Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2020, Volume 9, Issue 1, pp. 3374-3383
ISSN 2320 – 0243, Crossref: 10.23953/cloud.ijarsg.479

Research Article

Spatial Mapping of *Prosopis juliflora* (Swartz) DC in Pudukkottai District, Tamil Nadu, India

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Publication Date: 25 September 2020

DOI: https://doi.org/10.23953/cloud.ijarsg.479

Abstract Invasive Alien Species are serious threat to the natural ecosystem of the world. *Prosopis juliflora* (Swartz) DC is one such species introduced in India as a solution for desertification and to meet the fuel wood demand, but it has spread to various habitats and competes with the native species. The present study focuses on the spatial mapping of *P. juliflora* using Resourcesat – 2 Linear Self Scanning LISS (IV) Imagery through supervised classification and recoding methods. The influence of water bodies and road network on the distribution of *P. juliflora* and the variation in NDVI values of *P. juliflora* from various distances from the water body was assessed using buffer analysis. The results showed that .94% (4404.37 ha) of total geographical area of the district is occupied by *P. juliflora* with Viralimalai taluk contributing highest area (1083.49 ha) among the various taluks. Of the 4404 ha area under *P. juliflora* in the district, 2386 ha falls within the 1 km distance from rivers and streams while 1705 ha area falls within the 1 km distance from road. The percentage of Prosopis patches falling in higher NDVI category showed a decreasing trend when the distance to the water body and streams increased.

Keywords *Supervised Classification; Remote Sensing and Geographic Information System*

1. Introduction

Prosopis juliflora (Swartz) DC is an invasive alien species which has become one of the world's 100 most dominant invasive species (Walter and Armstrong, 2014; Becker et al., 2016). It spreads through the transportation of seeds along water courses and through animal dispersal, replacing native plant communities (Pasiecznik, 2001) and causing negative implications on ecosystem including loss of biodiversity, impact on bird's diversity and habitat, reduction of water resources, loss and degradation of grasslands, farmlands and rangelands, change in plant community composition and plant mortality (Tiwari, 1999; Robbins, 2001; Gorgens and Wilgen, 2004; Scott et al., 2006; Zimmermann et al., 2006; Maundu et al., 2009; Kaur et al., 2012; Schachtschneider and February, 2013; Chandrasekaran et al., 2014).

Information on spatial extent is considered necessary for developing policies regarding invasive species management (Wittenberg and Cock, 2001). Efforts have been made to map the *P. juliflora* invasion in different parts of the world using remote sensing data (Mohamed, et al., 2011; Hoshino, et

al., 2012; Van den Berg, 2013; Mustafa Mirik, et al., 2012 & 2014; Amboka, et al., 2015; Michele Meroni, et al., 2016). However, quantitative assessments of the area invaded by *P. juliflora* and its probable distribution have not been studied adequatelyin India (Ramachandra, 2010; Pasha et al., 2014; Ragavan, 2015; Vidhya et al., 2017). Keeping this in view the present study focuses on the spatial mapping of the *P. juliflora* in the Pudukkottai district of Tamil Nadu, India.

2. Study Area

Pudukkottai district of Tamil Nadu state lies between the 78° 25' and 79° 15' East longitude and between 9° 50' and 10°40' of the North latitude has been selected for the study (Figure 1). It covers 4663 km² area with a coastline of 39 km, the district accounts for 3.58 percent of the total geographical area of the State. The district is further subdivided into 12 taluks such as Pudukkottai, Kulathur, Tirumayam, Gandarvakottai, Illupur, Karambakudi, Alangudi, Ponnamaravati, Viralimalai, Aranthangi, Avudayarkovil and Manamelkudi. The district comes under hot dry semi-arid agro-climatic zone and the climate is semi-arid tropical monsoonal type.

Generally, a dry and hot climate prevails in this district with the temperature ranges from a maximum of 40.49^0 C (104.9^0 F) to minimum of 22.63^0 C (72.7^0 F). April to June are the hottest months while December to January are the coldest months. The annual rainfall was 978.8 mm. The soil of the district can be classified into black, red, ferruginous, lateritic, alluvial and beach soils. Vellar is the main river and Agniyar, Pambar and Korai are the seasonal rivers which flows in the district. Apart from these rivers, a number of water bodies like tanks, lakes etc. are available in the district. Most of the fallow lands, dry water bodies and waste lands in the district are invaded by *P. juliflora*. However, there is no information on the spatial extent of *P. juliflora* invasion in the district. (District office website)

Figure 1: *Pudukkottai district of Tamil Nadu, India (Study Area*

3. Methodology

Mapping the spread of *P. juliflora*.

