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MAPPING INVASIVE PLANT SPECIES IN KARACHI USING HIGH RESOLUTION SATELLITE IMAGERY: AN OBJECT BASED IMAGE ANALYSES APPROACH

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ABSTRACT

Invasive species (also known as exotic species) are prime focus of government departments, plant conservationist, ecologist, environmentalist and farmers now days. One of the major non climatic drivers of global change are these plant invasive species that pose serious damages to anthropogenic activities and biodiversity. The study aims at mapping plant invasive species in Karachi using high resolution satellite imagery. World View (WV2) satellite imagery was used as high resolution satellite data source. The imagery was pan-sharpened to the spatial resolution of 0.5 m. Principal component resolution merging technique was used for pan-sharpening of WV 2 imagery. Three level image segmentation was performed using eCognition software. We performed quadtree at first level then multiresolution segmentation was performed at second and third level with different parameters at each level. Once, we picked the shrub canopies well with image segmentation, the WV 2 image was processed for vegetation indices. Threshold classification was performed for all three vegetation indices: ratio vegetation index (RVI), normalized difference vegetation index (NDVI) and enhanced vegetation index EVI2. We conclude that EVI2 mapped the invasive species with the less generalizations and mix classes as compared to RVI and NDVI.

Keywords: Plant invasive species, Karachi, OBIA, vegetation indices, World View 2

INTRODUCTION

Plant invasive and exotic species in an ecosystem are persistent and costly environmental problem that has been the emphasis of ecosystem management activities from past decades. Plant species invasion is an emerging problem in some of the fragile zones of the world. The purpose behind such plants being invading and setting up themselves in localities that were once homes of indigenous and endemic species can be ascribed to different reasons, for example, proceeding with anthropogenic related aggravations, such as land cover / land use change, grazing, and habitat fragmentation, consolidated with global exchange, environmental and climate change, show that these patterns are probably going to proceed (Zedler and Kercher, 2004).

A naturally hostile plant might be particularly invasive when it is introduced into a new territory. These species result in economic transformations by lessening crop yields or the quality of grazing lands and can have negative biological impacts including lessening biodiversity, endangering uncommon plant communities and changing natural processes, for instance, nutrient cycle (Higgins *et al*., 1999). Invasiveness is depicted by vigorous vegetative growth, rapid reproduction, plentiful seed production, fast seed germination, and persistence. In the recent times invasion of plant species in existing biodiversity is changing the capacity of natural resources in Karachi city. As agricultural, grazing and protected land is being lost into biological invasion and the harmful effects cause by them.

Mapping of the actual extent of invasive species and native plant communities is the dire need of today's time. At field analysis of mapping extent of invasive species is time taking, biased to some extent and labor intensive task. Satellite Remote Sensing (SRS) provides efficient, cost effective and accurate estimation tool for mapping and monitoring natural vegetation. Current advancement in multispectral sensors opens a floor for development of new methodologies for mapping and monitoring of natural resources with spectral indices. Keeping in mind this fact, the research study aims at mapping extent of invasive plant species in Karachi city. The methodology developed in this study can be used for other part of southern Sindh.

MATERIALS AND METHODS

Study area

In this research, part of Karachi city is selected as a study area for mapping of invasive plant species (Fig. 1). The city area contains semi-arid climate with patches of natural vegetation comprised of mostly shrubs and herbs. Calcareous hills are dominant land forms in the city with varied slopes and seasonal rivers. The dominant native species are *Acacia Senegal*, *Commiphora wightii* and *Euphorbia caducifolia* at the calcareous hills. Over the past century this natural vegetation undergoes a change and now an invasive plant species *Prosopis juliflora* become dominant in Karachi (Fig. 3).

