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HYBRID TECHNIQUE FOR DETECTION OF WATER USING SATELLITE IMAGES

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Abstract: The use of Satellites in remote sensing has been increased to the extent that now it becomes possible to retrieve information about changes occurring in any activity over the Earth. Remote sensing can be defined as a process of gathering and clarifying information for an object, area without having a physical contact with it. Meteorology, Glaciology, Geology, Agriculture, Land planning, etc. are various fields that deploy remote sensing. Presently, water detection using satellite images is one of the interesting research areas. In this research, firstly the review of the basics of remote sensing and its use for water detection has been done. A Hybrid method has been proposed which consists of k-means clustering and morphological segmentation techniques for water detection. The MATLAB tool was used to implement both techniques. The performance of proposed technique has been evaluated in terms of accuracy, specificity, and sensitivity. It has been observed that the proposed technique shows the better results.

Keywords: Remote sensing; image processing; water detection; k-means clustering; morphological segmentation

I. INTRODUCTION

In modern era, some of the issues related to water include water shortages, droughts and floods [1]. Though Earth's 71% surface is covered with water, only a small portion of it is available as Freshwater. Water is the main resource for various activities varying from agricultural to numerous industrial production activities. The arid regions of the world are specifically scared about less availability of the water. The global climate change is even posing more risks to arid regions. Therefore, it is highly essential to explore, map and monitor the available water resources to maintain availability, rational management and fair utilization of these water resources [2].

Satellite Remote Sensing is the most important inventions which have influenced every human sphere. It is used to access the forests, agriculture, geology, mapping, infrastructures, health and national securities, etc. It is the science which is used to obtain the information about an object without making direct contact with the object.

II. REMOTE SENSING

Remote sensing is a technique to gather the information for the areas which are dangerous or impossible to reach by using the sensors.

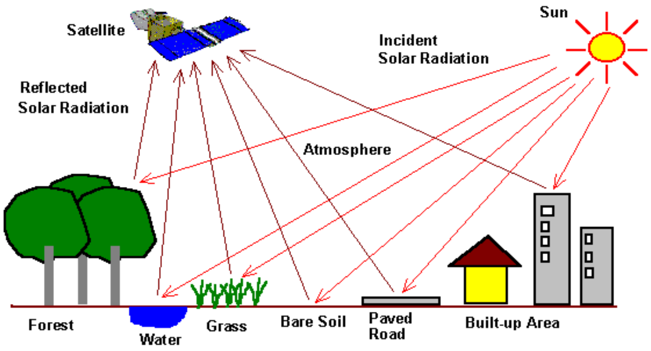

Figure 1: The Process of remote sensing

The common platforms of remote sensing are aircraft and satellites which collect all the information about earth and its natural resources. Aerial photography was the original form of remote sensing which used the technological techniques and enabled the acquisition of information at other wavelengths. It mainly includes the infrared, microwave and thermal infrared wavelengths which help it to collect the information. The collection of a substantial number of wavelengths bands is referred to as multispectral or hyperspectral data.

III. PRINCIPLE OF REMOTE SENSING

The main fundamental principle of the satellite remote sensing is that for any of the given material, the amount of radiation which is absorbed, reflected or transmitted varies with the wavelength. Different materials have the different reflectance characteristics which help in differentiating the features on the surface of the earth. Sensors seeing ability is pre-planned in order to suit the goals of the objectives of the mission for which the satellite is launched. It is determined by the type of the spectral reflectance which we want to record.

Satellite remote sensing works on the principle of electromagnetic radiation. Electromagnetic radiations are the energy that propagates through the free space or a material medium in the form of the electromagnetic waves. Electromagnetic radiations which are detected by the satellite remote sensing instruments are divided into two radiations:

A. Terrestrial radiation

Emitted by the earth's surface in the different degrees according to the temperature.

B. Solar radiation

Comes from the sun and reflected by the earth's surface.

Satellite remote sensing detects and measures the radiations of different wavelengths which are emitted or reflected from the distant object. It helps in the categorization and identification. Different objects have the different amount of energy in the different band of electromagnetic spectrum. It depends on the wavelength, intensity, angle of incidence, surface roughness, and the property of the material of the radiant energy.