Resourcesat-2 Linear Imaging Self Scanning Scanner (LISS- IV) images having 5.8-meter spatial resolution procured from the National Remote Sensing Centre (NRSC), Hyderabad were used for mapping the spread of *P. juliflora* in the district. Data from field survey, toposheets of Survey of India, information from Google Earth and GPS points were used for the mapping. The procured satellite images were georeferenced and supervised classification was done using Maximum Likelihood Classifier (MXL) in ERDAS IMAGINE 2014. Signatures for seven different classes (*Eucalyptus*, *Casuarina*, *P. juliflora*, Water body, Agriculture fields, Coconut and Barren land) were created. Multiple signatures have been collected to help the software for accurate classification.

The accuracy of the supervised classification was assessed with random points and producer accuracy, user accuracy and kappa statistics were calculated based on error matrix. Misclassified pixels were recorded by comparing with False Colour Composites and Google Earth images which highly improved the accuracy of classified images. The recoded raster images were converted into vector layers for assessing the spatial extent of the *P. juliflora* in ESRI ArcGIS 10.1.

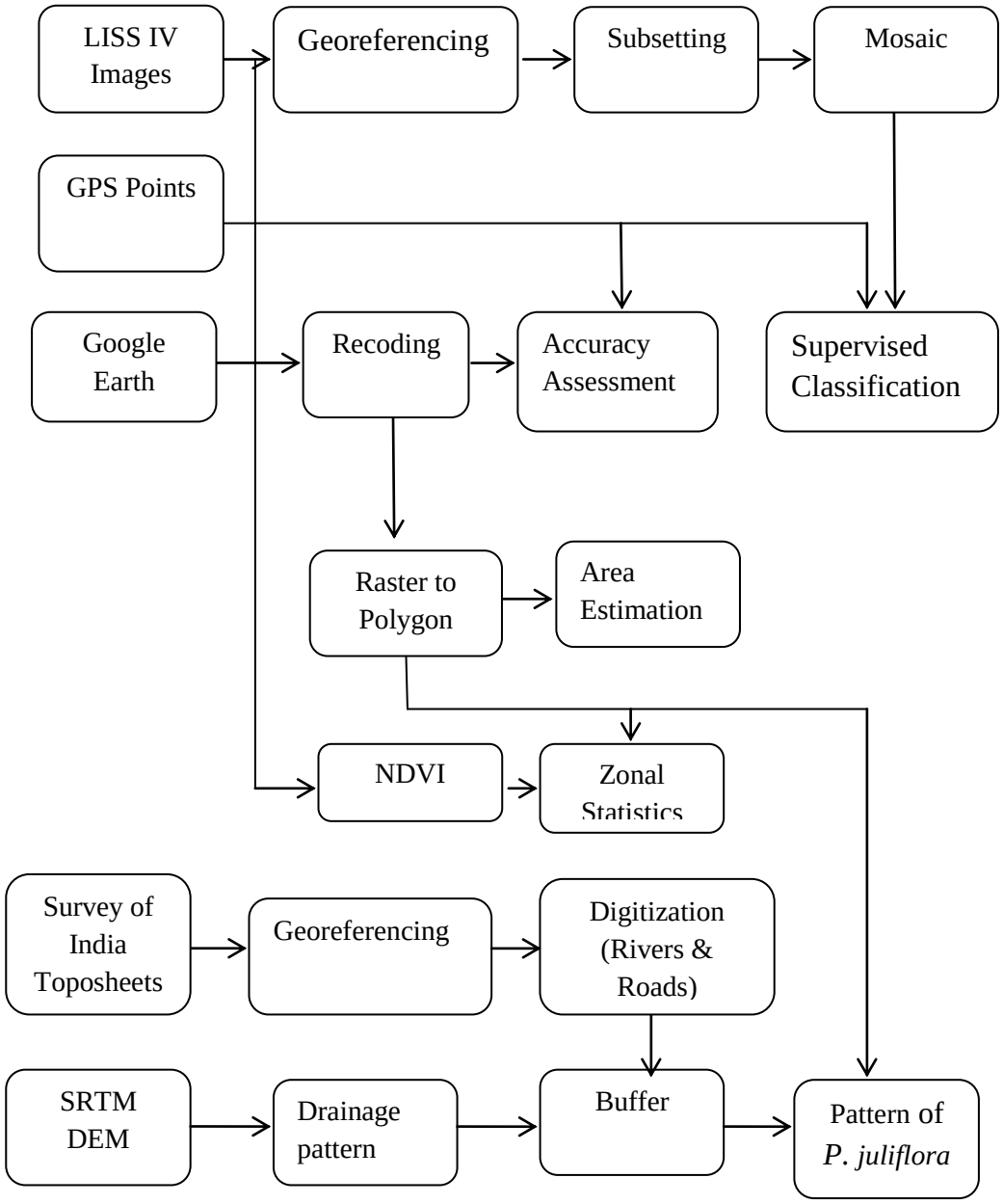
Buffer analysis

The influence of water bodies and road network on the distribution of *P. juliflora* was assessed using buffer analysis. The Shuttle Radar Topography Mission (SRTM) Digital Elevation Model for the study area downloaded from the website (http://earthexplorer.usgs.gov) was used for preparation of drainage map by conducting watershed analysis. The river/stream and major roads for the study area digitized from the Survey of India toposheets were superimposed on the drainage maps to identify the rivers/streams of the study area. Buffer of 100, 250, 500, 750 meters and 1 kilometre for the major rivers and roads of the study area were created to analyse the influence of water bodies and road network in ESRI ArcGIS 10.1.

Variation in Normalized Difference Vegetation Index (NDVI) values

