the weed was also less commonly adapted to habitats of higher altitudes. (Pasiecznik et al. 2001; Zewdie and Worku, 2009).

About 32.69% of the sample waypoints in which *Prosopis* occurred were on roadsides followed by habitation areas (26.92%). The least occurrence of the species was found in forests (7.69%) (Figure 4). This result indicated the domination and colonization of *Prosopis* along roadsides. Similarly, Shashitu (2008) also observed that *Prosopis* invasion was high around roadsides than other habitats since *Prosopis* seeds were distributed from one place to another by animals through their dung along roadsides. *Prosopis* infestation around habitation areas ranged from abundant (75-100%) to frequent (30-50%) levels (Figure 4). Generally, the plant showed its ability to invade diversified habitats in the surveyed areas. The adaptability of *Prosopis* in different habitats is mainly attributed to the ability of the plant to produce many, small and hard seeds that can survive after passing through the digestive system of animals, attractive and rewarding pods for animals, accumulation of long-lived seeds in the soil, ability of seedling survival under stressed conditions, ability of regeneration and fast coppice growth from stumped/damaged trees (Hailu, 2002; Ameha, 2006).

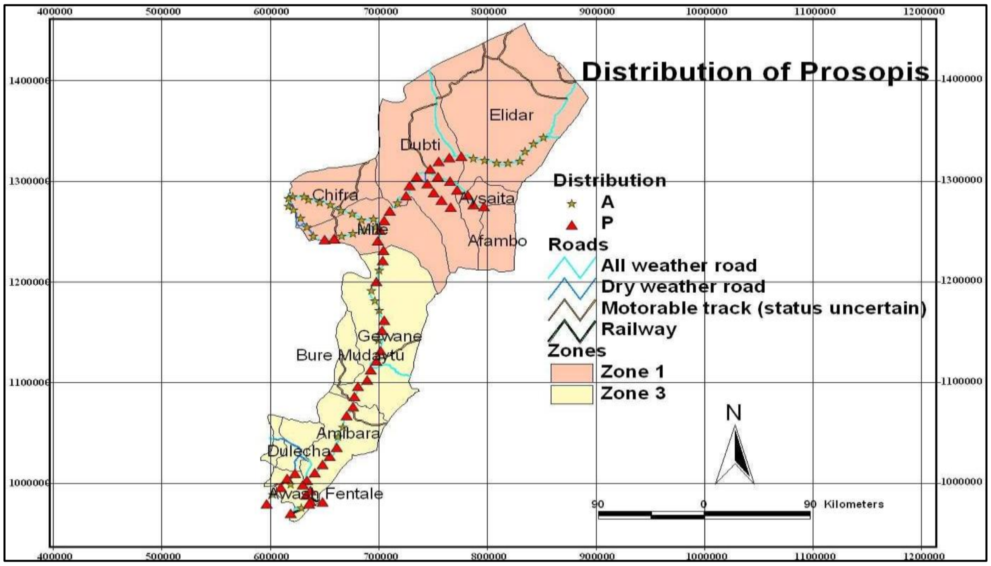

Figure 1. Distribution of *P. juliflora* in Zone 1 and 3 of the Afar region (A-Absent; P-Present).

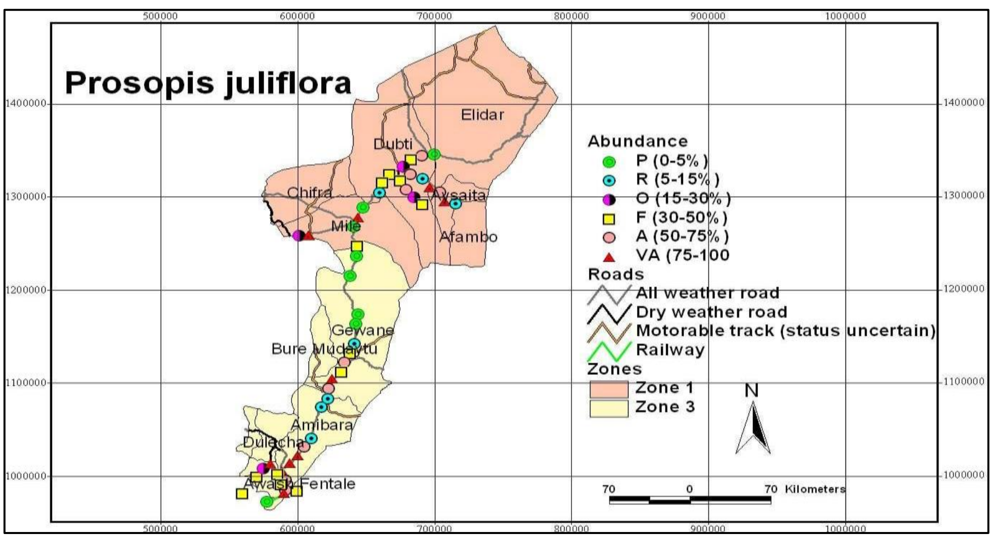

Figure 2. Abundance of *P. juliflora* in Zone 1 and 3 of the Afar Region (P-Present; R-Rare; O-Occasional; F-Frequent; A-Abundant; VA-Very abundant).