IV. WATER DETECTION USING REMOTE SENSING

The capability to monitor the global water supply through the satellite images is a great effort in the remote sensing community. The remote sensing of water can be described as observing water from a long distance and checking its availability, properties, and gradual development without taking any water samples [3].

A thorough analysis of satellite images can play a significant role in discriminating and differentiating the changes in the earth areas between different changes of imaging [4]. Scientists and researchers are continuously putting their effort to design and develop tools and techniques that can help in analyzing the changes in the earth areas more rapidly and easily. There are numerous analysis applications for food, agriculture and fuel type assessment [5]. Similarly, we can use these strategies to detect the water on the surface of the earth.

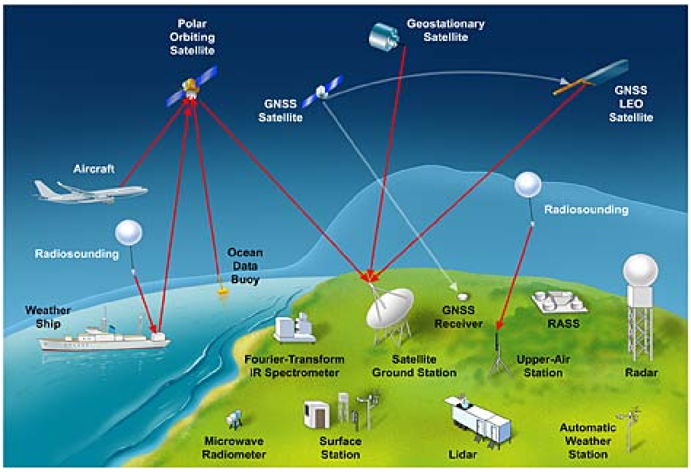

Figure 2: Remote Sensing of Water

Infrastructure shapes an essential part for development and advancement of any region. Satellite pictures, attributable to their spatial, temporal and spectral qualities, give important data about the land (both past and future), existing framework, and landscape qualities and so on, which are crucial to encourage foundation arranging, observing and administration in cost effective and timely way [6]. Geological Information System (GIS) with modified choice bolster instruments encourage coordinated investigation of various datasets and their representation for remote sensing [7].

V. SATELLITE IMAGE PROCESSING

The satellite image processing is a technique of using satellites such as Landsat, Quickbird, Worldview satellite imagery for the purpose of collecting useful information regarding the various human and natural activities happening on earth. The satellite image provides us with the exact location and details of the process and place on which we are doing any research. It is an application method of remote sensing. It has mainly three parts: image rectification, image restoration, and image extraction.

The water resources on earth are continuously degrading in the standards of quality. Also, the availability of the fresh water sources is decreasing with the advancement of the technology. The satellite image processing provides us a window to reach the water resources which are still not located due to the unreachability or inability to locate them by the human surveys and researches. The satellite image processing technique provides access to the hydrological information of an area through the use of image sensors which collectively help in extracting information and mapping of the area.

Figure 3**:** Image taken from satellite

The water detection using satellite image processing has three major parts: rectification of the water images, image enhancement, and extraction of image data.

A. Rectification

Rectification of the images is done by rectifying the image over the planar surface so that the distance values can be plotted accurately over the sheets. The rectification helps in setting the boundary of water areas on the paper or maps printed by using the information on the images.

B. Image enhancement

Enhancement of the image taken by the satellite is done to bring out the details from the original image. The image is processed by using contrast adjustment techniques such as contrast enhancement. The gray scale of the image is adjusted for better details. The most important part of image enhancement is spatial filtering which is a process of dividing the spatial frequencies into high and low-frequency areas on the image according to the brightness value of the image per unit.

C. Image Extraction

Extraction of the image is the process of getting the final image which can be used as a source of information. The gray scale is adjusted, and the blue area of the image is enhanced to show the area of low moisture content or high water content in the picture.

