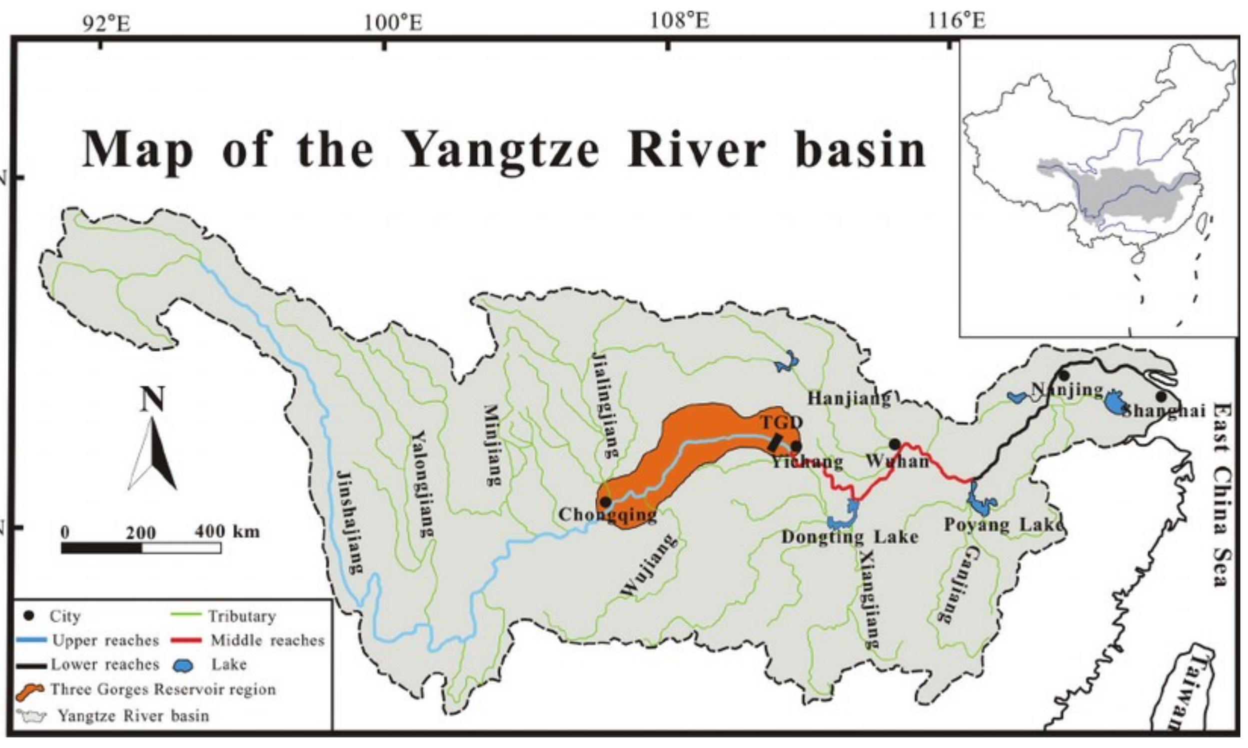
Impact of Three Gorges Dam on the Upstream of Yangtze River and its Tributaries



Introduction

China is investing heavily on hydroelectric power generation, tapping the potential of the transboundary rivers coming down from the Tibetan Plateau.[1] The Yangtze River is the longest river in Asia, originated from the Qinghai-Tibet Plateau and ends in the East China Sea. The three Gorges Dam on the Yangtze River is the world's largest power station with a 185 height above sea level and installed capacity of 22,500 MW. The reservoir needed for the dam submerges an area of 1,084 km2, flooding the natural ecosystem and its inhabitants. Figure 1 shows the river basin and the reservoir region.[2]