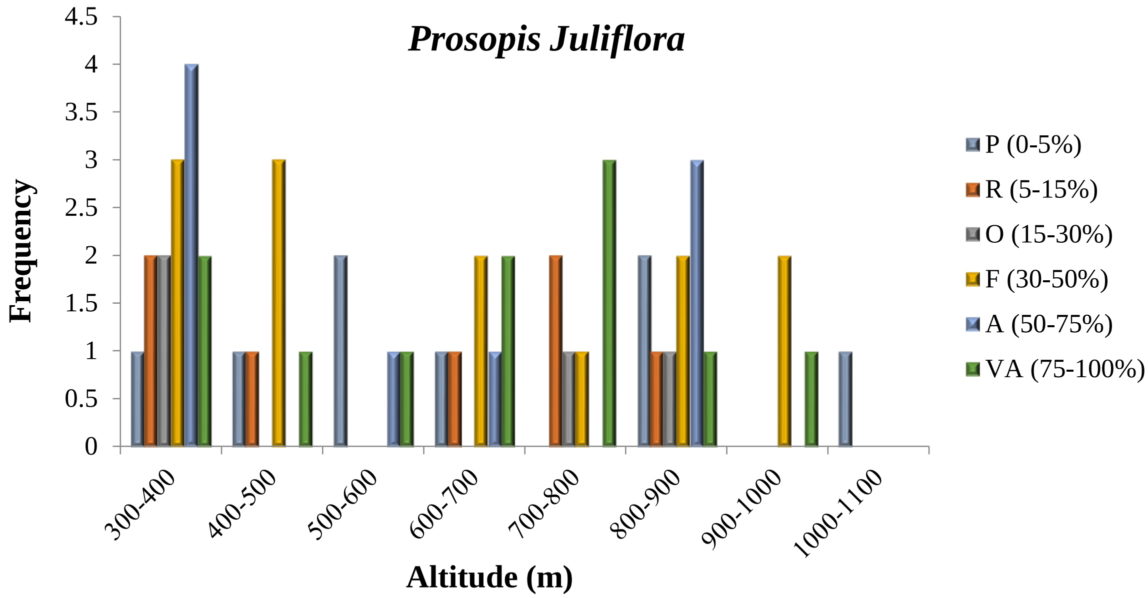

Figure 3. Relative abundance of *P. juliflora* over altitudinal variation in Zone 1 and 3 of the Afar region (P-Present; R-Rare; O-Occasional; F-Frequent; A-Abundant; VA-Very abundant).

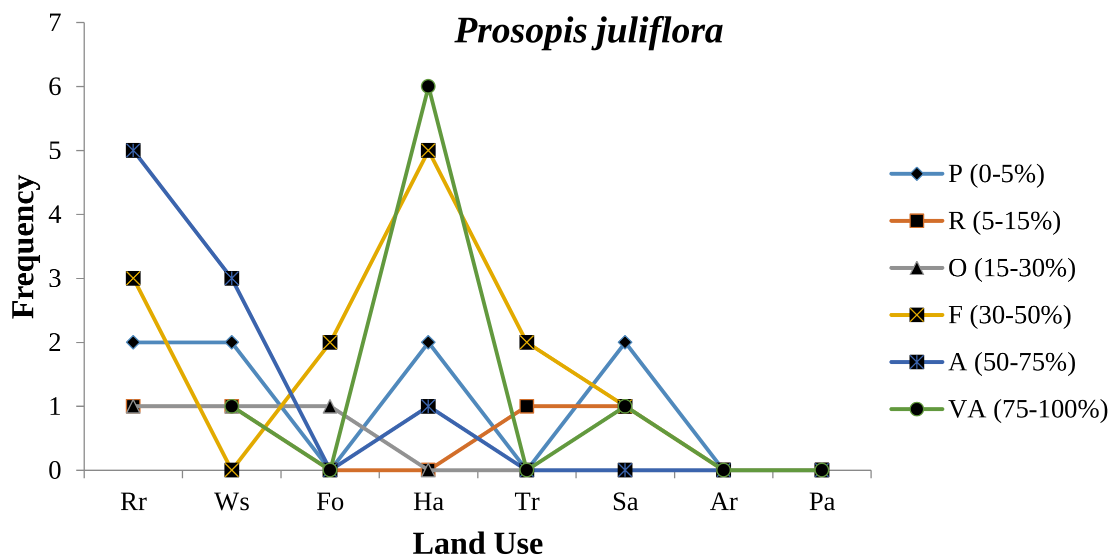

Figure 4. Abundance of *P. juliflora* over land use or habitats in Zone 1 and 3 of the Afar region (Rr-Road side; Ws-Wasteland; Fo- Forest; Ha- Around habitation; Tr-Transformed; Sa-Savanana, Ar-Arable, Pa- Pastoral Area) (P-Present; R-Rare; O-Occasional; F -Frequent; A-Abundant; VA-Very abundant).

Distribution and abundance of Parthenium hysterophorus

Parthenium was found on 21 waypoints out of 91 in which most of them (85.71%) were recorded in Zone 3 whereas it was found in only one district in Zone 1 (Chifra). About 33.33 % of the occurrence was recorded in Gewane district (Figure 5). The most abundant infestation was observed in Chifra followed by Gewane and Amibara (Figure 6). The altitude within which *Parthenium* abundance recorded ranged from 603 m to 1005 m a.s.l with the mean altitude of 820.23 m. About 28.57% of its occurrence was observed in the altitude range between 800 m and 850 m a.s.l. and the least (9.52%) was found in the altitudes of 650-750 m a.s.l. (Figure 7). This result revealed that the species preferred to grow at relatively higher altitudes than *Prosopis* while it was also showing its ability to grow in lower altitudes. Taye et al., (2009) reported that *Parthenium* occurrence ranged from hot arid and semi-arid low altitude to humid high-mid-altitude areas (900-2500 m a.s.l.). In contrast to this, it has been observed in the present study that the species had also been infesting areas at altitudes lower than 900 m (as low as 600 m).

Our study confirmed the report by Chamberlain and Gittens (2004) who observed that *Parthenium* infestation occurred in areas with summer rainfall greater than 500 mm per annum because all areas (Except Gewane district) in which *Parthenium* occurrence recorded in the present study had more than 500 mm annual rainfall. However, according to CDO (2019), Gewane district had 466 mm rainfall per annum and our study showed that frequent (30-50%) and abundant (50-75%) levels of *Parthenium* infestations were observed in this district. This might suggest that the plant could also manage to adapt relatively drier areas; and the proximity of Gewane to the neighboring districts, where annual rainfall exceeds 500 mm, could also be the reason for the weed's subsequent establishment.