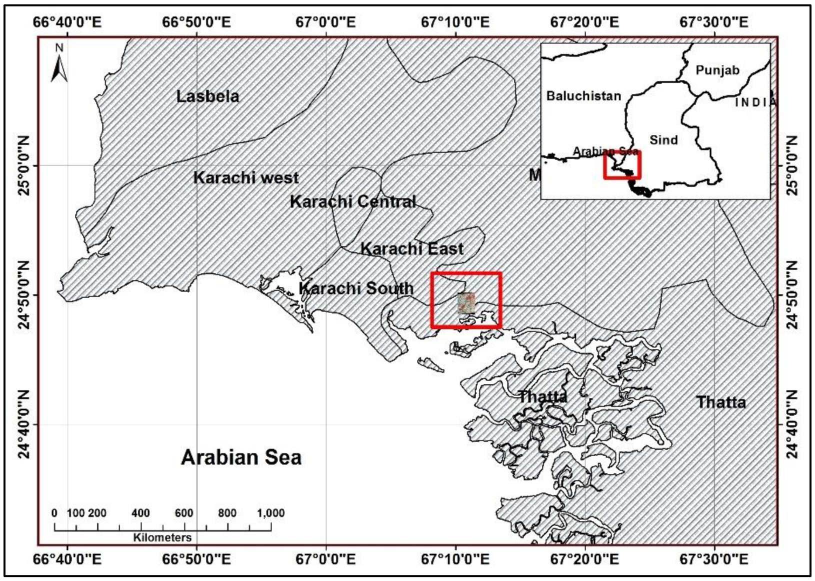

Fig. 1. Location Map of Study Area**.**

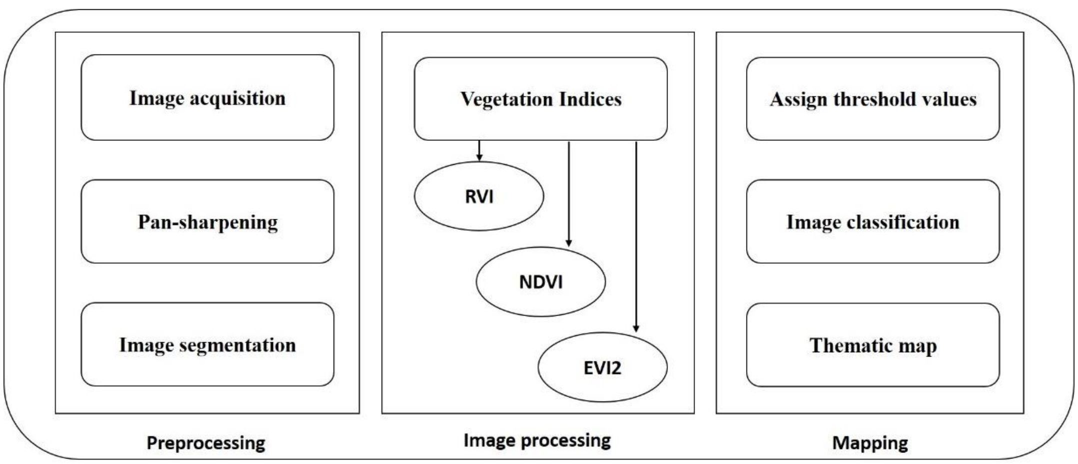

Fig. 2. Methodology of mapping invasive species in the study area.

Datasets

In this research work World View (WV2) bundle (multispectral + panchromatic) imagery was used to map *Prosopis juliflora* in the study area. The date was 08 Oct 2013 when the imageries were acquired. The WV 2 multispectral imagery's specifications are mentioned in

Table 1. The scene size was 16.4 km. The scene acquired with sun azimuth angle of 157.10^0, sun elevation of 57.10^0, and the incident angle of 24.40^0. The panchromatic band of the acquired WV 2 imagery covered the Visible Near Infrared (VNIR) range having a pixel size of 0.46 m at nadir. The radiometric resolution of both multispectral and panchromatic imagery was 11 bits per pixel.

Table 1. Satellite Image specifications.