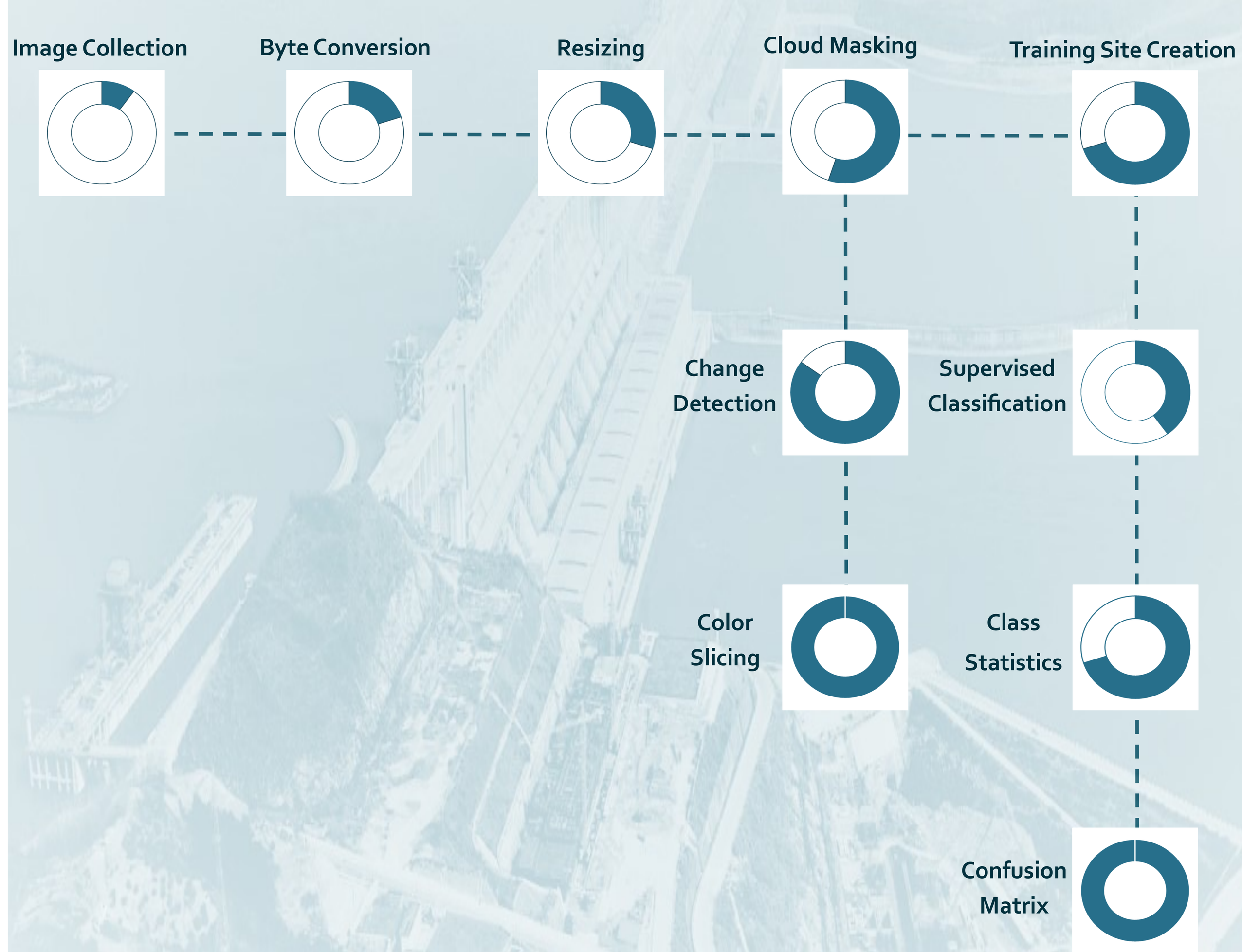
The dam disrupts the natural flow of water and sediment of the river, which affects both upstream and downstream. After the construction of the dam, several studies have stated that the dam in reducing the flow downstream, as well as changing the geographic features. This created impact on changing the geography of the river both upstream and downstream of the dam.[3]

A river runs through a large spatial area, which is easier to see with satellite imagery. The effects of water flow upstream and the spatial correlation of the main river and its tributaries are easily detectable through remote sensing. Application of remote sensing to understand morphological changes has been a well-known practice in the present days.[4] This project was inspired by NASA's Images of Change website, which showed the drastic change that can be recognized from the satellite images of before and after the construction of the dam.[5] The scope of this project is to locate and quantify the change of the shape of the river and its tributaries upstream of the dam.

Research Questions

- In what locations the Yangtze River has changed its shape the most?
- How much the shape has changed over the years between 1992 and 2016?

