Urban Lake Conservation Using Fuzzy logics and Geospatial Technology- Case Study Bhopal, MP, India

Aruna Saxena

***Abstract*—India is home to a wide range of water impoundments located in a diversity of climates, stretching from mountain conditions near the Himalayas in the north, to tropical conditions in the south. The impoundments include natural lakes, wetlands and coastal lagoons, as well as constructed reservoirs and tanks. This paper provides an overview of the urban lake management in Bhopal, India, focusing on use of geospatial and fuzzy logic techniques. Bhopal upper lake is exhibiting varying degrees of environmental degradation caused by encroachments, eutrophication (from domestic and industrial effluents) and siltation. The high population density ensures that this water body is under severe and direct pressure from anthropogenic activities in their catchments. Actions to control and prevent these problems are addressed. In this study, a noble concept of a fuzzy logic for lake water quality analysis is proposed. The aim of this evaluation on upper lake water quality is not only for decision support system (DSS) for environmental planning & management but also to facilitates urban planner, environmental experts and the community towards the conservation of water bodies.**

***Keywords*—lake water quality, Fuzzy set, Geo-spatial techniques.**

I. INTRODUCTION

Bhopal city has been dotted with a number of lakes, which formed very important component of its physical environment. With rapid urban sprawl of the city, many of the water bodies have been totally in bad conditions. Many have been shrunk in size while the waters of several lakes got polluted with the discharge of untreated domestic and industrial effluents. Environment monitoring and quality evaluation is an important tool for environmental quality management and that further facilitates to sustainable development of physical environment of the city. Good quality of urban environment is more significant for socio-economic development and sustainable development of natural resource. For sustainable development based on urban planning and effective planning is totally based upon the completely & precisely understanding of the environmental quality.

Aruna Saxena is Prof. & Head, Training placement & Student Welfare, Maulana Azad National Institute of Technology, Bhopal (M.P.), India saxena.aroona@gmail.com

To do precise evaluation, an effective evaluation method is important. Conventional environmental quality evaluation method as described by Oh and Jeong (2002) uses some threshold to classify the evaluation criteria. For every environmental quality class, there is corresponding threshold to classify the evaluation criteria. Based on this classification, the evaluation criteria are scored by some discrete value according to the class which it belongs to. The score for each criterion is then multiplied by weight for the criterion and summed to give a total score represents the quantitative description of environmental quality. This conventional evaluation method belongs to the traditional (Boolean) set field. One constraint of this conventional (Boolean) evaluation method is the discontinuous classification. The new fuzzy based classification is able to resolved amount of vagueness, uncertainty and ambiguity of environmental quality class as compare to conventional method (Boolean). Therefore, evaluation & analysis of environmental parameter of lakes with accuracy is a challenge and both conventional methods and recent advance technology (fuzzy, rough theory) play important role for environmental management (Panchal et al, 2008). Conventional methods have its own limitation in terms of in constraint of imprecise knowledge and constraint of vagueness & discontinuity of classification. (Uncertainty and ambiguity).

2. STUDY AREA

The Bhopal city, capital of Madhya Pradesh state of India, is known for its cultural heritage, water bodies and it is highlighted in the world after one of the biggest industrial disaster “Bhopal gas Tragedy” occurred in year 1984. Now this city is growing rapidly in all spheres of development. Since last 10 years, the population growth was remarkably increased. The upper lake of Bhopal (1000 years old) is one of the largest artificial lakes in Asia. The lake has an area of 31 sq km and drains a water shed of 361 sq Km with its geographical location between $23^{o}12'$-$23^{o}16'$ N latitude to $77^{o}18'$-$77^{o}23'$ E longitude. It was constructed as earthen dam across the Kolans River in 11th century by the King Bhoj. The lake has full tank level of 508.65 meters MSL (Mean Sea Level). The storage capacity is 117.05 million cubic meters. The rain water is the only source of water in this lake. Its contribution is of cities 40% water supply. There are 87 villages in its catchment areas in Bhopal and Sihor district. The upper lake is intimately connected with the identity of this city as Bhopal known as the city of lakes.