The weed had mostly invaded roadsides (42.86% of the samples) having abundant (50-75%) and frequent (30-50%) levels at seven sites (33.33% of the 21 waypoints) followed by habitation areas, savanna and forest habitats (14.29% each) (Figure 8). A very abundant (75-100%) *Parthenium* infestation was observed in habitation areas during the field survey while it is found rarely (5-15%) on wastelands; hence showing the plant's preference to disturbance. Taye et al., (2010) have also observed *Parthenium* infestations along road sides, habitation areas such as towns, waterways and crop lands. Similar findings were reported elsewhere in different parts of the country (Berhanu et al. 2015; Jemal and Taye 2015; Amare et al. 2017; Reda and Tewelde, 2018). Our results are also in line with Mcconnachie et al. (2011) who reported the suitability of disturbed habitats such as roadsides, railway tracks, building areas and agricultural areas for *Parthenium* establishment because of lack of competition. Generally, similar to *Prosopis*, *Parthenium* has also been observed invading diversified habitats in the present study. Lakshmi and Srinivas (2007) and Javaid and Adrees (2009) also made similar observations elsewhere in the world. Some of the mechanisms for wide dispersal of *Parthenium* weed are through movement of animals, flooding, farm machinery or vehicles, stock feed and to a lesser extent by the wind (Kaur et al. 2014).

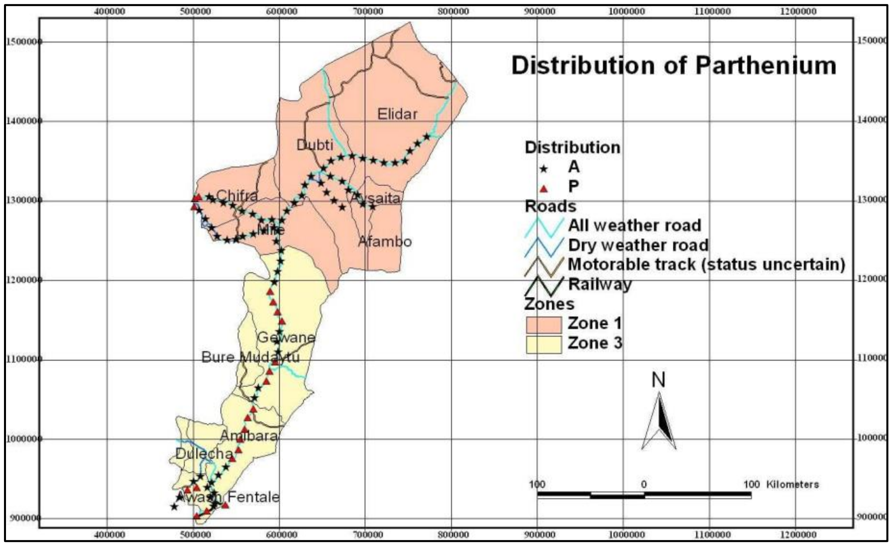

Figure 5. Distribution of *P. hysterophorus* in Zone 1 and 3 of the Afar region (A-Absent; P-Present).

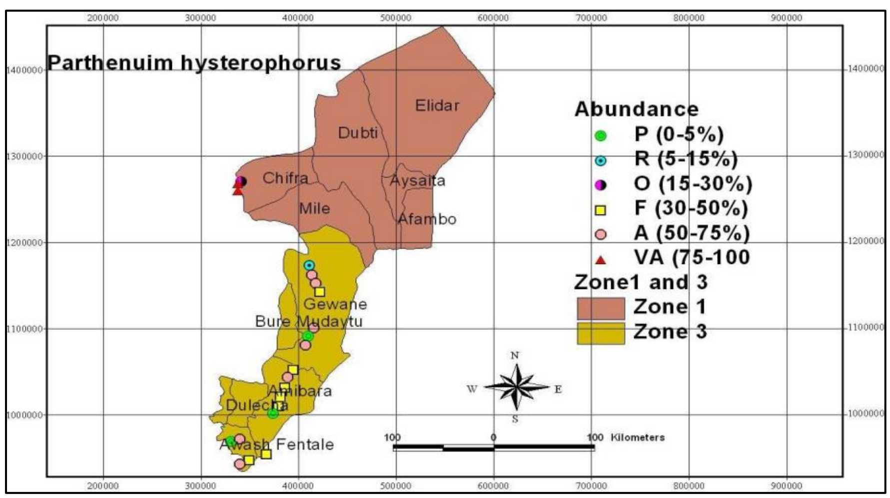

Figure 6. Abundance of *P. hysterophorus* in Zone 1 and 3 of the Afar Region (P-Present; R-Rare; O-Occasional; F-Frequent; A-Abundant; VA-Very abundant).