Methodology



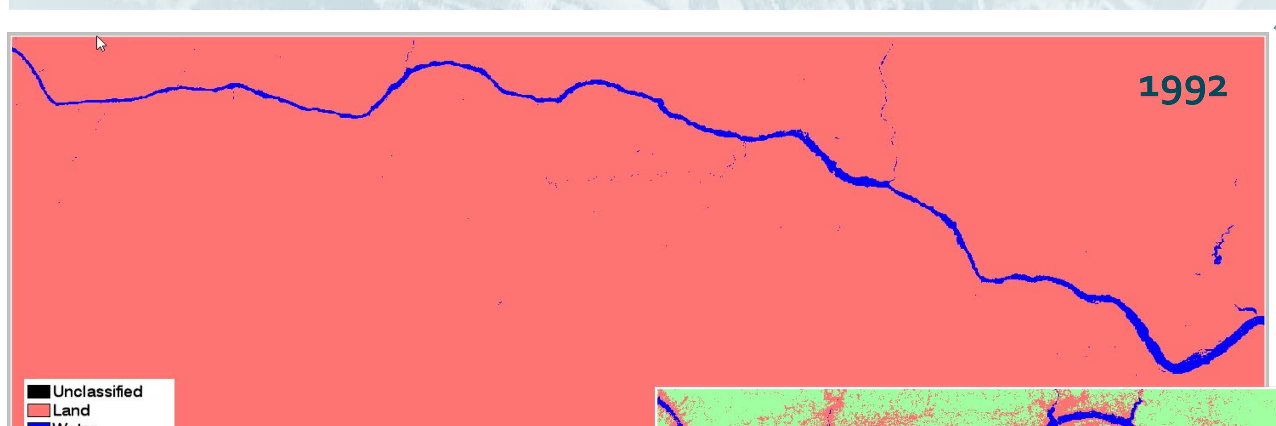


Fig. 4: Classified image of the 1992 image.

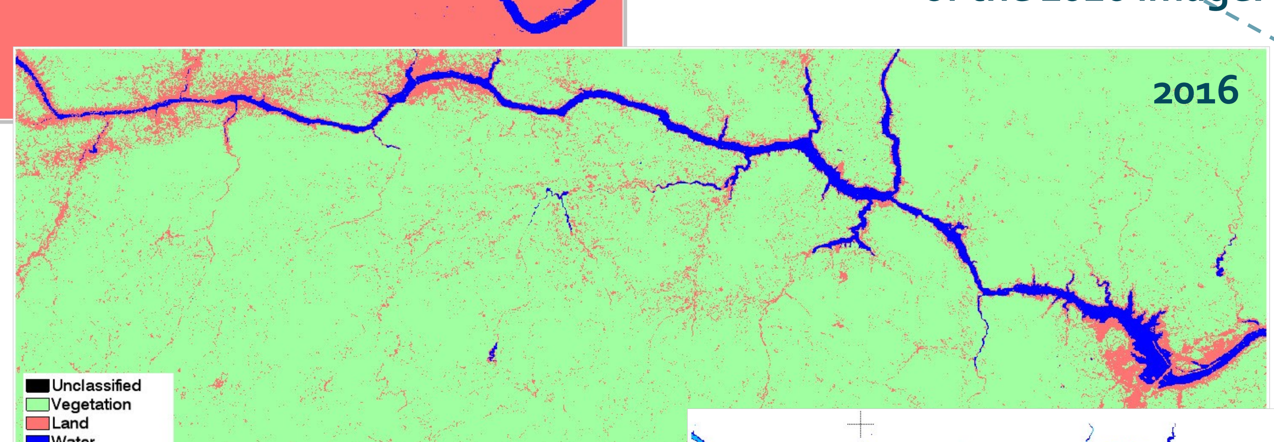


Fig. 5: Classified image of the 2016 image.

Image Classification

To quantify the change in the amount of area of the water surface, it was required to separate the water feature in both the images from the other land cover types. Supervised Classification method was used for the classification task. Training sites were produced beforehand to use as guidance for the supervised classification. Both the image was classified using the Maximum Likelihood method. The 1992 image was classified into only two classes, Water and Land, to make the classification process simplified and less erroneous. Figure 4 shows the training sites from the 1992 image. The 2016 image was classified in three classes, such as Water, Land and Vegetation. Here, water represents the river and its tributaries, land represents the bare earth surface and the urban areas, and vegetation represents all the green cover in the image. Figure 5 is showing the end result of the classification of the 2016 image.

