Extraction And Classification Of Water Bodies In Bangalore

Geographic Information Systems

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Prof. Uttam kumar
Prof. Rajagopalan

- Submitted by -

Anushka Parashar - MT2017024
R.Lakshmi Priya - IMT2015037
Rohil Pal - IMT2015520

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ABSTRACT

As the title suggests, this project comprised of two parts:

- extraction of water pixels from LANDSAT 8 satellite data
- classification of water pixels based on their contamination level

For water-pixel extraction, we experimented with different methods like NDWI (McFeeters, 1996), MNDWI (Xu, 2006), AWEI (Feyisa , Meilby, Fensholt, Proud, 2013).

But we finally choose to go with AWEI index. This index describes two different indexes for waterpixel extraction viz. $AWEI_{nsh}$ and $AWEI_{sh}$. $AWEI_{sh}$ takes into account separating shadow pixels while $AWEI_{nsh}$ does not. By virtue of this, we got relatively better results with $AWEI_{nsh}$. The image has a higher dynamic range and is more saturated.

For water-pixel classification, we observed differences in pixel values of highly contaminated and relatively less contaminated water areas in different LANDSAT 8 bands. Band 5 showed a notable difference between the two areas, with values from 5400 to 6200 for low contamination and 6200 to 8000 for high contamination.

Subsequently, we added a third category to capture areas primarily including roads and water-soil mixed land whose pixel value were more than 8000.

The final result after extraction and classification shows that approximately 98.2% of area under study comprised of non-water pixels. The remaining 1.784% area consisting of water pixels was 0.084% low contaminated area, 0.652% high contaminated area and 1.046% roads/water-soil mixture.

Contents

1 INTRODUCTION

1.1 Goal

The goal of our project was to :

1. Extract water bodies all over Bangalore.
2. Classify them on the basis of the level of contamination.

1.2 Motivation

We are concerned about water pollution in Bangalore, which was our main motivation. This is what made this an interesting area of research.

1.3 Technology

To perform the extraction and classification of water bodies, we used GRASS GIS. Geographic Resources Analysis Support System is a geographic information system software suite used for geospatial data management and analysis, image processing, producing graphics and maps, spatial and temporal modeling, and visualizing.

2 MAIN TEXT

2.1 Data

The data we used was from Landsat 8 (OLI). Landsat 8 is used as a collaboration between NASA and the US Geological survey(USGS). Landsat 8 instruments represent an evolutionary advance in technology. OLI(Oerational Land Imager) includes on past Landsat sensors using a technical approach demonstrated by a sensor flown on NASAs experimental EO-1 satellite. OLI is a push-broom sensor which collects data for visible, near infrared, short waves, infrared spectral bands as well as panchromatic bands.
It has a total of 11 bands including OLI and TIRS(Thermal Infrared Sensor) bands.
All the bands have a 30 m spatial resolution except TIRS bands which have a 100 m resolution and panchromatic band which has a resolution of 15 m.
TIRS collects data for two more narrow spectral bands in the thermal region formerly covered by one wide spectral band on Landsats 4-7.The 100 m TIRS data will be registered to the OLI data to create radiometrically and geometrically and terrain-corrected 12-bit data products.

2.2 Extraction

The common indexes used for extracting water pixels in LANDSAT imagery are:

1. **NDWI (Normalised Difference Water Index):**
   It uses green (Band 2) and NIR(Band 4) of Landsat 7. The formula is:
   $$NDWI = \left(\frac{Green - NIR}{Green + NIR}\right)$$
   The value is positive for water pixels and zero/negative for soil and vegetation pixels.
   The drawback of NDWI is that it does not work well in water region with a build-up land background.

2. **MNDWI (Modified NDWI):**
   The only difference is that band 4 is replaced with band 5 or MIR(Middle Infrared) band of Landsat 7. The modified formula is:
   $$MNDWI = \left(\frac{Green - MIR}{Green + MIR}\right)$$
   Again, in this index positive values correspond to water pixels while zero/negative values correspond to soil/vegetation pixel.