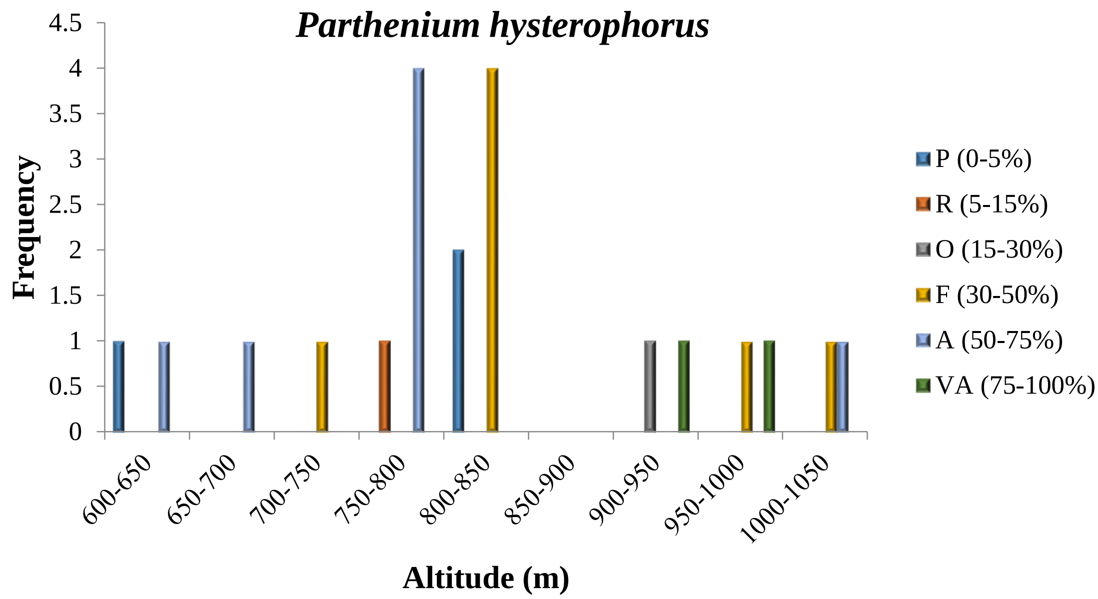

Figure 7. Relative abundance of *P. hysterophorus* over altitudinal variation (P-Present; R-Rare; O-Occasional; F -Frequent; A-Abundant; VA-Very abundant).

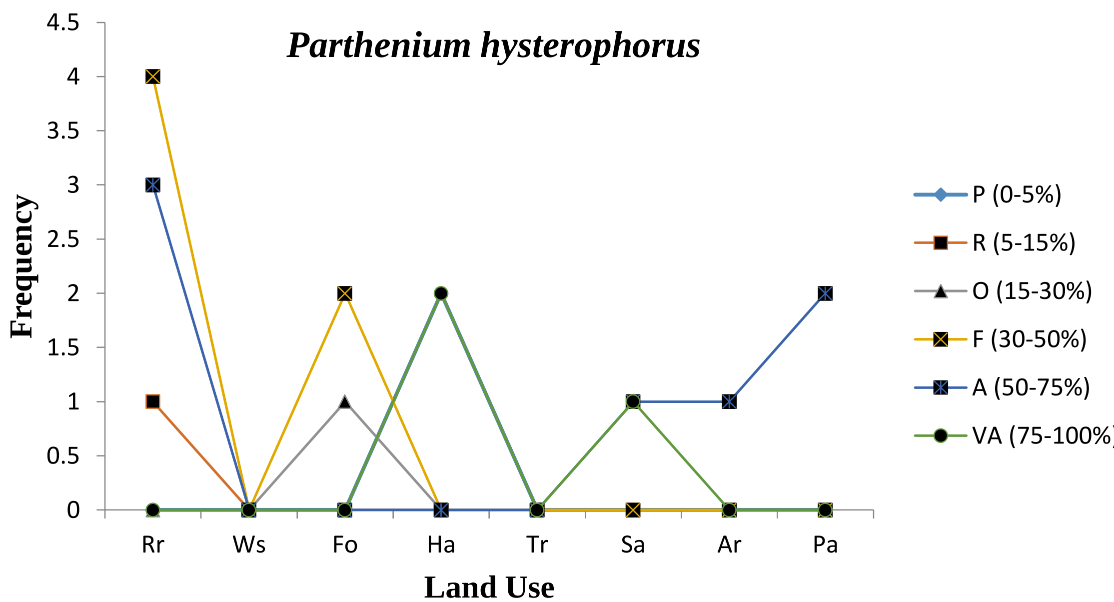

Figure 8. Abundance of *P. hysterophorus* over land use or habitats (Rr- Road side, Ws-Wasteland, Fo- Forest, Ha- Habitation area, Tr- Transformed, Sa- Savanana, Ar- Arable, Pa- Pastoral area) (P-Present; R-Rare; O-Occasional; F -Frequent; A-Abundant; VA-Very abundant).

Distribution and abundance of Calotropis procera

Calotropis procera was recorded in 39 waypoints from which 58.97% of them were located at Zone 3; Awash Fentale district had the highest percentage at about 30.77 % followed by Chifra at 23.07% (Figure 9). It had been recorded in 28.21% of the way points having a scattered occurrence (5-15%) while it was observed covering the land very abundantly (75-100%) only in few occasions (7.69%) (Figure 10). *C. procera* was observed in the altitude range of 347 m to 1010 m a.s.l. (784.25m mean altitude). Most of its occurrence was observed in the altitude range between 700-900 m a.s.l. (28.21%) and the least (9.52%) was between 600 and 700 m a.s.l. (Figure 11). This may indicate that the species favors relatively lower altitudes than *Parthenium* while still showing its ability to grow in higher elevations. The minimum range, however, is almost identical with *P. juliflora* indicating similar habitat preferences of the two species over the study area.

The majority (30.77%) of the sample waypoints for which *Calotropis* occurred were on roadsides followed by forest areas along with river beds and habitation areas (23.77% and 20.51%, respectively) (Figure 12). Ellison and Barreto (2004) and Sobrinho et al. (2013) have reported similar *C. procera* invasions in Brazil where it posed problems on roadsides, pasture lands, natural abandoned land and savannah ecosystems. Csurhes (2009) has observed most abundant infestation of in northern Australia on disturbed sandy sites such as dunes, water courses, along road sides, sparsely vegetated arid and semi-arid grassland. In addition, *C. procera* invasions have also been reported in different parts of the world (Linney, 1988; Wagner et al. 1999; Parsons and Cuthbertson, 2001; Grace, 2006).