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

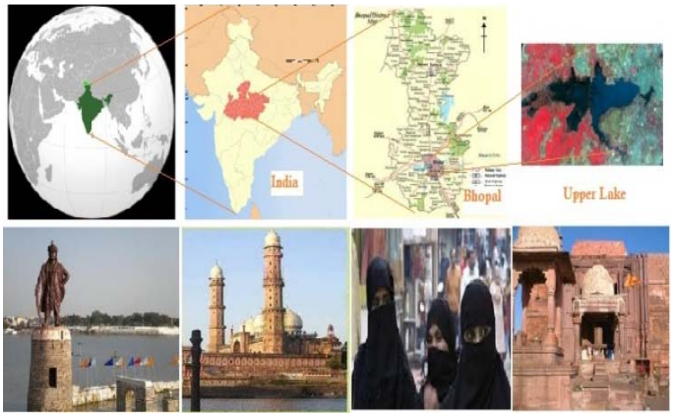

Fig 1- Location map of study area, Raja Bhoj statue, Tajul Masjid, People of Bhopal, monument Moti Masjid.

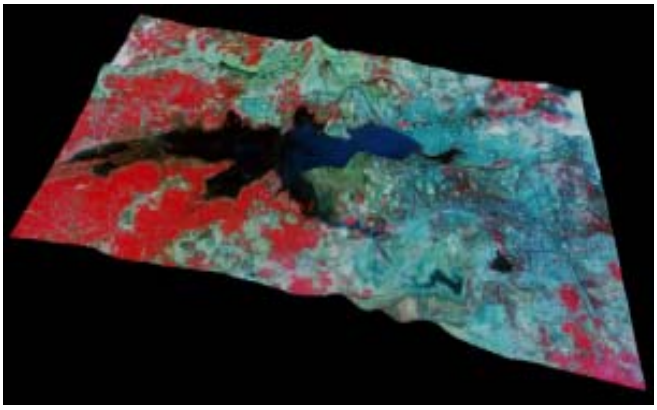

Fig 2- 3D view of study area

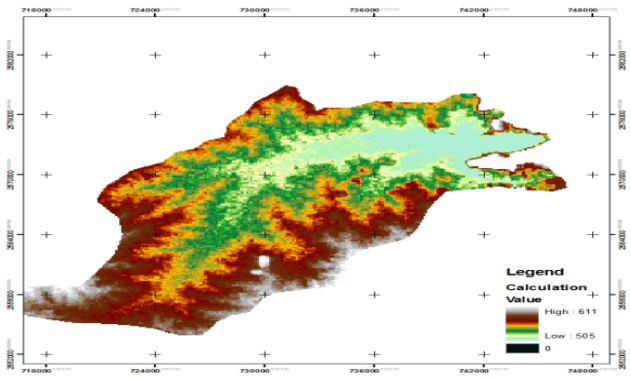

Fig 3- DEM of Study Area (At Catchment level)

III.PROBLEM IDENTIFICATION

Due to many reasons especially the anthropogenic pressure, the upper lake of Bhopal city is threaten to loss its existence as its water level falling consistently. The lake is primarily rain feed. Over the last years the amount of rainfall was not consistent. On the other hand despite of having 31 inflow points to lake, the rain storm water/runoff not properly reached to the lake. The encroachment of channels is the main cause. While seepage in nearby agriculture area is another important factor which affected the lake storage. 40% of water supply has been done from the lake which is nearly about to 527 million gallons of water per day (MGD). On the other hand the growing population mainly due to human intervention adversely impact on lake water quality and lake ecosystem too. Thus it is high time to pay attention on present scenario.