3. **AWEI (Automated Water Extraction Index):**
   It is used for differentiating between water pixels and non-water pixels.
   $$\begin{aligned} AWEI_{nsh} &= 4\,(b_2 - b_5) - (0.25 * b_4 - 2.75 * b_7) \\ AWEI_{sh} &= b_1 + 2.5 * b_2 - 1.5\,(b_4 + b_5) - 0.25 * b_7 \end{aligned}$$
   High +ve values for water pixels and high ve values for non-water pixels.
   The coefficients used in the equations are empirical results determined based on reflectance patterns observed across the dataset of pure pixels of various land cover types.

- **Why $AWEI$?**
  Five spectral bands of Landsat 7 were used in developing the $AWEI$ index to increase the contrast between water and other dark surfaces. The primary aim of the formulation of $AWEI$ was to maximise separability of water and non water pixels through band differencing, addition and applying different coefficients.
  Particular emphasis was given to the enhancement of the separability of water and dark surfaces surfaces such as shadow and built-up structures that are often difficult to distinguish due to similarities in reflectance patterns.

- **Why $AWEI_{sh}$?**
  $AWEI_{nsh}$ is an index formulated to effectively eliminate non water pixels, including dark built surfaces in areas with urban background and $AWEI_{sh}$ is primarily formulated for further improvement of accuracy by removing shadow pixels that $AWEI_{nsh}$ may not effectively eliminate.This is why we used $AWEI_{sh}$ over $AWEI_{nsh}$ for the extraction of water bodies.

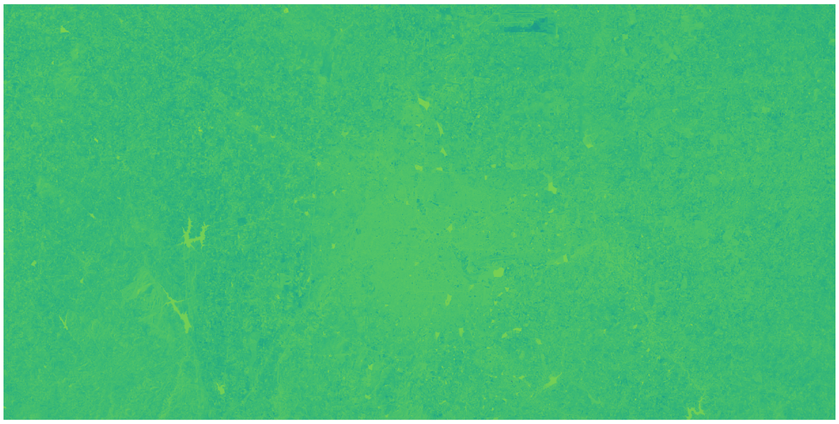

Figure 1: $AWEI_{nsh}$

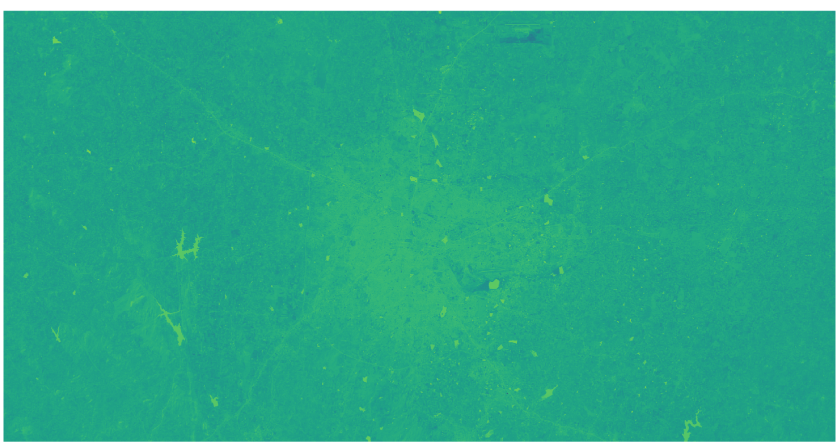

Figure 2: $AWEI_{sh}$

The formula defined for $AWEI_{sh}$ uses bands from Landsat 7 but we used Landsat 8 data. Hence, we tried to find relation/mapping between the bands of Landsat 7 and Landsat 8. It turned out, the range of bandwidths matches. And we followed following information to redeine the formula for $AWEI_{sh}$ using Landsat 8 bands.