Normalized Difference Vegetation Index (NDVI) was computed for the study area to assess the variation in NDVI values across various *P. juliflora* patches. The mean NDVI values for various *P. juliflora* polygons were extracted to vector layer using Zonal Statistics method in ERDAS IMAGINE 2014. The variation in NDVI values of *P. juliflora* polygons in 1 km buffer zones was also studied to assess the role of the water bodies in the growth and health of the *P. juliflora*.

Flow chart of Methodology followed



4. Results and Discussion

Extent of Prosopis distribution

In this study, the spatial extent of *P. juliflora* invasion in Pudukkottai district was mapped using Remote Sensing and GIS. The study revealed that 4404.37 ha area of the district has been invaded by *P. juliflora* which is .94% of total geographical area of the district (Table 1). Among the various taluks, Viralimalai has the highest area (1083.49 ha) under *P. juliflora* invasion. The largest and smallest patches of *P. juliflora* are also found in Viralimalai taluk with 141.4 and 0.0074 ha area respectively. About 2 % total geographic area of the Viralimalai taluk is invaded by *P. Juliflora* while 1.65% of total geographic area of the Avudayarkovil taluk is invaded by *P. juliflora* (697 ha area). Though, Kulathur and Pudukkottai taluks have higher area under *Eucalyptus* and *Casuarina* plantations, only 0.96% and 0.89% of their geographical area under *P. juliflora* invasion respectively. Among the various taluks, Manamelkudi has very less area under *P. juliflora* with 86.07 ha (0.34%). Viralimalai and

Avudayarkovil taluks are being drained by Korai and Pambar rivers also have more area under *P. juliflora* invasion.

Table 1: *Extent of P. juliflora invasion in various taluks of Pudukkottai District*

Taluk names	Area of Taluk (ha)	No of patches	Extent (ha)
Viralimalai	49822.5	356	1083.49 (2.1%)
Avudayarkovil	42039.2	233	697.59 (1.6%)
Kulathur	47923.7	145	462.03 (0.96%)
Tirumayam	56667.9	106	376.76 (0.66%)
Gandarvakottai	31700.6	97	310.46 (0.97%)
Pudukkottai	33807.3	167	303.91 (0.89%)
Ponnamaravati	32822.2	142	292.11(0.88%)
Aranthangi	44176.05	80	264.99 (0.59%)
Alangudi	38916.5	66	218.28 (0.56%)
Illupur	35383.5	39	129.12 (0.36%)
Karambakudi	25962.8	51	102.21 (0.39%)
Manamelkudi	25120.3	35	86.07 (0.34%)
Total	464542.98	1566	4404.37 (.94%)

Values in parentheses are % of geographical area.