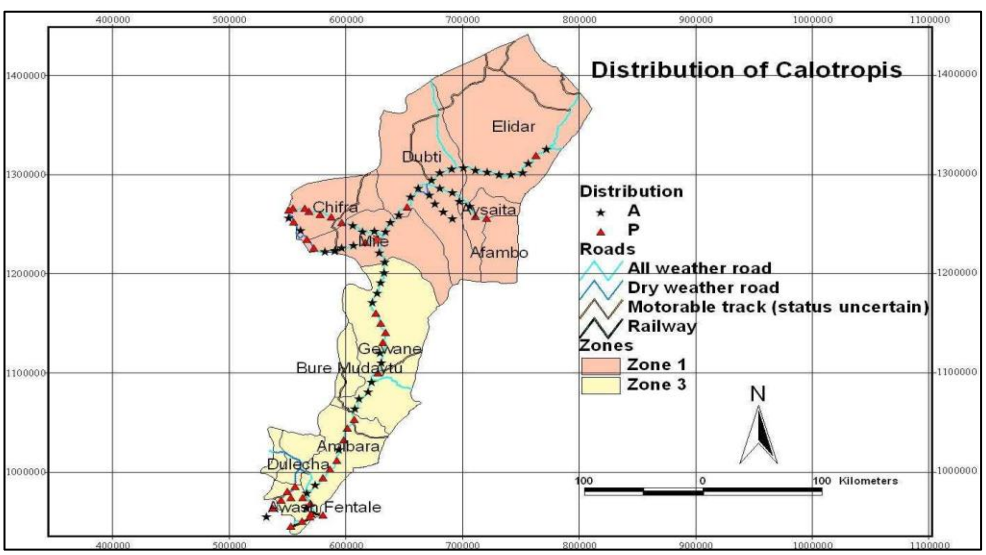

Figure 9. Distribution of *C. procera* in Zone 1 and 3 of the Afar region (A=Absent; P=Present).

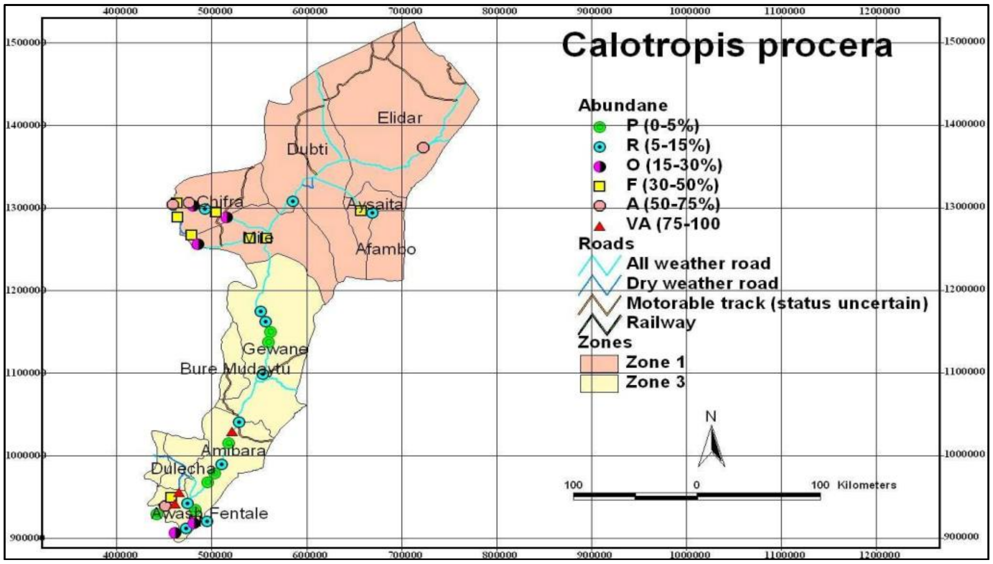

Figure 10. Abundance of *C. procera* in Zone 1 and 3 of the Afar Region (P-Present; R-Rare; O-Occasional; F-Frequent; A-Abundant; VA-Very abundant).

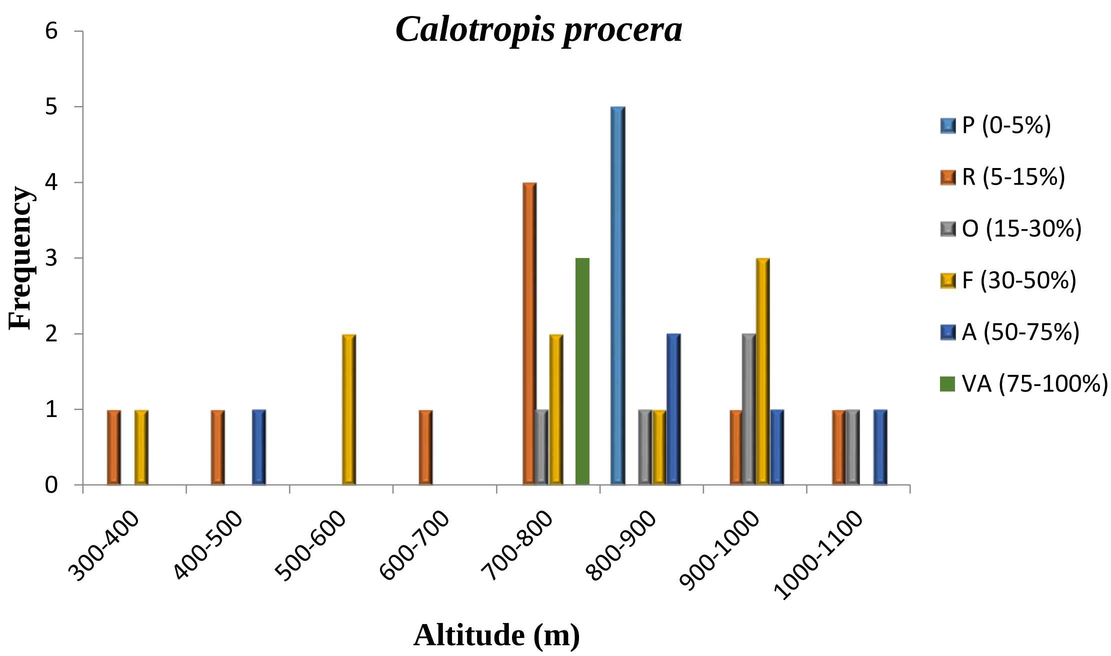

Figure 11. Relative abundance of *C. procera* over altitudinal variation (P-Present; R-Rare; O-Occasional; F-Frequent; A-Abundant; VA=Very abundant).