Landsat-7 ETM+ Bands (µm)			Landsat-8 OLI and *TIRS* Bands (µm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR	0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1	1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR	10.31 - 12.36	*100 m TIR-1*	*10.60 – 11.19*	Band 10
			100 m TIR-2	*11.50 – 12.51*	Band 11
Band 7	30 m SWIR-2	2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan	0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
			30 m Cirrus	1.363 - 1.384	Band 9

Therefore, the formula for $AWEI_{sh}$ for Landsat 8 is:

$$AWEI_{sh} = 4\,(b_3 - b_6) - (0.25 * b_5 - 2.75 * b_7) \tag{1}$$

As known, positive values of $AWEI_{sh}$ are water pixels and negative values for non-water pixels.After applying (1) on the Landsat 8 data, we were able to extract water bodies all over Bangalore.

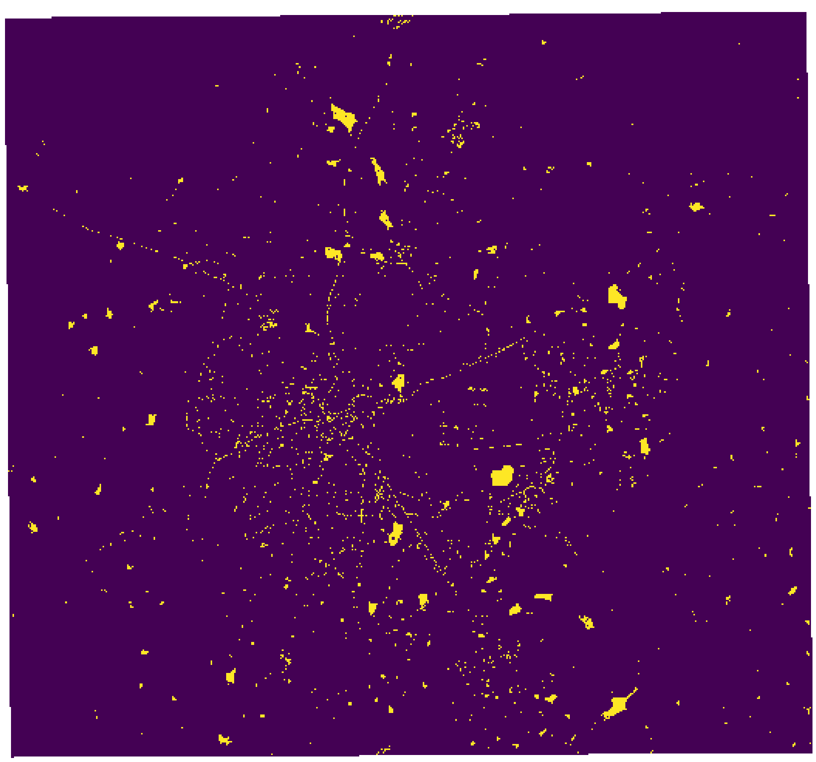

Figure 3: Water bodies in Bangalore

From ($Figure$ 3), we observed that $AWEI_{sh}$ is not enough to filter the road pixels and pixels with water-soil mixture, as their $AWEI_{sh}$ values are highly positive (just like water pixels), hence, even after applying the threshold (= 0), we are still not able to extract only water and roads and water-soil pixels get extracted along with the water.
This is the drackback of $AWEI_{sh}$, which was worked around in the Classification process.

2.3 Classification

The second objective of the project was to classify the extracted water pixels ($Figure$ 3) as 'High Contamination' and 'Low Contamination' pixels.
We mainly used band 5 to classify the data because the overlap between contaminated and non contaminated is less compared to other bands.