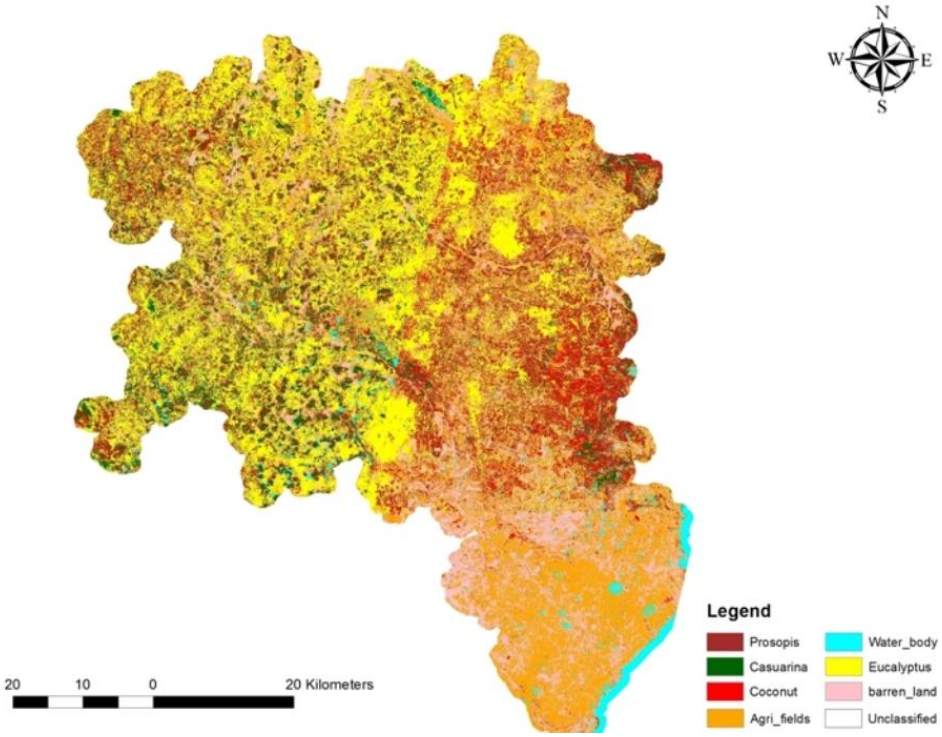


Figure 2: *Extent of various landuse in Pudukkottai district*

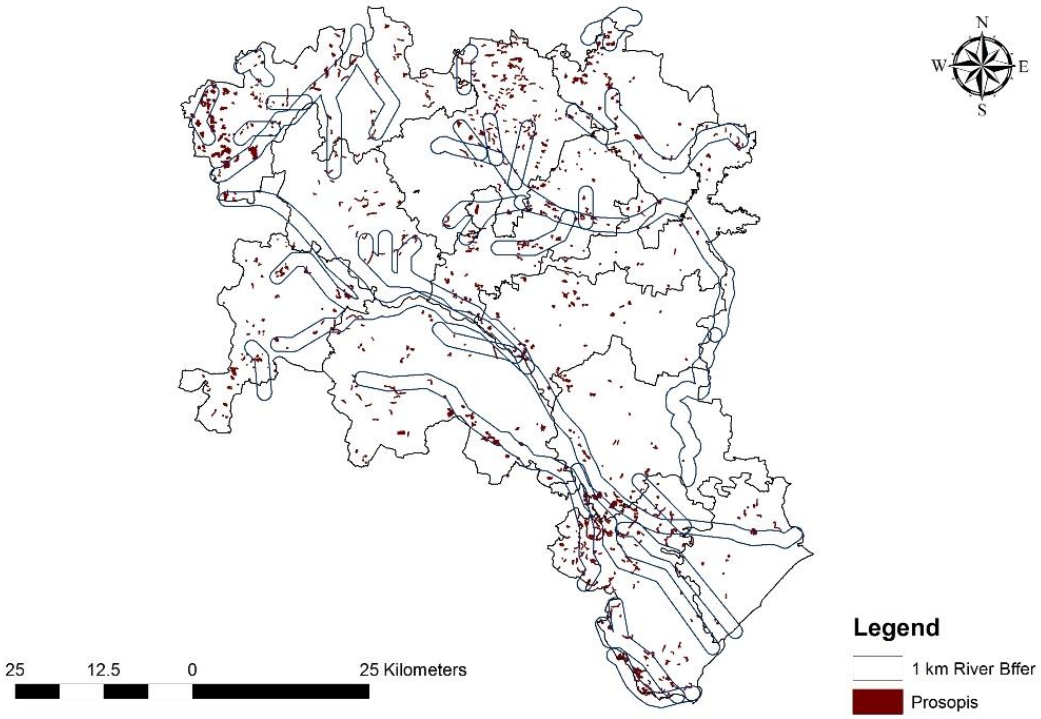


Figure 3: *P. juliflora invasion near water bodies in Pudukkottai district*

There are three zones of *P. juliflora* invasion in the district along the river banks in 1) Viralimalai 2) Kulathur and 3) Avudayarkovil taluks (Figure 3). The river Pambar which also flows through the neighbouring Sivagangai district showed higher *P. juliflora* invasion. It may also be noted that most of the *P. juliflora* invasion has been observed in areas which lies very near to adjacent districts such as Sivagangai, Tiruchirapalli and Ramanathapuram. The output of supervised classification showed that most of the *P. juliflora* occur along the water bodies and in the agricultural fallow lands (Figure 2). The Eastern and the Southern part of the study area showed the highest extreme *P. juliflora* invasion.

Buffer analysis of *P. juliflora* spread

In the present study an attempt was made to assess the influence of water bodies and road network on the distribution of *P. juliflora* using buffer analysis. The study revealed that out of 4404 ha mapped area during study, 2386 ha of area (54%) found within the 1 km buffer of rivers and streams (Figure 3 and Table 2) while 1705 ha area (38%) of *P. juliflora* falls within the 1km buffer of major roads (Figure 4) of the district.