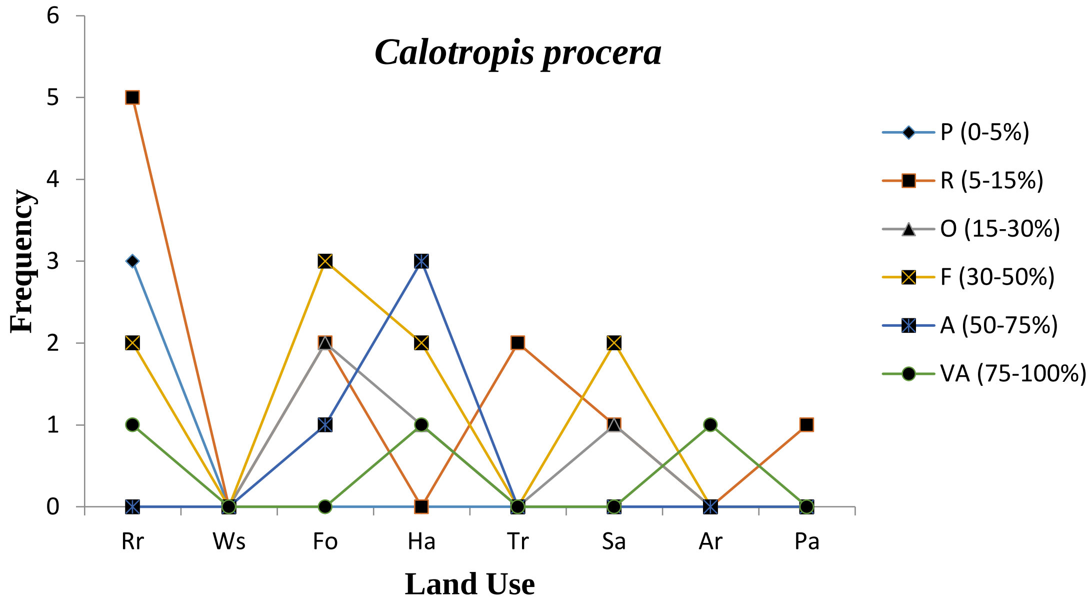

Figure 12. Abundance of *C. procera* over land use or habitats in Zone 1 and 3 of the Afar region (Rr- Road side, Ws-Wasteland, Fo- Forest, Ha- Habitation area, Tr- Transformed, Sa- Savanana, Ar- Arable, Pa- Pastoral area) (P-Present; R-Rare; O-Occasional; F-Frequent; A-Abundant; VA-Very abundant).

Distribution and abundance of emerging IAPS

The results of the field survey revealed that *Cryptostegia grandiflora*, *Opuntia stricta* and *Lantana camara* have been found only in Awash Fentale district of Zone 3 whereas *Parkinsonia aculeata*, *Solanum incanum* and *Senna occidentalis* were recorded only in Awash Fentale and Chifra districts. Thus, Awash Fentale district has the highest invasive species richness.

The resulting distribution maps showed that some of rubber vine (*C. grandiflora*) infestations were occurred inside Awash National Park (ANP) located at Awash Fentale district; hence it might pose serious threat to the park's local biodiversity (Figure 13). It had also occupied habitation areas, dry land, water courses and forest areas with various abundance levels (frequent, abundantly and very abundantly) in the altitude ranges of 754-1005 m a.s.l. *O. stricta*, *J. curcas* and *L. camara* have been found at only one waypoint of (habitation area) at an altitude of 812 m a.s.l. having abundant (50-75%), present (0-5%) rates, respectively. *S. occidentalis*, *S. incanum* and *P. aculeata*, were found in only two districts with various abundance levels (Figure 14, 15, 16) in the altitude range of 765-999m, 933-1005m and 812-1005m a.s.l., respectively. The respective maps of the relative abundance of the above mentioned invasive plant species that were recorded in more than one occasion are shown in Figure 14, 15 and 16.

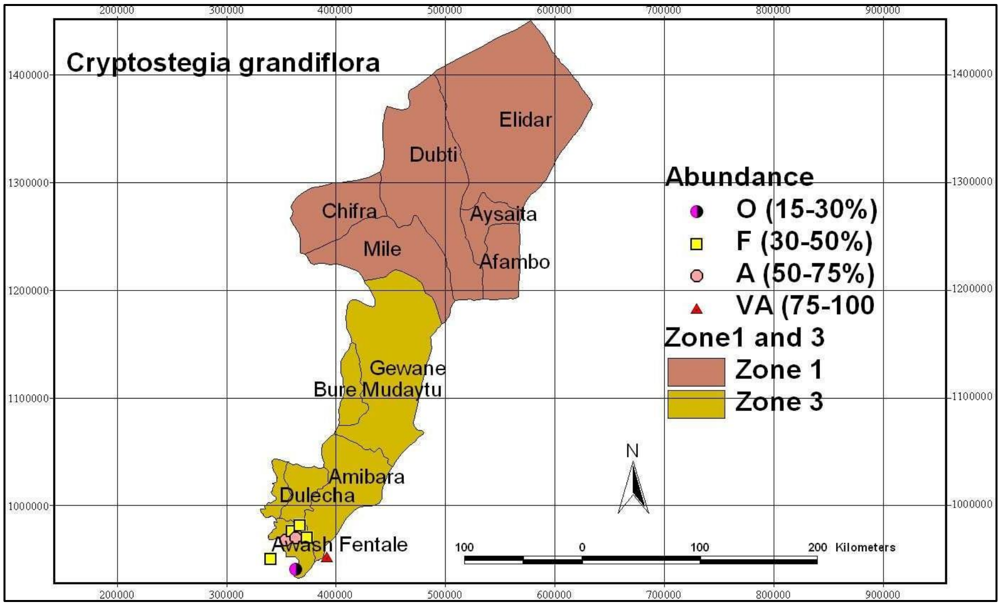

Figure 13. Abundance of *C. grandiflora* in Zone 1 and 3 of the Afar region (O-occasional; F-Frequent; A-Abundant; VA- very abundant).