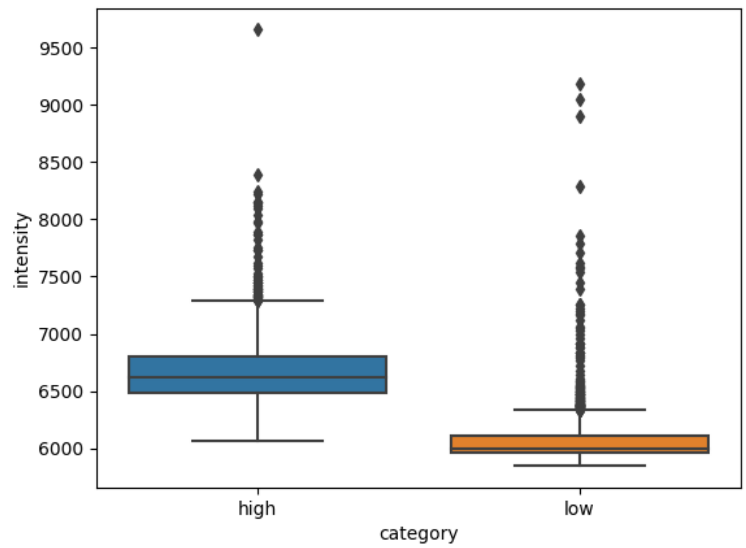

Figure 4: Intensity values in band 5 of highly contaminated and less contaminated lakes - Box Plot

As observed in $Figure$ 8, different categories of the water pixels shows different reflectance values. Keeping that in mind, we classified the extracted water pixels into 3 pixel classes each having it's own range of reflectance values.

$Pixel\ class$	Minimim Pixel Value	Maximum Pixel Value
$Low\ Contamination$	5400	6200
$High\ Contamination$	6200	8000
$Roads/Water - soil\ mixture$	8000	>8000

Table 1: Pixel Classification

Using ranges defined in $Table$ 1 we were able to obtain three classes out of the extracted water pixels $Figure$ 3. Output images are shown in the result section.

2.4 Result

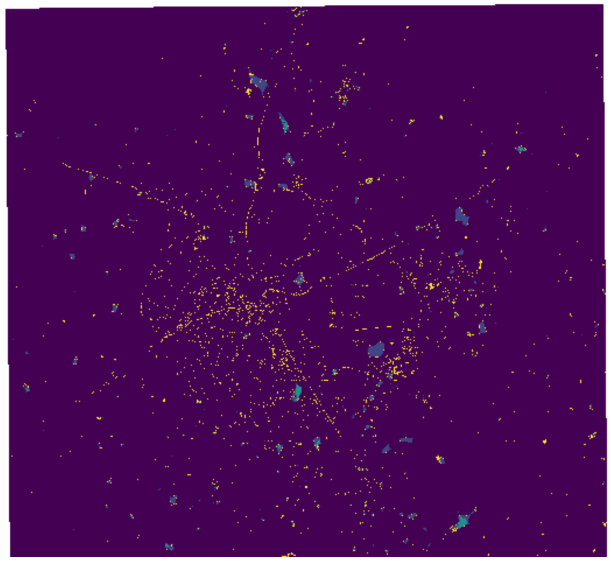

Figure 5: Three classes

$$\begin{aligned} &In\ Figure\ 5: \\ Green\ pixels &= Low\ Contamination\ pixels \\ Grey\ pixels &= High\ Contamination\ pixels \\ Yellow\ pixels &= Roads/Water{-}soil\ mixture\ pixels \end{aligned}$$