The extent of *P. juliflora* varied across the different buffer zones of the river and roads. 100 m buffer around the river and roads have 12% and 17% of the total area of *P. juliflora* invasion in the district while at the 250 m buffer of river and roads the *P. juliflora* invasion is 16% and 25% respectively. The study indicates that the invasion of the species is more along the water bodies than along the roads. The *P. juliflora* patches are also found near smaller water bodies such as tanks, lakes and minor roads etc. Hence, the buffer analysis along these smaller water bodies and roads will also give more information on the distribution of *P. juliflora*. Since the number of smaller water bodies and minor roads in the district are more, due to paucity of time and non-availability of spatial data on these water bodies and roads, the same could not be included in the analysis.

Table 2: *NDVI values of P. juliflora in different distances from water bodies*

NDVI values	*P. juliflora* extent (ha)	Distance from water body (m)				
		100	250	500	750	1000
1.000 - 0.500	2005 .15 (45)	470 (59.6)	556 (48.9)	773 (46.1)	938 (44.1)	1006 (42.2)
0.499 - 0.300	2239.19 (50.9)	304 (38.5)	551 (48.5)	823 (49.1)	1087 (51.1)	1270 (53.2)
0.299 - 0.156	160.01 (3.6)	15 (1.9)	29 (2.6)	79 (4.7)	104 (4.9)	110 (4.6)
Total	4404	789	1136	1675	2129	2386