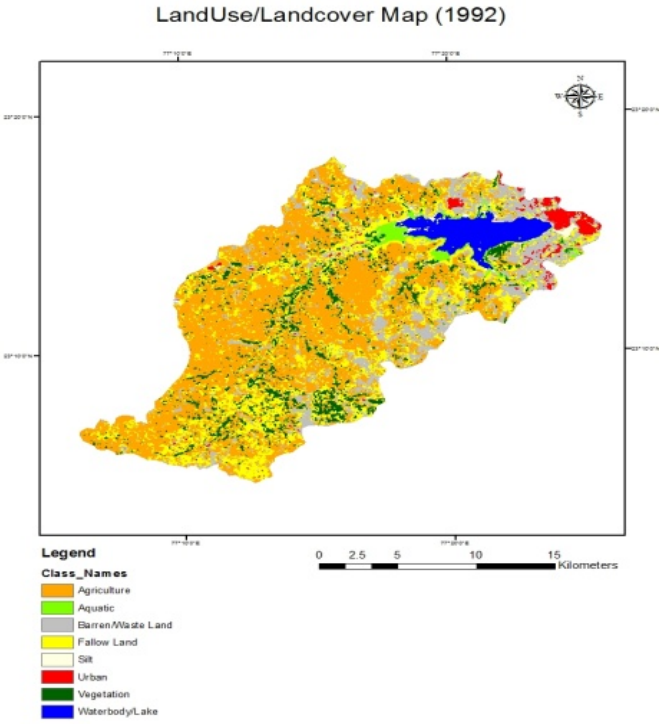

Fig 4- Chronology of upper lake (Year 1992)

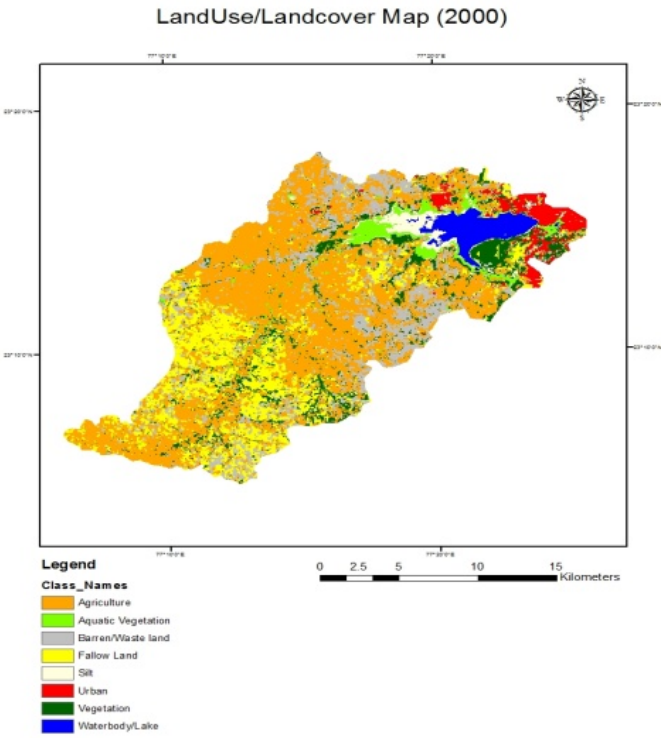

Fig 5- Chronology of upper lake (Year 2000)