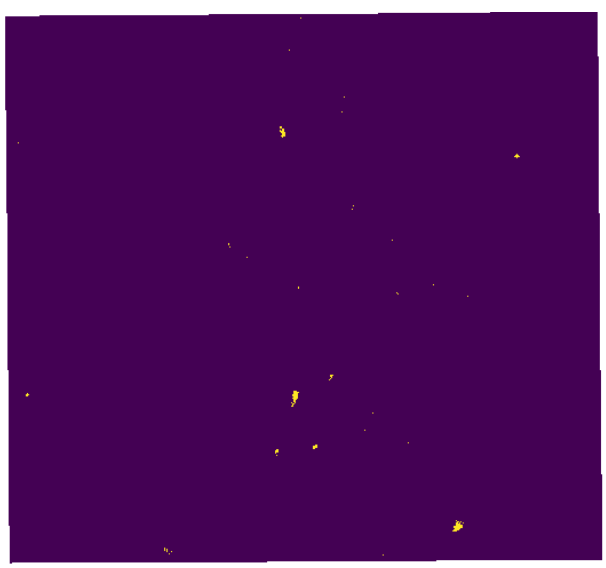

Figure 6: Low Contamination pixels

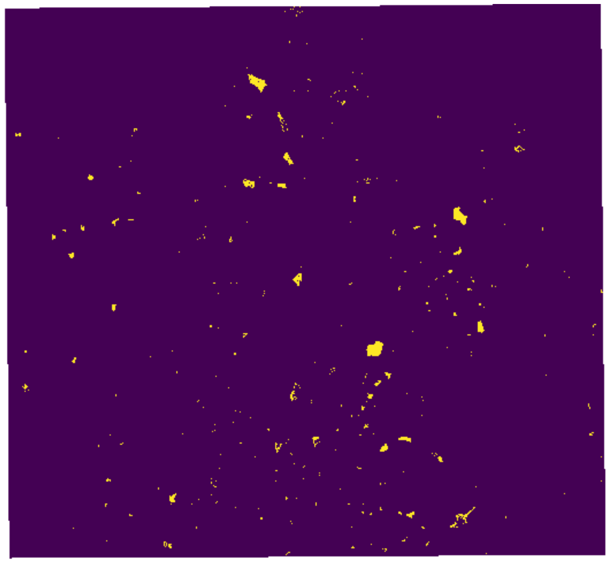

Figure 7: High Contamination pixels

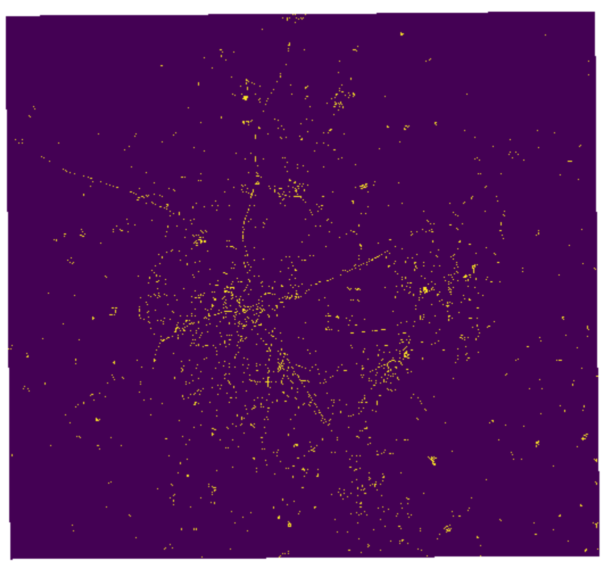

Figure 8: Roads/Water-soil mixture pixels

3 CONCLUSION

$Pixel\ class$	No. of Pixels	Area (sq. kms.)	Percentage(%)
$Bangalore$	1973866	1776.479	100
$AWEI_{sh}(Non-water\ pixels)$	1938641	1744.769	98.215
$AWEI_{sh}(Water\ pixels)$	35225	31.7025	1.784
$Low\ Contamination$	1675	1.5075	0.084
$High\ Contamination$	12889	11.6001	0.6529
$Roads/Water-soil\ mixture$	20661	18.5949	1.0467

Table 2: Distribution of classes

$Table$ 2 shows that only 1.784% area in Bangalore is covered with water, but since $AWEI_{sh}$ can't differentiate between water and Roads/Water-soil mixture, so actual percentage of water in Bangalore is 0.71% (1.784% − 1.0467%). Out of the water covered area in Bangalore 88.5% is highly contaminated and rest 11.5% of water has low contamination. This shows how pollution in Bangalore is increasing and it's definitely not a good sign, therefore quick actions must be taken by authorities to prevent further increase.

4 ACKNOWLEDGEMENT

I respect and thank Prof. Uttam Kumar, for providing us an opportunity to do the project ”Extraction and classification of water bodies in Bangalore” and giving us all support and guidance which made us complete the project duly. We are extremely thankful to him for providing such a nice support and guidance, although he had busy schedule managing the corporate affairs.

5 CITATIONS

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