In figure 6, the two water classes produced from the two years are shown by overlapping. The class statistics are produced to acquire the measurements of the area of the water surface in each image. Table 2 shows the area of water in square meters from the classified image of year 1992 and 2016.

To check the accuracy of the classification, confusion matrix were generated for both the images using another set of training sites as groundtruthed reference sources. The overall accuracy of the 1992 image and the 2016 image turned out to be 99% and 96% respectively.

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CEE 0189: Introduction to Remote Sensing
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Data source

The construction of the dam started in December 1994. Even though it was opened in 2003, the construction and addition of turbines and ship lift continued until December 2015. to understand the change brought by the construction, satellite images of the region before 1994 and after 2015 were required.

While searching for satellite images for the analysis, first preference was given to a clear cloudless image that shows a significant portion of the Yangtze River upstream of the Dam. The geographic area where the dam is located is observed to have sub-tropical monsoonal climate. Because of this reason, most of the images found were fully or partially covered by clouds. A collection of images was assessed in USGS Earth Explorer and in EarthData to find the appropriate images for the project. Another criterion that dictated the data search was the time of the year. To match the atmospheric condition between the two comparing images, both were chosen from the same time of the year.

The images are products of U.S. Geological Survey, created and shared for educational purposes. Landsat images were chosen as the source of the dataset because of its vast collection of available data. Additionally, Landsat missions goes as far back as 1972, producing multispectral data with resolution appropriate enough for the scope of this project. The two images required for the analysis were more than two decades apart, this timeline was only covered continuously by Landsat missions. Image 1 and 2 are the images collected for this project, and table 1 shows lists the properties.

Table 1: Image Properties

Properties	1992	2016
Satellite Type	Landsat 5	Landsat 8
Time of the month	September 5	August 22
Pixel size	30m	30m
Unit	Meters	Meters
Radiometric Resolution	8-bit	16-bit
DN range	0-255	0- 65535
Number of bands	8	11

Resizing and Cloud Masking

This project is only concerned about the portion of the river and its tributaries upstream of the dam. Therefore, both images were resized to focus only on that portion. The resizing was also necessary to avoid the cloud cover in the images. But, there were still some clouds left in both the images. These could create erroneous results during the analysis if left unattended.

To avoid the errors, a binary mask was created from the BQA files. The mask is then used to crop out the clouds and the cloud shadows out of the images.

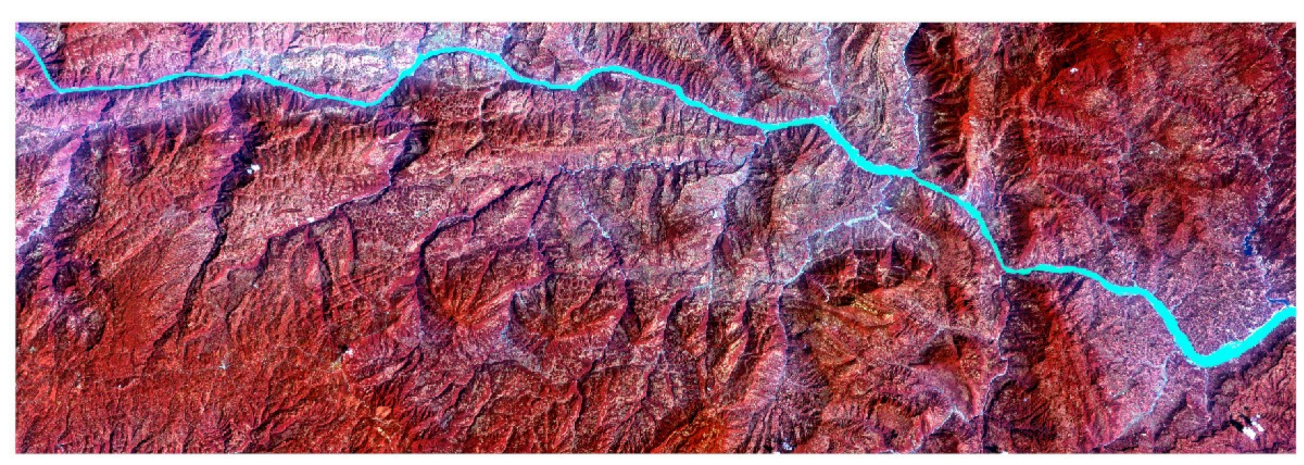

Image 1: Yangtze River and the Three Gorges Dam, 5 September 1992 (Resized).