Platform	**Sensor**	**Spatial Resolution**		**Spectral Resolution**					**Radiometric Resolution**
				PN (nm)	**MS (nm)**				
World View 2	PN, MS	**Pan m**	**MS m**	450-800 (VNIR)	450-510 (blue)	510-580 (green)	630-690 (red)	770–895 (NIR)	11 bits
		0.46	1.84						

Fig. 3. Ground View of *Prosopis juliflora* at the Study Area**.**

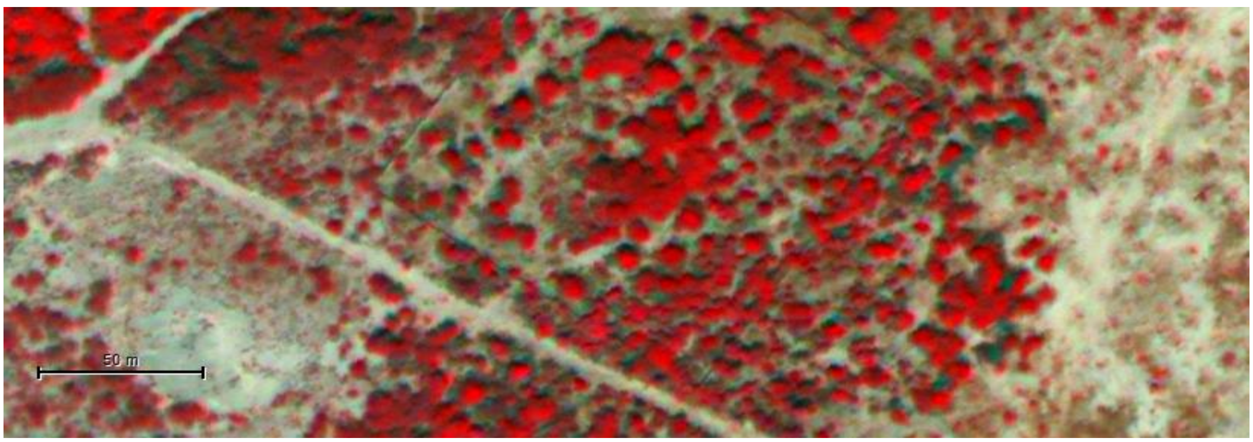

Fig. 4. WV 2 imagery showing *Prosopis juliflora* at the study area (in red color).

Preprocessing

Principal component resolution merging techniques was used to pan-sharpened the WV 2 image in Erdas Imagine software. Cubic convolution resampling method was used for output pan-sharpened image.

Image segmentation

Segmentation is a process by which using multiple spectral, spatial and contextual parameters, entire images are subdivided into objects at various levels – from the pixel level to groups of pixels as larger and larger clumps at different scales, up to the entire image level. In this research work, three level segmentations were performed to develop polygons that fits to the shrub canopies (Fig. 7). In the first level of segmentation quadtree segmentation was performed, whereas, at level 2 and level 3 multiresolution segmentation was performed with changes in scale, compactness and shape values.

Vegetation Indices

Vegetation Indices (VIs) are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation. They are derived using the reflectance properties of vegetation. Ratio Vegetation Index (RVI), Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI2) were used to map *Prosopis juliflora* in the study area. RVI can be calculated by the following formula (Birth and McVey, 1968);

$$\textbf{RVI = NIR / Red}$$

NDVI was estimated using the reflectance of Near Infrared (NIR) band and Red band (Rouse et al., 1973)

$$\textbf{NDVI = [(NIR – Red) / (NIR + Red)]}$$

EVI2 can be calculated by the following formula (Jiang et al., 2008).

$$\mathbf{EVI2 = 2.5 * (NIR - RED) / (NIR + 2.5*RED + 1)}$$

Where,
NIR = Reflectance of NIR band
Red = Reflectance of Red Band

Mapping of *Prosopis juliflora*

Object Based Image Analysis (OBIA) has been used for extracting invasive species at the study area. Segmentation and mapping of WV 2 data were performed using eCognition software. The RVI was used in the first level of mapping with threshold value of 1.18. In the second level the extracted polygons from RVI was remapped using NDVI. A threshold value of 0.095 was used to filter invasive species map developed using RVI. In the last level EVI2 was used to remap the output polygons of NDVI using threshold value of 0.15. Finally, the thematic map was developed in ArcGIS 10.3 software.