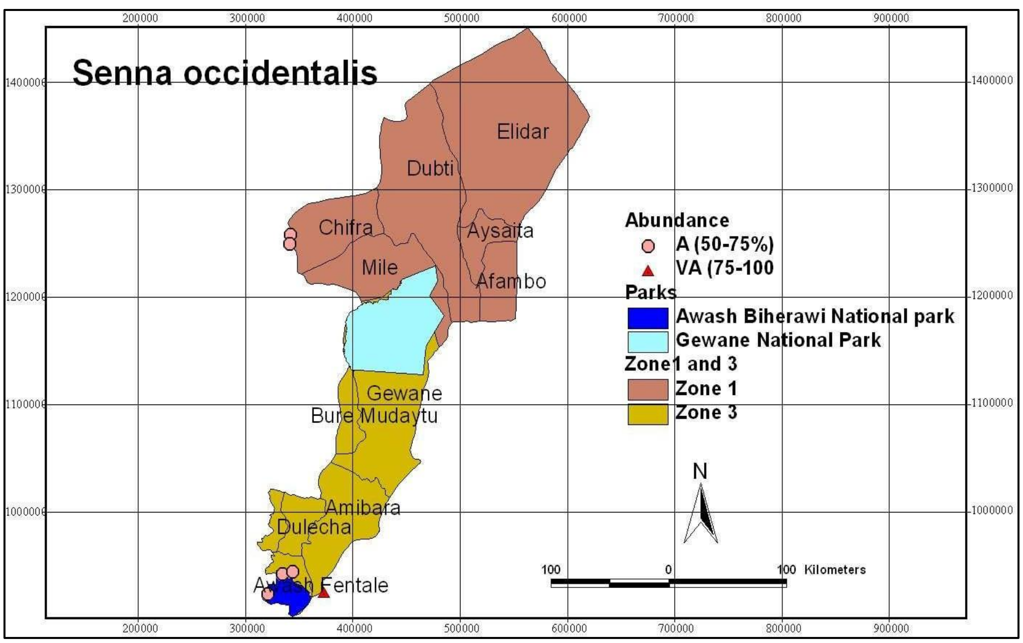

Figure 14. Abundance of *S. occidentalis* in Zone 1 and 3 of the Afar region (O-occasional; F-Frequent; A-Abundant; VA- very abundant).

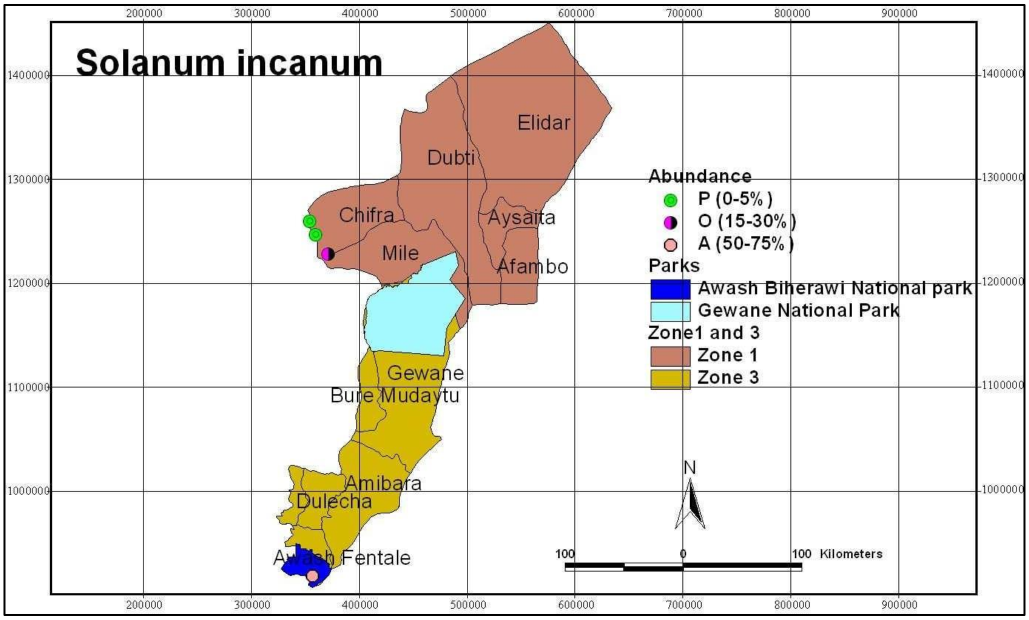

Figure 15. Abundance of *S. incanum* in Zone 1 and 3 of the Afar region (O-occasional; F-Frequent; A-Abundant; VA- very abundant).