Image 2: Yangtze River and the Three Gorges Dam, 22 August 2016 (Resized).

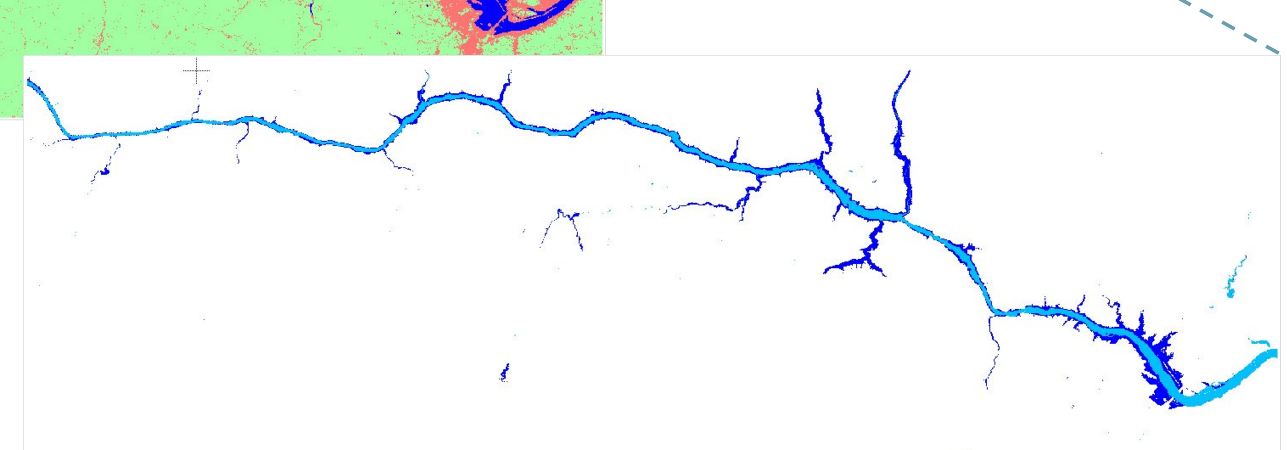

Fig. 6: Water classes from before and after the construction of the dam. The light blue represents the river from 1992, and the dark blue is from 2016.

Table 2: Surface area of the water cover in the years 1992 and 2016 produced by class statistics.

Year	1992	2016
Area	58,004,100 m²	110,108,700 m²
Difference in area of the water surface	52,104,600 m²	

