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POTENTIAL OF WATER HYACINTH INFESTATION ON DAM JAIKWADI, MAHARASHTRA: A PREDICTION USING A GIS-BASED MULTI-CRITERIA TECHNIQUE

Rushikesh S. Metangale[1]

[1]Town and country planner, GIS Analyst, India.

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ABSTRACT

Water hyacinth is a well-known invasive weed in dams across the world and harms the aquatic environment. Since 2011, the weed has invaded Dam Jaikwadi substantially posing a challenge to the ecosystem services of the dam. The major factors which affect the growth of the weed are phosphorus, nitrogen, temperature, pH, salinity, and dam depth. Understanding and investigating the hotspot areas is vital to predict the areas for proper planning of interventions. The main objective of this study is therefore to predict the hotspot areas of the water hyacinth over the surface of the dam using the geographical information system (GIS)-based multi-criteria evaluation (MCE) technique. The main parameters used in the multi-criteria analysis were total phosphorus (>0.08 mg L−1), total nitrogen (>1.1 mg L−1), temperature (<26.2 °C), pH (<8.6), salinity (<0.011%), and depth (<6 m). Fuzzy overlay spatial analysis was used to overlay the different parameters to obtain the final prediction map of water hyacinth infestation areas. The results indicated that 24,969 ha (8.1%), 21,568.7 ha (7.1%), and 24,036 ha (7.9%) of the dam are susceptible to invasion by the water hyacinth in August, December, and March, respectively. At the maximum historical dam level, 30,728.4 ha will be the potential susceptible area for water hyacinth growth and expansion at the end of the rainy season in August. The north and northeastern parts of the dam are highly susceptible for invasion.

Keywords: water hyacinth; Dam Jaikwadi; MCE; fuzzy overlay; source area; Godavari

1. INTRODUCTION

Water hyacinth (Eichhornia crassipes), is a perennial, herbaceous, free floating aquatic plant originating in the Amazon Basin, South America. It can grow in stagnant and flowing water bodies. The reason for the wide spread and growth of the weed in these areas might be due to eutrophication caused by a high level of nutrients. Factors that can create favorable conditions for this growth can be salinity, pH, temperature, sunlight shading, disturbance, and reproduction systems of the invasive weed. Since 2011, water hyacinth has invaded Dam Jaikwadi, which is the largest dam in the highlands of Maharashtra.

Water hyacinth has a strong impact on the physicochemical components of the water of the invaded ecosystem. Its presence in the form of floating carpets on the surface leads to drastic reductions in temperature, pH, oxygen concentration, and the amount of nutrients in the water column. The reporting of the invaded coverage area is a source of conflict among the stakeholders. The invaded area of the dam was 20,000 ha, 50,000 ha, and 34,000 ha in 2012, 2014, and 2015, respectively, whereas the government offices estimated the coverage to be below 5000 ha in the peak growing season.

2. DATASET

Water quality data such as total phosphorus (TP), total nitrogen (TN), water surface temperature (T), total dissolved solids (TDS), and pH were collected in August, December (2016), and March (2017) from a total of 143 sampling sites (Figure 2) across the dam at a 5 km interval and 0.5 m depth.

The representative sample of each point was then kept in polyethylene bottles and stored at −4 °C until it was analyzed. Total phosphorus (TP) concentrations were determined using PhosVer®3 (Hach Company, Loveland, CO, USA) based on the acid-per-sulfate digestion method in the range of 0.06–3.50 PO43− mg P L−1. Total nitrogen (TN) concentrations were also determined using the acid-persulfate digestion method in the low range of 0.5–25.0 mg N L−1). Digestion was realized at 105 and 150 °C for 30 min, respectively, for TN and TP.

The absorption was then measured using Hach product DR.2008 and DR.3900 spectrophotometer at a wavelength of 410 nm and 890 nm for TN and TP, respectively.

The temperature of the water surface was determined in-situ using a WM-32EP EC/pH meter (DKK-TOA Corporation, Tokyo, Japan). Transparency of the water was measured by a Secchi disc of 20 cm in diameter (Abel's Boat maintenance and assembly microenterprise, Bahir Dar, Maharashtra). The maximum depth at which the disc can be seen when lowered into the water is marked and measured.

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3. METHODS

To achieve the objectives of this study, the application of ArcGIS tools, especially the spatial analyst tool, was very useful. To predict the water hyacinth hotspot invasion area of Dam Jaikwadi, three steps were applied. The first step was interpolation and prediction of the spatiotemporal distribution of each major factor using the measured data across the dam. The second step was validation of the threshold values of each major factor by using a map of the invaded area which was prepared by Global Positioning System (GPS) tracking method. Finally, using a fuzzy overlay technique, we predicted and prepared maps of the spatiotemporal hotspot invasion areas of the dam.

1. Interpolation

   The spatiotemporal variability of the water quality data was predicted by ordinary kriging interpolation method, with a spherical semivariogram model using the spatial analyst tool in ArcGIS (ESRI, Redlands, CA, USA). The ordinary kriging method is the most basic method of kriging interpolation, which allows for the application of a statistical model including autocorrelation, rather than applying a deterministic approach by using inverse distance weight (IDW). Using these interpolated values, raster layers for each parameter were developed, which show the spatial variability of water hyacinth potential infestation areas. Using the maximum historical dam level (1788.2 m a.s.l), the probable flood area of the basin which is connected to the dam water was estimated and mapped using a 30 m resolution digital elevation model (DEM).