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

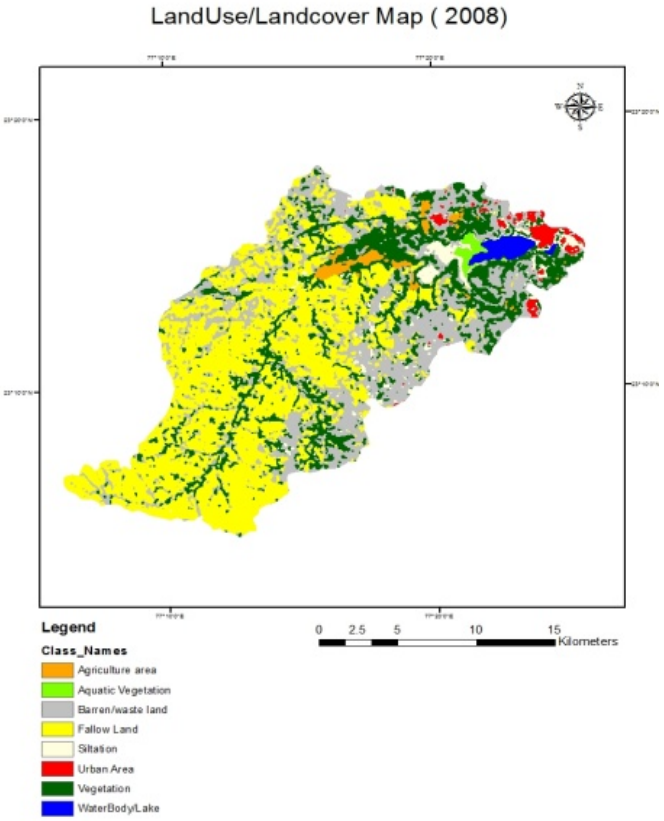

Fig 6- Chronology of upper lake (Year 2008)

IV. OBJECTIVES

In the above mentioned problems, the emphasize of this research is:

1. To identify various source of pollution (point & non point) in upper lake using ground data, remote sensing and GIS techniques.
2. To prepare urban evaluation maps of upper lake and its surrounding regions using fuzzy logic and GIS technologies.
3. To prepare guidelines for sustainable environmental planning for upper lake and its surrounding area.

V. DATA USED

For this research the IRS LISS III & LISS IV Data (year 2005, 2008, 2009), SRTM Data, Landsat ETM (2000 and 2006), SOI Toposheet-55 E/3, E/7, E/8 has majorly been used. While the ground truth data has been obtained and verified with the aid of GPS. Water samples were collected from various sites in and around the lake from 2008 to 2011. The SRTM data has been used to produce the DEM of the study area at catchment level.

VI. METHODOLOGY

The methodology for environment evaluation using fuzzy logic adopted in this paper has been given in following Steps.

A. Mat lab's Fuzzy Logic Toolbox

This Toolbox is a compilation of functions built on the MATLAB numeric computing environment and provides tools for creating and editing fuzzy inference systems within the framework of MATLAB. The Fuzzy Logic Toolbox provides a number of interactive tools that allow accessing many of the functions through a graphical user interface (GUI) using Fuzzy Inference System (FIS) and Adaptive Neuro-Fuzzy Inference System (ANFIS).

B. Classifier

Here the Sugeno type inference system is used. It shows a simple diagram with the names of the input (red, green, NIR, MIR, RS1, RS2 and DEM) and output (Rocky, barren, urban, vegetation, and water body). Another block in the shown diagram mentions the type of the system used. After assigning the names to the inputs and outputs, the next diagram is the membership function editor. It displays all the membership functions related with the input and output. Because of the smoothness and non-zero values, in order to define a membership function, in the process of image classification simple Gaussian curve (gaussmf) is used as shown in figure 8. The values of the parameters for the input are taken from the mean and standard deviation calculated earlier from the training set. Since the system is Sugeno type, so for the output, constant type membership function is best suited. After membership function editor, the next diagram is the rule editor (Fig 9). The rules here are entered in the verbose format. The inputs are connected with and function. Basic if-then rules are used as shown in Table 1.