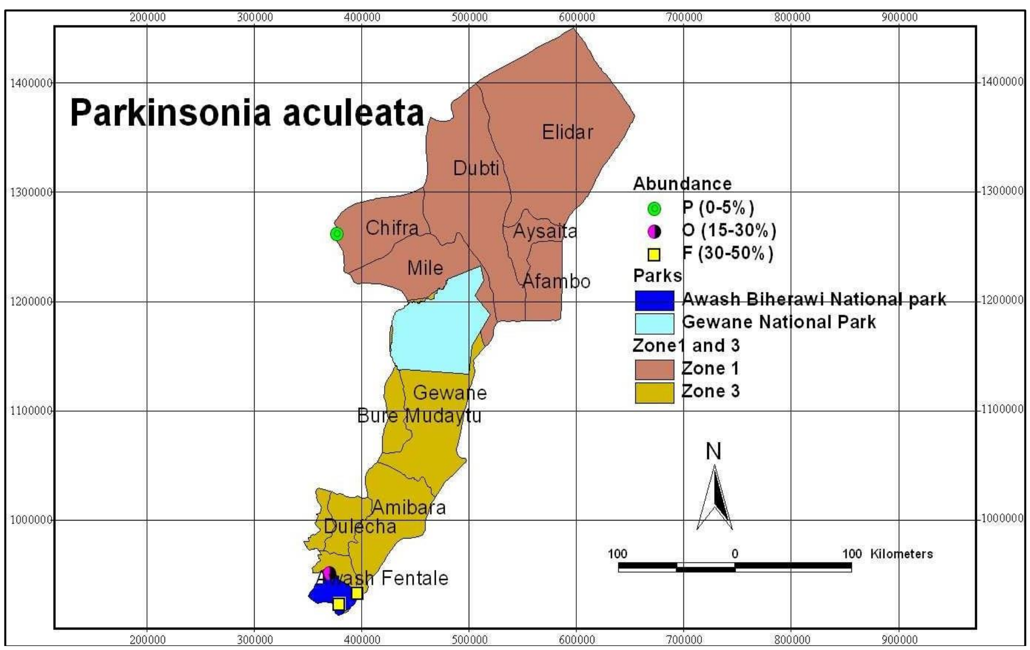

Figure 16. Abundance of *P. aculeata* in Zone 1 and 3 of the Afar region (O-occasional; F-Frequent; A-Abundant; VA- very abundant).

Proportion of all IAPS

The distribution and spread of invasive plants in the surveyed area had been varied in magnitude in different agro-ecological zones. These observed patterns of variation in distribution and abundance could be used for the prioritization of invasive plants in the region. Accordingly, the highest number of observations (38%) throughout the 91 interceptions made was for *Prosopis juliflora* followed by *Calotropis* (28%) and *Parthenium* (15%) whereas *Lantana*, *Jatropha* and *Opuntia* took the least portion (1% each) (Figure 17). Thus, *Prosopis juliflora* was identified as the most invasive plant species in the region.

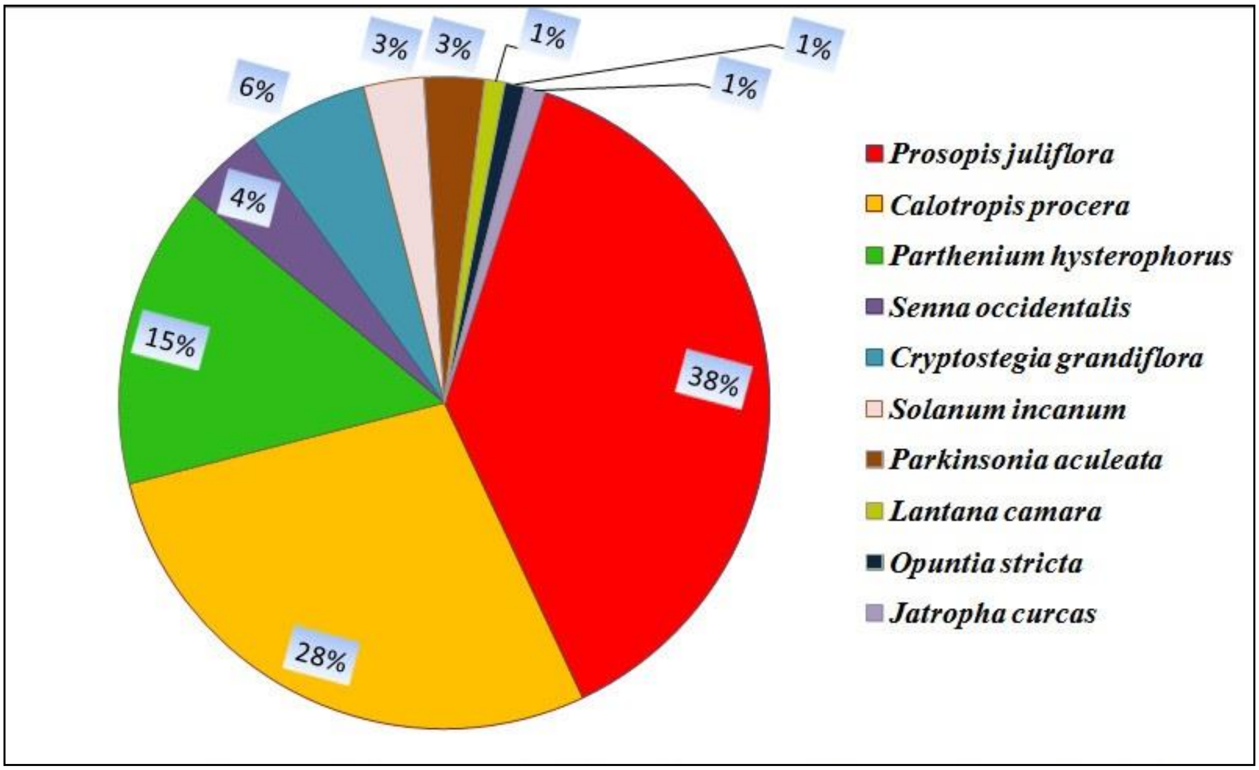

Figure 17. Proportion for all IAPS Recorded in Zone 1 and 3 of the Afar region.

Conclusion

It can be concluded that *Prosopis juliflora*, *Parthenium hysterophorus* and *Calotropis procera* were major invasive plant species of Zone 1 and 3 of the Afar region invading diverse agro-ecological areas such as croplands, grazing lands, forest areas, road sides, riversides, habitation areas, national parks etc. Other invasive plants such as *Cryptostegia grandiflora*, *Senna occidentalis*, *Solanum incanum*, *Jatropha curcas*, *Opuntia stricta*, *Lantana camara*, *Parkinsonia aculeata* were also identified as emerging IAPS in the region. The observed invasive plants dominated a large area of landmass with various abundance levels across the study area. The government and other stakeholders must take strong measures to control the spread of these invasive plants. Priority must be given to the major invaders that are already established in the region as they are causing significant damage to the environment as well as on the livelihood of the community. Strict attention must also be given to the emerging invasive plants that are at their early stage of invasion before they pose serious threat to the agro-ecological system. Long-term extension strategies and programs should be designed and implemented with the participation of the local Afar community in order to eradicate invasive plants from the region.

Acknowledgements

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Conflicts of Interest

No conflicts of interest have been declared.

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