VI. LITERATURE SURVEY

N. Mueller, et al. (2015) observed presence of water from space that is mapped for the surface water of Australian Landsat imagery from 25 years [11]. The WOfS (Water Observations from Space) product provided a nationally consistent tool for understanding surface water across Australia. The maps which are being generated using WOfS on Australian floodplains had provided a source of information. A program established by Australian government across Australia which helps in accessing the improved flood information. They used an algorithm which was used for the water detection and was based on the principle of decision tree classifier, and logistic regression. The development of this analysis can be applied in a systematically manner through decades of data which is a combination of standard grid arranged surface reflectance data and large high-speed storage attached to supercomputer processors [1][11].

Klemas, V. and Pieterse, A. (2015) used remote sensing technique to Monitor and Map Water Resources in the areas like Arid and Semiarid Regions. An overview has been discussed for managing various water resources and monitoring drought in various arid and semiarid regions using the satellite and airborne remote sensing techniques. The basic objective of their research was internally mapping of arid regions and to prepare them on a global scale to get the condition of soil degradation level and deserted areas. To identify this, powerful computer programs were developed. Various techniques like MCDM were used to delineate potential ground zones[11]. The results of detection, mapping, and monitoring of surface water and vegetation in arid and semiarid regions using Airborne and satellite remote sensors. This research also explains the various modeling techniques to determine the intensity and extent of the flooding, forecasting the vulnerability to the flooding area, and accessing the damage caused by floods [2][11].

Madhavana, S., et al. (2016) focused on the dust detecting schemes by using multi-sensor measurements, legacy sensors like Terra (T) and Aqua(A), MODIS (MODerate-resolution Imaging Spectroradiometer) which is fused with OMI (Ozone Monitoring Instrument). They extended the previous work by adding channels: cloud top channel of 13.1 μm along with the water vapor channel of 7.1 μm [11]. Using OMI-based aerosol type, dust pixels were easily identified. In this research, firstly an approach was developed to address all the drawbacks of traditionally used metric of AOT to qualify the large dust particles. In dust monitoring, the improvement of particles exploited with the help of MODIS band 29 used in the cloud detection. After that, the author presented the quantitative and qualitative validation. This research also describes the extent of thermal infrared based dust particles with the help of wavelengths. It leads to the high sensitivity to the Saharan dust which results in the enhancement of the dust radiometry [3][11].

Arvinda, C. S., et al. (2016) analyzed flood assessment using MODIS satellite images under unsupervised techniques like mean shift and SOM for water image pixel identification and its extraction. They determined algorithm performance based on various parameters such as ROC. The SOM algorithm performed well in all cases before, during and after flood images. The ROC performance evaluation parameters were used for identifying non-flooded and flooded regions. It helps in recording the flood database. The ROC parameters were applied for the algorithm and validated against the ground truth image. In the end, SOM method performance was the best in the extraction of flooded regions as compared to mean shift method [4][11].

Baeye, M. et al. (2016) research results used the concept of ocean color satellite imagery in turbid water and detected the shipwrecks. They demonstrated a method that wrecks generate SPM (Suspended Particulate Matter) concentration signals which further can be detected by using high-resolution ocean color satellite data like Landsat-8 [11]. The Surface SPM plumes extended downstream for up to 4km from the wrecks, with the concentration ranging from 15 mg/l to 95 mg/l. The ratio between the pump and the background SPM concentration was around 1.4. Slack tidal phases were used to create fluffy mud deposits near the seabed. The score pits which are developed around the wrecks act as the sinks in which the fine-grained suspended particles deposited at slacks. For the suspended particles, the scour pits act as the sources when bottom current increases after the slacks. During the maximum current and immediately after that, SPM plumps were developed before reaching the maximum flood current. [5][11].

Gierach, M. M., et al. (2014) detected plumes of wastewater diversion in Southern California. Their study examined the impact on the quality of water in the SCB on the basis of detection of capabilities of multi-sensor satellite data to detect the 2006 HTP (Hyperion Treatment Plant) and 2012 OCSD (Orange County Sanitation District) wastewater diversions [11]. Data included ocean color from MODIS-Aqua, sea surface roughness, and SST from ASTER-Terra and SAR instrument on Radarsat-1 Board. The result from this was applied to the recent HTP diversion, which occurred from 21 September to November 2015 in response to the observation made during 2006 HTP diversion inspection. It is also observed in their study that SST values CHL-a values used must have the difference of at least 1 mg m^{-3} and 0.5°C than the adjacent values of waters for the wastewater plumes and their impact which is biophysical in nature was detectable using the satellite. The wastewater plume which can be determined in wind speeds, SAR (Synthetic aperture radar) imagery must have a range between ~3-8 m s^{-1}. Multiple satellite sensors are also beneficial to monitor the changing environmental response to the wastewater plumes. It can also help in the future wastewater diversions in the coastal areas [6][11].