Values in parentheses are % to total

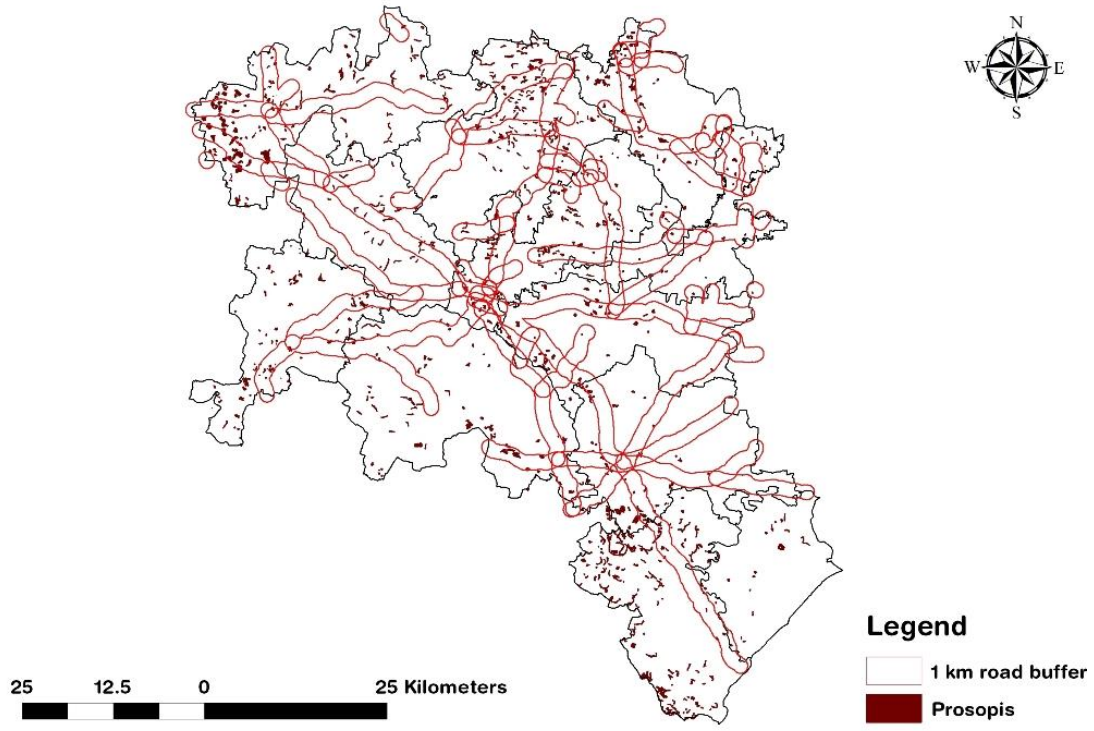


Figure 4: *P. juliflora invasion near major roads in Pudukkottai district*

Variation in Normalized Difference Vegetation Index (NDVI) values

The study showed that 50% of the *P. juliflora* recorded in the study area have NDVI values between 0.499 - 0.300, 45.5% between 1.00 - 0.500 while only 3.6% of *P. juliflora* in 0.299 - 0.156 category of NDVI values (Table 2). This variation in NDVI values could be due to various growth stages of *P.juliflora*, edaphic and topographic factors. Since about 45% of the patches have higher NDVI values than the surrounding vegetation, the NDVI values can also be used to distinguish the distribution of Prosopis and health in terms of biomass and leaf chlorophyll. Similarly, Gunawardena et.al, 2014 assessed NDVI values of Prosopis in Sri Lanka. However, time series analysis of NDVI and other vegetation indices along with field data may provide additional information.