2. The Threshold Value of the Major Factors

   The major factors which determine the growth and expansion of water hyacinth are total phosphorus (TP), total nitrogen (TN), water surface temperature (T), salinity, pH, and water depth [12]. The values of water surface temperature, TP, TN, salinity, pH, and water depth which are suitable for water hyacinth growth were determined from previous studies [9]. Some threshold values were taken from previous research and most of them were fixed after critical evaluation and monitoring of measured parameters and their values in the current invaded area of the dam. The map of the current invaded area was developed by GPS tracking from 4–14 October 2018 when the growth of the weed was highest. Those parameters will help us to identify the main source areas (hotspots) of the water hyacinth in the water bodies. On the basis of information from the literature and field observation and measurement, the depth of the dam which is suitable for optimum growth of water hyacinth is less than 6 m. Based on the threshold setup, a total of six spatial maps were prepared in each month and overlaid to identify the potential water hyacinth infestation area at different times across Dam Jaikwadi.

3. Multicriteria Analysis

   The suitability analysis was carried out using GIS-based multi-criteria decision analysis (MCDA) with the fuzzy overlay function. Even though the fuzzy overlay is computationally complex, it gives more accurate and consistent results than weighted overlay. Before applying the fuzzy overlay, suitable criteria for optimum water hyacinth growth for each water quality parameter were determined using the literature and the current infestation area survey of the dam. The map of the current water hyacinth covered area was used for validation.

4. RESULTS AND DISCUSSION

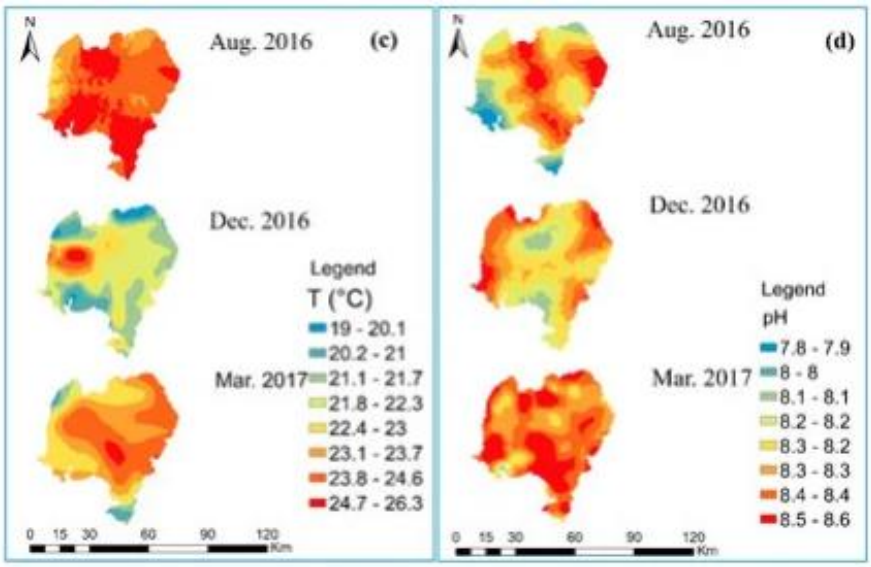

Figure 1. {Temperature (c) and pH (d)}

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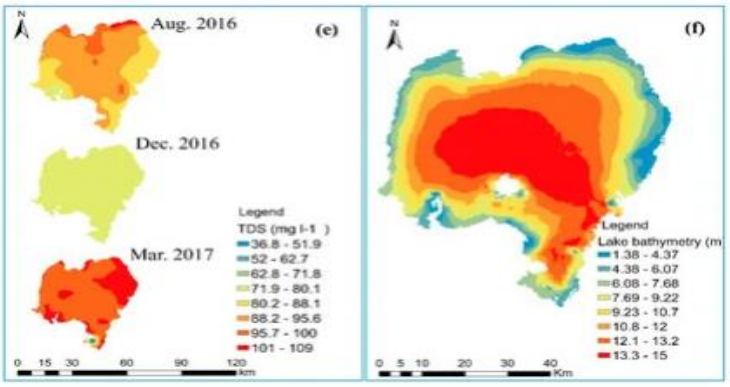

Figure .2 {Total dissolved solids (e) and lake bathymetry (f)}

5. HOTSPOT AREA PREDICTION OF WATER HYACINTH AREA USING MCDA

Currently, the hotspot areas which have been invaded by the invasive species are located on the northeastern shore of the dam (6–10 October 2018, shown in Figure 6b). In the rainy season (August), the western part is also susceptible to be invaded by the weed, but so far, there was no observation of an invasion. The reason why the northeastern shore of the dam is susceptible to invasion might be due to the large flood plain which has a great potential to sink nutrients

The area suitable for infestation was found to be larger in August than in March and December. This result is supported by the actual conditions of the infestation of the weed. In the last five or six years, the infestation has worsened at the end of the rainy season in the northeast corridor and has spread a little further southeast of the dam. In the dry season, the infestation is limited to the mouth of the perennial rivers and the littoral portion of the dam.

6. CONCLUSIONS

The major factors applied in the multi-criteria analysis to predict the hotspot areas of water hyacinth growth on Dam Jaikwadi were total phosphorus, total nitrogen, temperature, pH, salinity, and depth. According to the results, a substantial area of the dam is susceptible to water hyacinth invasion, especially the northeastern part of the dam. T (2. Giardini, 2004)his might be due to the large flood plain in the northeastern part, the wind direction towards it, and the shallow dam depth in this area. The maximum invasion area of the dam is 30,728.4 ha (10%) in August at the maximum dam water level. This study will help to implement control and management strategies for the stakeholders and the concerned governmental bodies. (Brendonck, et al., 2003) (3. Ceschin, et al., 2019)

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