RESULTS AND DISCUSSION

The invasive species in Karachi spread in agglomerations with scattered shrubs at the boundary. Hence, quadtree segmentation (Fig. 5) approach was adopted to pick small and large vegetated areas at level 1. In the second level of segmentation, multiresolution segmentation was used with scale 20, shape 0.1 and compactness 0.7. The scale 20 was used to develop large size polygons. High compactness and low shape values were used to develop polygons that grouped pixels with similar pixel values irrespective of shape of polygon (Fig. 6). The spectral values for invasive species are close in range within NIR and Red band, hence, the multiresolution segmentation was performed using only NIR and Red band. The segmentation developed in second level has polygons that contain mix system in them. The barren land/grassland and invasive shrubs were grouped together in one polygon (Fig. 6). This improper segmentation effects the final map produced using WV 2 imagery, hence, a third level segmentation has been carried out to develop polygons that fits the shrubs well. In the third level of segmentation, again multiresolution approach was adopted with change parameters as compared to second level segmentation. A scale of 10 with high compactness of 0.98 and low shape of 0.02 were used to get the final segmentation layer. High compactness with low shape values favored the extraction of shrubs mixed with landforms (Fig. 7).

In second step, vegetation indices were used for classification of polygons through OBIA approach. OBIA in eCognition software empowers customize inputs using variety of arithmetic operations. Vegetation indices are used to measures spatial distribution of vegetation, vegetation biomass, and health of vegetation (Boelman *et al*., 2004; Das, 2012; Heiskanen, 2006; Ko *et al*., 2017; Kundu *et al*., 2016). The interaction of daylight with green vegetation is firmly controlled by leaf colors and leaf structure. We see green leaves because of strong absorption of red and blue wavelengths in chlorophyll, the major leaf pigment. On the other hand, NIR wavelength of electromagnetic spectrum enters into the leaf inner structure where is interacts boundaries of air water, numerous cell components that bringing about solid upward diffuse reflection of this energy. The difference between solid NIR reflectance and low red reflectance of green vegetation is the reason for development of most vegetation indices (Huete, 1988; Jiang *et al*., 2008; Kaufman and Tanre, 1992; Qi *et al*., 1994).

The RVI generates generalized results for mapping distribution of *Prosopis juliflora,* as it mapped those areas as vegetation where there is little or no vegetation, see red color areas in Fig. 8. NDVI mapped *Prosopis juliflora* better than RVI, it picked those areas that contains vegetation with little generalization, see yellow areas in Fig. 8. The generated output of RVI was filtered using NDVI but still there are limitation with NDVI. It is not sensitive to atmospheric path radiance of red and blue color. The second problem is its saturation over dense vegetation areas. To remove both limitations EVI2 was used in this research that has been developed by Jiang *et al*. (2008). EVI2 mapped the true extent of *Prosopis julliflora* as can be seen by green areas in Fig. 8. The area mapped as invasive species with EVI2 also mapped as invasive species by RVI and NDVI but they contain extra mapping of areas as invasive which belong to barren land.

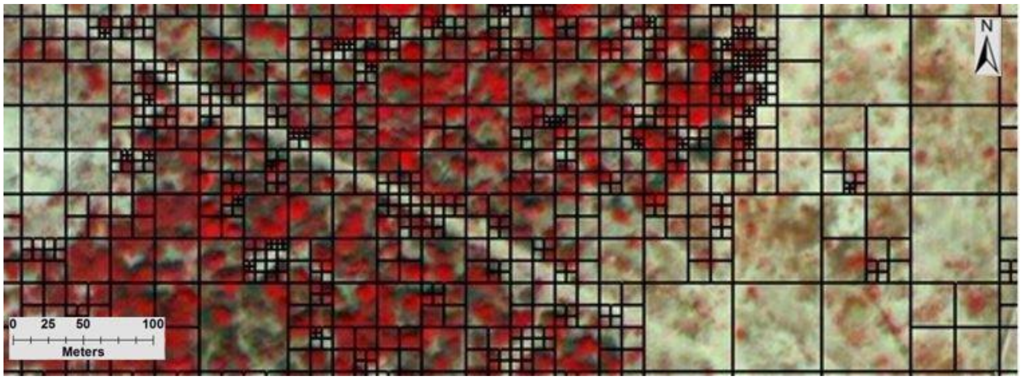

Fig. 5. First level Quadtree segmentation of study area showing *Prosopis juliflora* (in red color).