Ovakoglo, G., et al. (2016) used MODIS images for the detailed Lake Morphometric. They presented a methodology for easy updating the bathymetry of a lake with large level fluctuations in water level using high temporal resolution satellite image. It seems possible to produce the lake DDM (Digital depth model), which uses a time series of shorelines digitized near-infrared band of MODIS images. The validation of the produced DDM uses the GNSS measurements which produced the differences in the accuracy of the methodology. Two versions of the DDM were being produced to access the seasonal water fluctuation influence. Their evaluation was small and attributed to seasonal water ponds and vegetation as well as natural sedimentation process. This methodology was applied to the Lake Kerkini in Greece in order to produce the updated DDM. The application of this was limited to the exposed part of the lake bottom; this methodology seems to be useful to cover the parts of the lake that were too shallow to survey by boat. This research helps in updating the DDM of lakes and the reservoirs with inter and intra-annual fluctuations of the water level with the help of the satellite remote sensing. It was necessary to receive the frequent results of the morphometric mapping and the high sediment loads to define the effective life of the reservoirs and its storage capacity which is waste in nature for power generation, irrigation, domestic power supply, and flood control [7][11].

Rokni, K. et al. (2015) gave an approach for the change detection in surface water. They introduced a new approach based on Integration of image fusion and image classification techniques for surface water change detection. The effectiveness of the proposed method helps in detecting the changes of the lake surfaces as compared to the basic changes in the detection methods such as image differencing, post classification comparison and principle components analysis. The result shows the high performance by using the Gram Schmidt ANN and Gram Schmidt SVM approaches which provide a very high accuracy results. This approach has the advantage of producing a high-resolution multispectral image, provided the reliable results, highlighting the changed area in the fused image. In the end, the approach has provided effective results in detecting the changes in water surface of Lake Urmia, Iran. The result demonstrated that the Lake Urmia lost one-third of its surface area in 2000-2010 [8][11].

Gupta, R., & Panchal, P. (2015) concentrated on daytime cloud detection algorithm using Discrete Wavelet Transformation (DWT) and double threshold values by pixel to pixel processing. The realization of data on various satellite images of NOAA, VIRR and MODIS datasets with double threshold values, applied in the visible region of electromagnetic spectrum. The radiation in the microwave region is low and maximum at the visible region. Therefore, in this paper, computation was done in the visible region. DWT is STFT (Short Time Fourier Transformation). In this paper, images were categorized into different ecological surfaces such that water, soil, vegetation, and snow. The proposed method can differentiate the cloud from clear regions. Limitation of proposed method is that it faces some difficulties to differentiate between thick cloud and snow/Ice. The results of the proposed method were compared with the results of HSV and RGB models. The comparative results of the research show that the proposed method works better as compared to the other methods on various data sets with different ecological surfaces [9][11].

Sarp, G., & Ozcelik, M (2016) covered changes in Burdur Lake from years 1987-2011. This research is used in the satellite image interpretation and GIS to analyze and detect the spatial changes and quantify the water area changes of the Lake Burdur. Satellite images were used to extract the information of the lake water area change which was more fast and accurate as compared to the other observation methods. The approach used in this research was based on the spectral water indexing and SVM-classification. In this research, the spatial and spectral performance of each of the classifier was compared with the help of Root Mean Square Error (RMSE) and the Structural Similarity Index (SSIM). Overall SVM which is being followed by MNDWI, NDWI and AWEI provides the best results among the best techniques being used. It was also being observed that the spatiotemporal changes in the lake which were being applied on the proposed method shows the intense decrease in the surface area in years from 1987 to 2011 and also 1887 to 2000. In the years 1987 to 2000, the lake had lost around one-fifth of the surface area and in years from 1987 to 2011, the Lake has lost one tenth of its surface area as compared to the year 2000. The results indicated the success of the MNDWI and SVM based surface water changes detection which helps in identifying the changes between the specified time intervals [10][11].