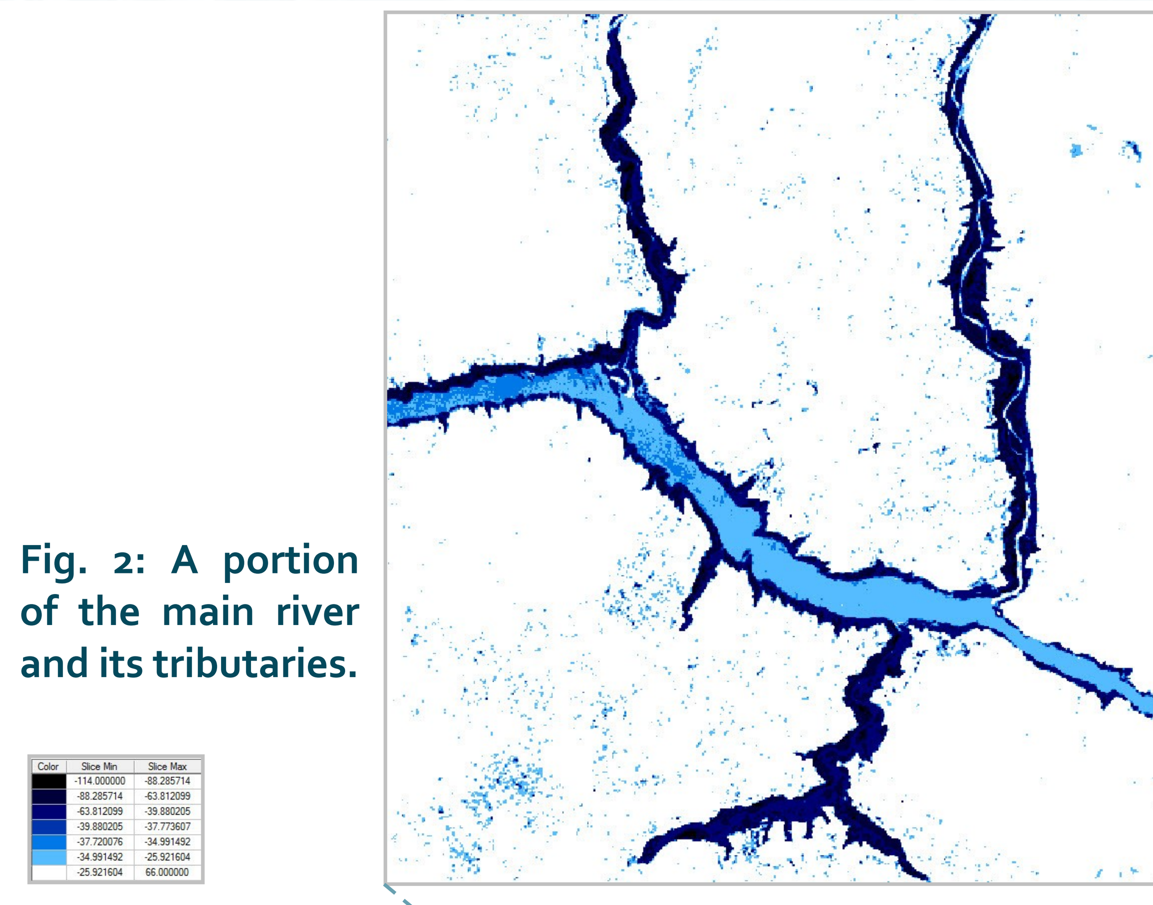

Fig. 2: A portion of the main river and its tributaries.

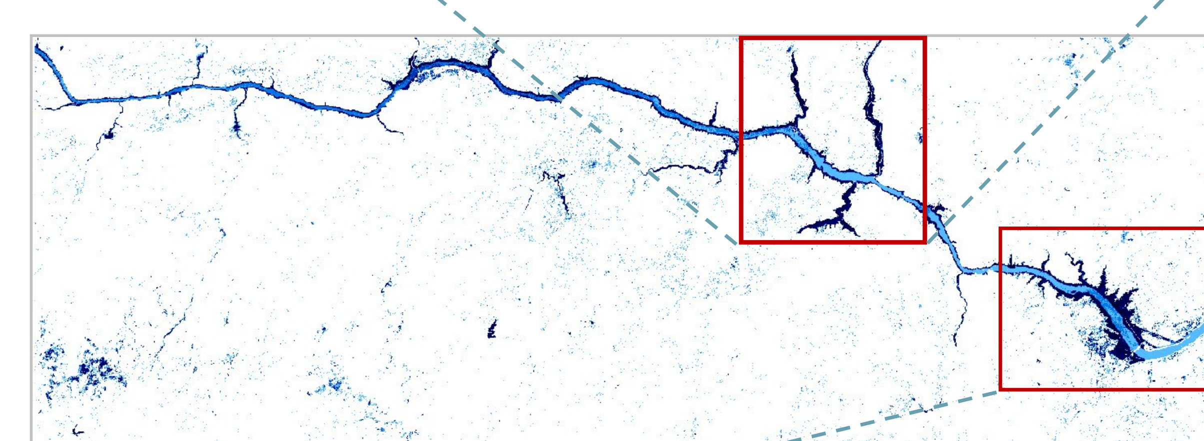

Fig. 1: End result of the NIR change image after color slicing.