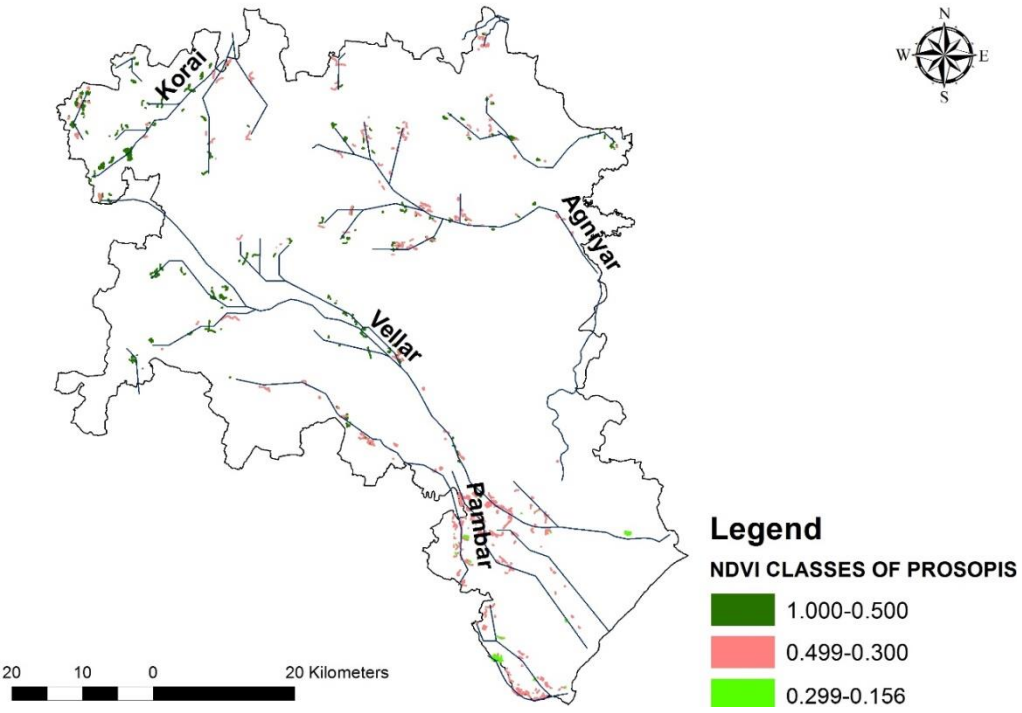


Figure 5: *Variations in NDVI values of P. juliflora*

The assessment of influence of water bodies and streams on the variation in NDVI values of *P. juliflora* using buffer analysis revealed that the percentage of Prosopis patches falling in higher NDVI category showed a decreasing trend when the distance to the water body and streams increased. Of the total 789 ha of Prosopis recorded (Table 2) within 100 m distance from the water body and streams in the study, about 470 ha (59 %) falling in higher NDVI value category (0.5 to 1.0), 38.5 % to the medium NDVI category (0.300 - 0.499) and only 1.9 % is low NDVI value category. However, of the 2386 ha of Prosopis recorded within 1 km distance from the water body and streams in the study, only 42.2% falling in higher NDVI value category (1.00 - 0.5), 53.2% to the medium NDVI category (0.499 - 0.300) and only 4.6 % is low NDVI value category (Table 2). However, NDVI values may vary in different growth stages of the plant, season and years. Hence time series analysis of satellite images is required to get additional information on the influence of water bodies and streams on the variation in NDVI.

5. Conclusion

The present study has quantified the extent of *P. juliflora* in the Pudukkottai district and found variation in spatial extent of *P. juliflora* cover in different distances from water bodies and roads. The spatial information generated will further help the land managers and policy makers in formulating preventive, control or eradication measures. However, the time series analysis of vegetation indices and spread of invasion is required to get additional information for effective management of *P. juliflora*.

Acknowledgements

We would like to thank Institute of Forest Genetics and Tree Breading, Coimbatore for necessary logistical support in completing this research work. The authors are grateful to the editors and reviewers for their valuable comments and suggestions which have greatly improved the manuscript quality.

References

Amboka, A.A. and Ngigi, T.G. 2015. *Mapping and monitoring spatial-temporal cover change of P. juliflora species colonization in Baringo Central, Kenya*. *International Journal of Engineering Science Invention*, 4(3), pp.50-55.

Becker, M., Alvarez, M., Heller, G., Leparmarai, P., Maina, D., Malombe, I., Bollig M. and Vehrs, H. 2016. Land-use changes and the invasion dynamics of shrubs in Baringo. *Journal of Eastern African Studies*, 10; pp.111-129.

Chandrasekaran, S., Saraswathy, K., Saravanan N.S., Kamaladhasan, N. and Arunnagendran. 2014. Impact of P. juliflora. on nesting success of breeding wetland birds at Vettangudi Bird Sanctuary, South India. *Current Science*, 106(5), pp.676-678.

Felix Rembold, Ugo Leonardi, Wai-Tim Ng, Hussein Gadain, Michele Meronia, Clement Atzberger. 2015. Mapping areas invaded by P. juliflora in Somaliland with Landsat 8 imagery. *Remote Sensing for Agriculture, Ecosystem and Hydrology*, XVII; pp.9637.

Gorgens, A., and van Wilgen, B. 2004. Invasive alien plants and water resources in South Africa: current understanding, predictive ability and research challenges. *South African Journal of Science*, 100; pp.27-33.

Gunawardena, A.R, Fernando, T.T. Nissanka, S.P. and Dayawansa, N.D.K. 2014. Assessment of spatial distribution and estimation of biomass of Prosopis juliflora (Sw.) DC. in Puttlam to Mannar Region of Sri Lanka using Remote Sensing and GIS*. Tropical Agricultural Research*, 25(2), pp.228–239.