VII. METHODOLOGY

In this work, water detection has been done from satellite images using the MATLAB Software 2015a. In this work, basically the Hybrid method is used which consists of k-means clustering and morphological segmentation methods in MATLAB. Also the water areas have been detected using this hybrid methodology.

To get the improved results, both the techniques K-means Clustering and the Morphological technique are used. First, we have performed the k-means clustering technique, and which is further combined with Morphological operation to remove the noise part from the output of K-means clustering technique. Using both the techniques together the improved results have been observed.

A. Implementation Process

A hybrid approach has been used using k-means clustering and morphological segmentation methods. The flow diagram is as shown below for the Implementation Process.

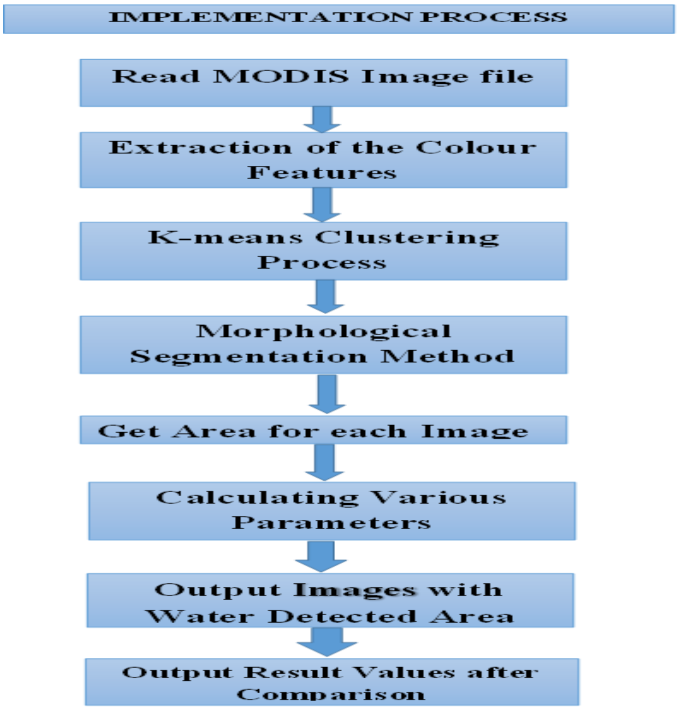

Figure 4: Methodology of Proposed Hybrid Technique for Water Detection

The very first step is that it will read all the MODIS data images. After this, it will perform the Segmentation and will extract the color features. After all these, the K-means clustering technique is applied. After that, the Morphological Segmentation method starts, in this method the output image of K-means Clustering technique is given as the input to it. After performing both the techniques, we have our final output image with Water detected area and the total water area. At the output, we have various parameters values like Sensitivity, Specificity and the Accuracy. We have also got the two plots of FPrate vs. TPrate and Sensitivity vs. Specificity.

B. *K-means Clustering Technique*

Clustering is mainly used to extract meaningful information from the satellite images. It is the process of partition the large group of data into the small number of clusters; K-means Clustering is the most popular partition technique which was given in 1967 by MacQueen. The main aim of this clustering is to partition the observations into 'k' clusters, where each observation belongs to the cluster with its nearest mean. Due to this, it is also known as Partition Method. This Algorithm is used to minimize the variance of the vectors which is assigned to the individual cluster. This technique is iterative in nature after one vector is assigned with one of the clusters. In this algorithm, the k-means is like treating each observation in the data as an object which is having its location in space.

As K-means is the iterative process, it minimizes the overall sum of the distance of each object to the centroid of clusters. In this, the objects are moving between the clusters until the overall sum cannot decrease further. For this k-means clustering technique, we have initialized the total number of clusters as eight, and we have taken total 10 iterations.