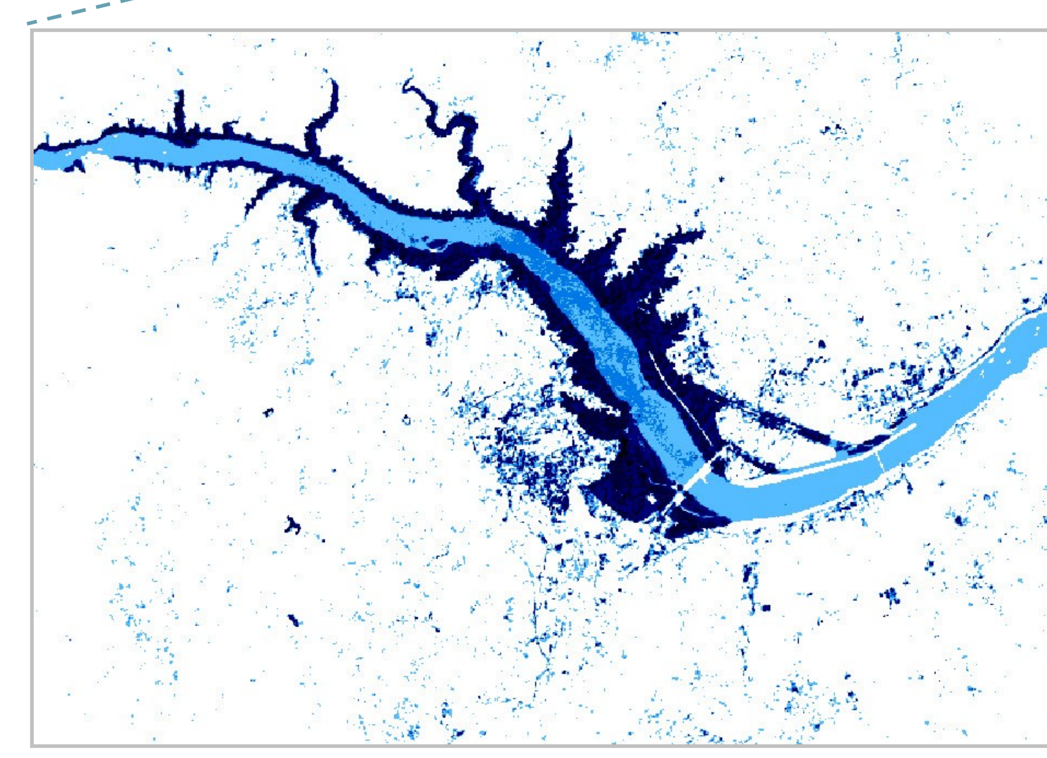

Fig. 3: Reservoir area in the change image.

Change Detection

Change detection was performed to understand where significant change has happened along the river and its tributaries. Single-band image algebra was used as the change detection method. The Near Infrared (NIR) band was selected for this step, as NIR better emphasizes the difference between vegetation, land and water. NIR also used for its high penetration capability in water because of its larger wavelength range (about 0.7 µm to 3.0 µm) than visible light (0.4 – 0.7 µm). A larger wavelength is useful because it produces an image that gives us a perception of the depth of the water. On the other hand, visible light scatters in water producing a lot of noise in the image, which might cause the change detection to be erroneous.

The change detection was performed by subtracting the NIR band of year 1992 from the NIR band of year 2016 using band math tool. The result in the change image produced by single-band image algebra shows the brightness change between the two compared images in grey scale. The pixel values in the change image comprises of positive and negative values, with darker shades showing negative values and lighter colors showing positive values. Color slicing is used to make the change image more understandable, where equal to or near zero values are grouped in white. Figure 10 is showing the range of values produced by the change detection, and the histogram of those values.

Results and Conclusion

The change detection result indicates a clear distinction between the shape of the river before and after the building of the Three Gorges Dam. Figure 3 shows the reservoir area, where the old shape of the river can be identified in the light blue shade. The shade appeared as light blue instead of white, because the depth of the river in that portion has increased. The reservoir can be identified in dark blue shade, as the land cover has changed from land to water, and the depth is also changed. Figure 2 zooms in on the main river and its tributaries. The tributary in the upper left corner of the image shows a thin white string, which appears to be as the old shape of the tributary from 1992. The darker blue shade on the both side of it indicates that the tributary has expanded dramatically after the construction of the dam. Similar explanation can be given for the other two tributaries in the image, where the streams used to be very narrow to even recognize when sensed remotely. The classification results shows that 52,104,600 m² of water surface area has increased 2016. This means that the water surface has almost doubled in 14 years within the region used for the analysis .

The analysis sheds some light on how large dams can be immensely influential on changing the geography, and therefore the ecosystem of a water basin. The benefits of large dams outweighs the environmental impact in many regions of the world. But negative impacts of the dramatic alteration that the environment goes through because of it is still to be realized, therefore necessary to be researched more.

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