Hoshino, B., Karamalla, A., Abd Elbasit, M., Manayeva, K., Yoda, K., Suliman, M., Elgamri, M., Nawata, H. and Yasuda, H. 2012. Evaluating the invasion strategic of mesquite (P. juliflora) in Eastern Sudan using remotely sensed technique. *Journal of Arid Land Studies*, 4; pp.1–4.

Kaur, R., Gonzáles, W.L., Llambi, L.D., Soriano, P.J., Callaway, R.M., and Rout, M.E. 2012. Community impacts of *Prosopis juliflora* invasion: biogeographic and congeneric comparisons. *PLOS ONE*, 7(9), e44966.

Maundu, P., Kibet, S., Morimoto, Y., Imbumi, M., and Adeka, R. 2009. Impact of Prosopis juliflora on Kenya's semi-arid and arid ecosystems and local livelihoods. *Biodiversity,* 10; pp.33–50.

Mohamed, A.H., Holechek, J.L., Bailey, D.W., Campbell, C.L. and DeMers, M.N. 2011. Mesquite encrochment impact on southern New Mexico rangeland: remote sensing and geographic information systems approach. *Journal of Applied Remote Sensing*, 5; pp.1-11.

Mustafa Mirik, Sriroop Chaudhuri, Brady Surber, Srinivasulu Ale and R. James Ansley. 2013. Detection of two intermixed invasive woody species using colour infrared aerial imagery and the support vector machine classifier. *Journal of Applied Remote Sensing*, 7(1); 073588.

Pasha, S.V., Satish, K.V., Reddy, C.S., Prasada Rao, P.V.V. and Jha, C.S. 2014. Satellite image-based quantification of invasion and patch dynamics of mesquite (P. juliflora) in Great Rann of Kachchh, Kachchh Biosphere Reserve, Gujarat, India. *Journal of Earth System Science*, 123(7), pp.1481-1490.

Pasiecznik, N., Felker, P., Harris, P., Harsh, L. and Cruz, G. 2001. *The P. juliflora – P. pallida complex: A monograph. Forest Ecology and Management*, 174(1-3), p.605.

Pudukkottai District Administration, 2020. *https://pudukkottai.nic.in/*

Ragavan, K. and Johnny, J.C. 2015. Quantification of invasive colonies of P. juliflora using remote sensing and GIS techniques. *International Journal of Engineering and Technical Research*, 3(5), pp.110-115.

Ramachandra, T.V. 2010. Mapping of fuel wood trees using geoinformatics. *Renewable and Sustainable Energy Reviews*, 14; pp.642–654.

Robbins, P. 2001. Tracking invasive land covers in India, or why our landscapes have never been modern. *Annals of the American Association of Geographers*, 91; pp.637-659.

Schachtschneider, K. and February, E. C. 2013. Impact of Prosopis invasion on a keystone tree species in the Kalahari Desert. *Plant Ecology*, 214(4), pp.597–605.

Scott, R., Huxman, T., Williams, D. and Goodrich, D. 2006. Eco-hydrological impacts of woody-plant encroachment: seasonal patterns of water and carbon dioxide exchange within a semiarid riparian environment. *Global Change Biology*, 12; pp.311-324.

Tiwari, J.W.K. 1999. Exotic weed P. juliflora in Gujarat and Rajasthan, India: boon or bane. *Tiger paper*, 26; pp.21-25.

Van den Berg, E.C., Kotze, I. and Beukes, H. 2013. Detection, quantification and monitoring of P. juliflora in the Northern Cape Province of South Africa using remote sensing and GIS. *South African Journal of Geomatics*, 2(2), pp.68-81.

Vidhya, R., Vijayasekaran, D. and Ramakrishnan, S.S. 2017. *Mapping invasive plant P. juliflora in arid land using high resolution remote sensing data and biophysical parameters*. *Indian Journal of Geo Marine Sciences*, 46(6), pp.1135-1144.

Walter, K.J. and Armstrong, K.V. 2014. Benefits, threats and potential of P. juliflora in South India. *Forests, Trees and Livelihoods*, 23; pp.232-247.

Wittenberg, R. and Cock, M.J.W. 2001. *Invasive alien species: A toolkit of best prevention and management practices*, CAB International; Wallingford, UK.

Zimmermann, H., Hofmann, J. and Witt, Arne. 2006. A South African perspective on Prosopis. Biocontrol News and Information. 27; pp.6-9.