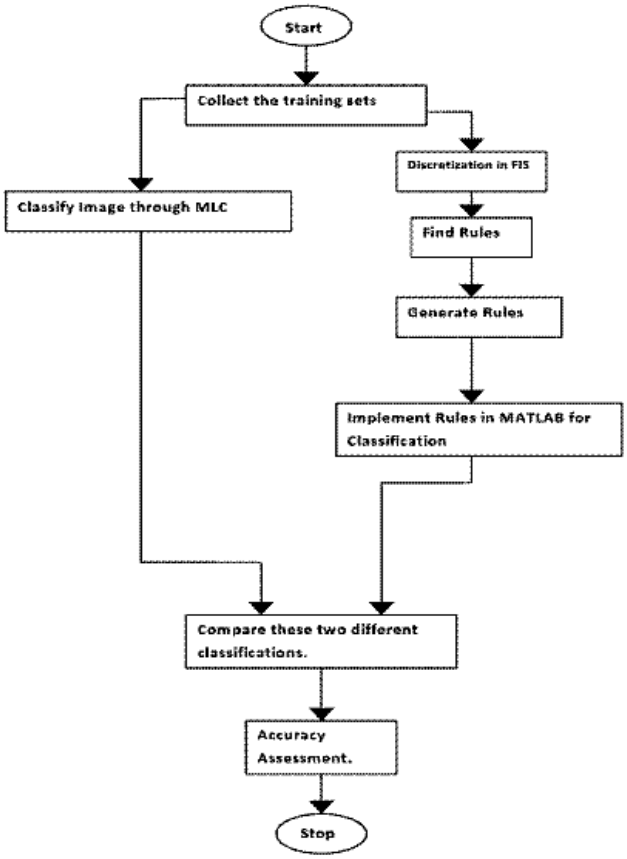

Fig 7- Methodology

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Table 1
Basic if-then rules to classify the pixels

IF (red is mf1) AND(green is mf1) AND(NIR is mf1) AND(MIR is mf1) AND(RS1 is mf1) AND(RS2 is mf1) AND(DEM is mf1) THEN (class is Barren)
IF (red is mf2) AND(green is mf2) AND(NIR is mf2) AND(MIR is mf2) AND(RS1 is mf2) AND(RS2 is mf2) AND(DEM is mf2) THEN (class is Rocky)
IF (red is mf3) AND(green is mf3) AND(NIR is mf3) AND(MIR is mf3) AND(RS1 is mf3) AND(RS2 is mf3) AND(DEM is mf3) THEN (class is Urban)
IF (red is mf4) AND(green is mf4) AND(NIR is mf4) AND(MIR is mf4) AND(RS1 is mf4) AND(RS2 is mf4) AND(DEM is mf4) THEN (class is Vegetation)
IF (red is mf5) AND(green is mf5) AND(NIR is mf5) AND(MIR is mf5) AND(RS1 is mf5) AND(RS2 is mf5) AND(DEM is mf5) THEN (class is Water body)

Abbreviation of term used in pixels classification using fuzzy based approach
DEM: Digital Elevation Model
NIR: Near Infrared Region
MIR: Mid Infrared Region
RS: Remote sensing image (input)
MF: Membership Function

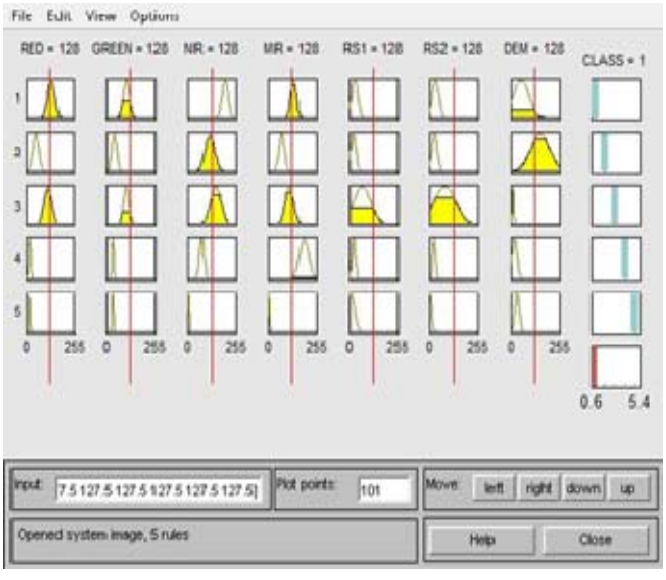

Fig 8- Membership function editor

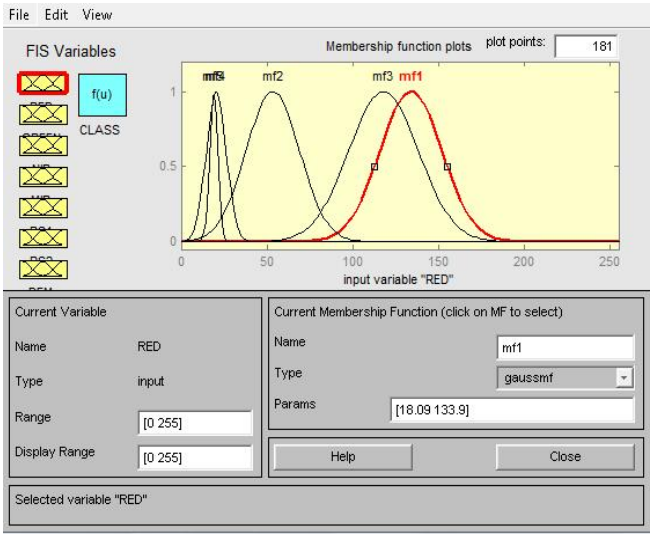

Fig 9- Rule viewer

Now the fuzzy inference system has been completely defined here. The Rough-Fuzzy classifier is capable of classifying all the pixels of the image.