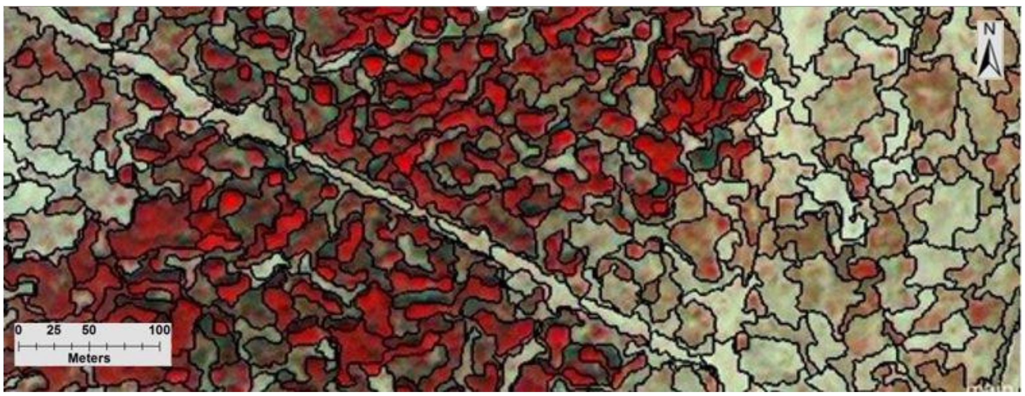

Fig. 6. Second level Multiresolution segmentation of study area showing *Prosopis juliflora* (in red color).

Fig. 7. Third level Multiresolution segmentation of study area showing *Prosopis juliflora* (in red color).

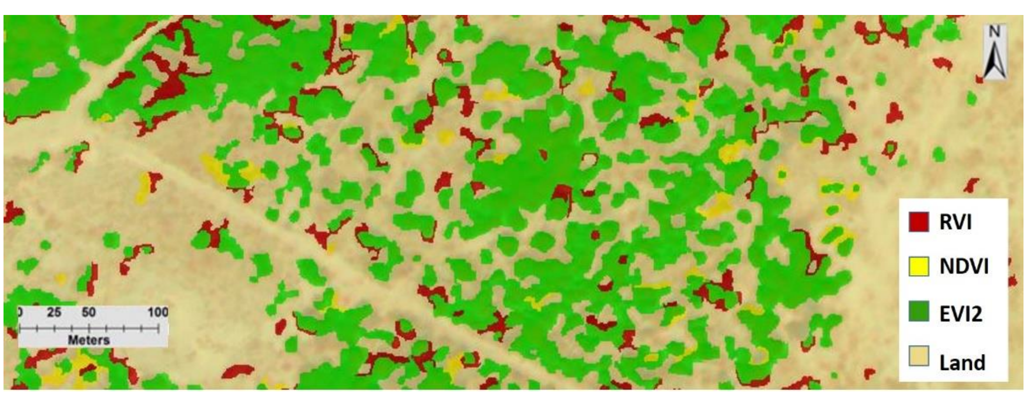

Fig. 8. Map of *Prosopis juliflora* extents using different vegetation indices.

CONCLUSION

In this study, we conclude that the recent technique OBIA is more effective that will be employed for mapping of invasive species in Karachi, and elsewhere, using high resolution satellite imagery. Correct segmentation of the satellite image enables the researcher to pick right target areas as can be seen in Fig. 7. The final conclusion of the study belong to EVI2. EVI2 will map invasive species with very less generalizations and mixing of other classes.

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