Next an algorithm is developed in the form of Matlab's m-file which assigns different colors to the various classes. The classified image of is shown below (Fig 10).

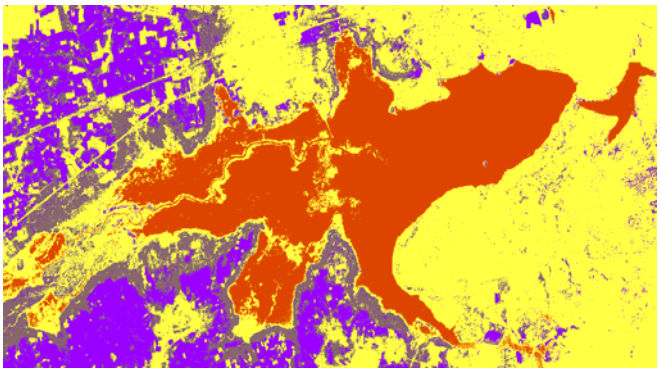

Fig 10- Classification of image using rough-set

The fuzzy based approach of classification is very vital because the complexity of environmental phenomena and lack of clear cut distinction between features could not be assured. In such condition the classical Boolean approach has certain limitation, which can be overcome by fuzzy based approach.

Our area of interest for performing environmental water quality classification of the 3-band LISS 3(optical) image pertains to upper lake (Bhopal, MP, India).The aim of this evaluation on urban environment quality is not only for decision support system(DDS) for environmental planning &management but to facilitates urban planner, environmental experts and the community.

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Interferences

New1- Orange color shows the concentration of turbidity and yellow west land.

New2 -in gray scale we can perceive the deep water with comparatively less dissolved solid (DS) & Total Dissolved Solid (TDS).

New3- in FCC, the RED color near Upper Lake's bank shows more significance Eutrophic; and if the rate of pollutants will continue at this speed, it will be more significance for eutrophication process into lake.

New4- the violet color in Upper Lake shows the high concentration of Sulphate & Phosphate with debris, organic matter, and algae. It's more significance for lake water pollution.

New5- Orange color shows fresh water with Blue-green algae as primary producer of lake water ecosystem.

New6- the Orange color shows the secular reflection in Near Infra-Red band, thus sig. trace amount of Oil.

New7- If training sets of only land area and discrete value in fuzzy comparatively is less, then there is not sig. of reflection in Blue band. Thus discretization should be more.

VII. FINDING WITH FURTHER SCOPE OF STUDY

In the figure 11, we can see the high concentration of SO_4 & PO_4 due to change the reflectance value of water in higher value of visible spectrum.

Here, using visible as well as Infrared, and far wave length, we could find more accuracy of water pollutants and thus, provide further scope of study.

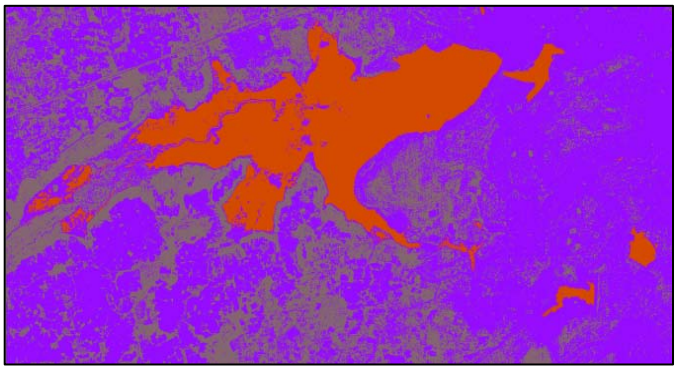

Fig11- Violet color shows the high concentration of Sulphate & Phosphate with debris, organic matter, and algae. It's more significance for lake water pollution.

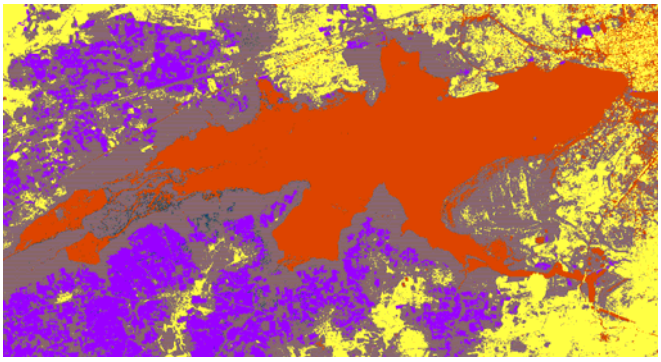

Fig 12- Orange colour shows the concentration of turbidity and yellow shows west land.

Fig 13- In gray scale we can perceive the deep water with comparatively less dissolved solid (DS) & Total Dissolved Solid (TDS).

Fig14- source of pollution in lake catchment area.

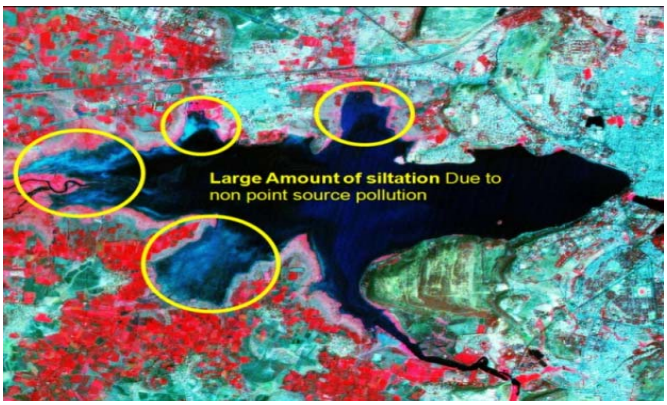

Fig 15- Siltation in Lake catchment area.

VIII. SUGGESTIONS AND RECOMMENDATIONS

The catchment area of the Upper Lake covers about 361 km2, with agricultural practices being undertaken in most of the area. During the rainy season, runoff from the catchment carries much silt and organic debris to the lake. The urban catchment runoff and sewage enters the lakes through various drains, causing both siltation and water pollution. Silt accumulation near the gates also caused high pressure on the gates. As an insufficient spillway system discharge capacity could lead to the buildup of water

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

pressure in the Upper Lake, causing a threat to the dams. In order to prevent encroachment by human settlements, cultivation, grazing within the lake area & siltation, buffer zones has been created, particularly in the western, southern and northern fringes of the Upper Lake. Accordingly, a "No Construction Zone," located up to 50 m from the FTL of the Upper Lake, should be demarcated with boundary stones. A physical barrier, in the form of arches along the Lower Lake, may be constructed to prevent direct access to the lake.

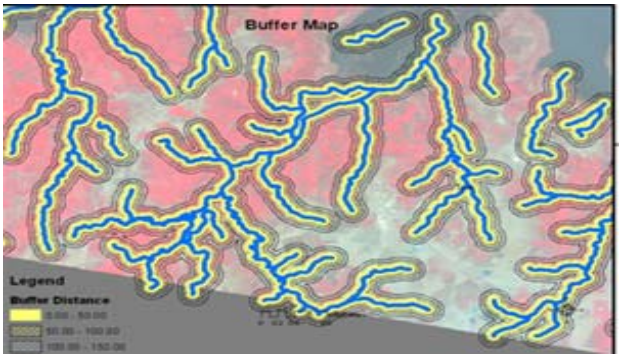

Fig 16- Buffer creations along drains

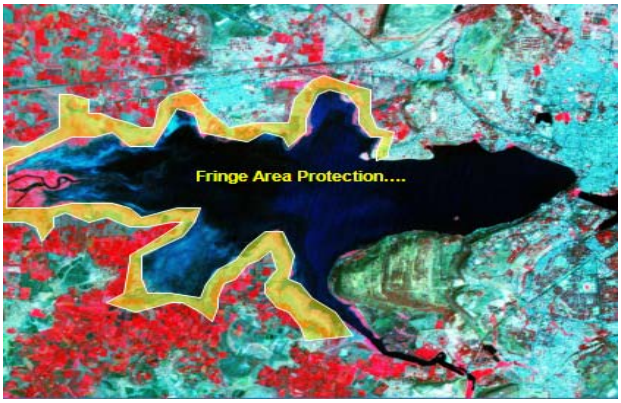

Fig 17- Fringe protection around the lake

Permanent structures must be established along the side of upper lake which is attached with urban fringes to prevent direct urban intervention. A large area exposed around the periphery of upper lake used for agriculture is more responsible for non point source pollution and sedimentation in lakes and, while encroachment on the in late channels is responsible for reduced fresh water supply in the lake. Intensive planting activities must be carried out in the lake's watershed area to control soil erosion. To mitigate the inflow of silt, agricultural residues and other wastes into the lakes check dams of loose boulder/gabion structures, and silt traps having a cumulative silt trapping capacity should be constructed across the inlet channels. Due to silt deposition from the various drains, mass land formation is occurring at the confluence points, resulting in decreased water storage capacity and spread area. The excavated materials could be transported to wastelands transforming them into productive agricultural and plantation lands. To maintain the Upper Lake's water level, deepening and widening of the spill channels should be done for the smooth discharge of excess water during the rainy season through gates.

IX. POLICY RELATED RECOMMENDATIONS

The critical need today is to recognize the inter-linkages and benefits that could be obtained if the lake with its Wetland is managed in an 'integrated manner' and is 'sustainably used'. It is a challenging task and requires action at many levels. Such an approach must begin with involving all stakeholders in the form of a local area institution. This would be helpful in eliciting their views for the use and future management of the lake. The Institution so formed could frame an action plans to cover all ecological economic, social issues along with public participation.

X. CONCLUSIONS

The use of fuzzy classification helps to classify the mixed pixels in the image. Classification depends upon expert knowledge/ training set. All the mixed pixels have been classified**.** This research has achieved the Fuzzy set for lake water quality evaluation with the help of Matlab s/w.
Satellite data can be effectively utilized in the mapping and monitoring of large reservoirs with the aid of advance digital image processing techniques that is fuzzy based classification approach. The present study indicated increase of various pollutants in lake water spread area as well as changing ecological balance due to siltation of upper lake. The study also concluded that satellite data can be of immense help in the urban catchments where anthropogenic pressure is dominant.
There is an urgent need for long term management planning for maintaining the lake water quality and its ecosystem for existence of this lake. The people should also make aware about pollution produced by them directly and indirectly.

ACKNOWLEDGEMENT

Author is sincerely thankful to Department of Science & Technology, New Delhi, India for funding grants to do this research work.

REFERENCES

[1] Durga rao, Singh Ambesh kumar, Roy P.S.; "Study of Morphology and Suspended Sediment of Bhopal Upper Lake Using Spatial Simulation Technique and Remote Sensing Data." *JISRS*, 37:433-441, September 2009.

[2] Oh K, Jeong Y, "The usefulness of the GIS - fuzzy set approach in evaluating the urban residential environment" Environment and Planning B: Planning and Design 29(4) 589 – 606, 2002.

[3] Panchal VK, Singhal Naresh, Kumar Shashi, Bhakna Sonam, "Rough-Fuzzy Sets Tie-Up for Geospatial Information" Proceedings of International Conference on Emerging Scenarios in Space Technology and Applications (ESSTA2008), vol-I, 2008.

[4] Lillesand, T.M., Kiefer, R.W. and Chipman, J.W. , "Remote Sensing and Image Interpretation", Fifth Edition, Wiley & Sons Ltd., England, pp.586-592, 2003.