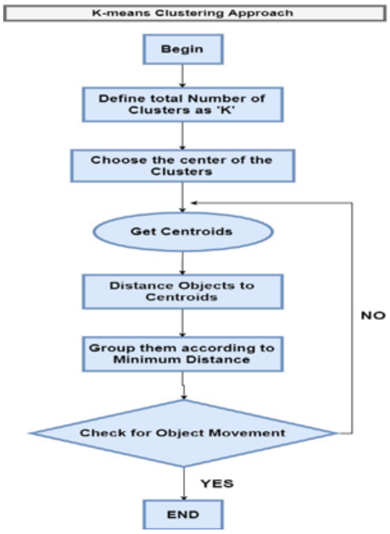

Figure 5: Block diagram of K-means clustering approach

The above flow chart represents the k-means clustering method in brief.

We have chosen the center of Clusters in the form of a matrix of size (3x8). The center of clusters that we have taken is as shown below:

Table 1: Center of Clusters

0.397116898299459	0.351172534109267	0.261197157811776
0.397116898299459	0.736997007846801	0.706257773680218
0.264933462359307	0.298397606154724	0.239401675966032
0.127940030021654	0.170891407339892	0.154054811467728
0.0543733313094744	0.0836509196770732	0.103521569405785
0.610309978120239	0.559658142758356	0.472746772630111
0.109405035931173	0.262343791979201	0.251877884841130
0.491044122815900	0.455329638992379	0.359650646257574

After applying K-means Clustering algorithm, we have used the morphological segmentation method for improving our results and to have better output.

C. *Morphological Segmentation Method*

For understanding the Morphological Segmentation Method, first, let us discuss the Segmentation of the image. Image Segmentation is defined as the division of the image into the multiple segments or into the sets of pixels. The main purpose of the segmentation is to represent the image into the more simple way so that it contains some meaningful information and will be easier to analyze.

When the images are processed in the K-means clustering, after that there are various noise factors usually adds on and there are chances of Clustered region occurrence and to remove all these, we use the Morphological Segmentation Process. This is also used to filtering the label maps which occur due to erosion or dilution. Morphological Operation is performed on the set of the pixels. The Binary image has two-pixel values, they are Black and White, or we can say that they have two values 0 and 1 that is 0 for black and 1 or 255 for white.

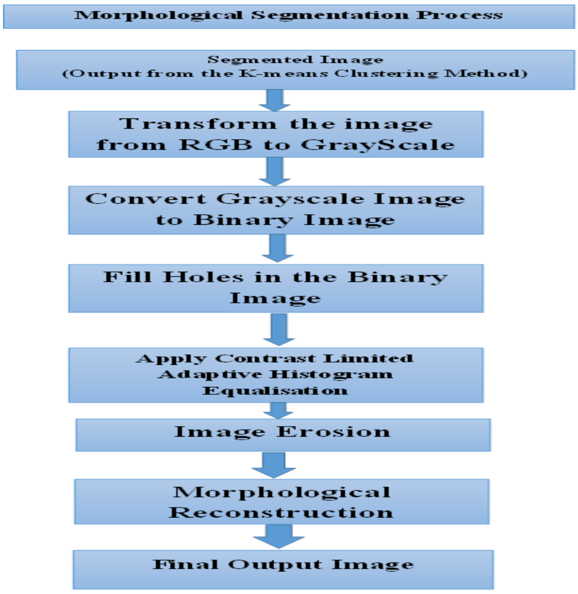

Figure 6: Block Diagram of Morphological Segmentation Method

The above flow chart represents the Morphological Segmentation Method in brief.

After performing Morphological Operation, we have calculated various output values that include false positive, true positive, false negative, true negative, true positive rate, false positive rate, sensitivity, specificity, and accuracy.

The formulas for all the Parameters are explained below[1]:

1) True Positive (TP) is defined as the test result is one which detects the condition when the condition is present.
2) False Positive (FP) is defined as the test result is one that detects the condition when the condition is absent.
3) True Negative (TN) is defined as the test result is one that does not detect when there is no presence of the condition.
4) False Negative (FN) is defined as the test result is one that does not detect the condition when there is the presence of the condition.

True Positive Rate (TP Rate) = $\frac{TP}{(TP+FN)}$

True Negative Rate (TN Rate) = $\frac{TN}{(TN+FP)}$

Sensitivity = $\frac{TP}{(TP+FN)} * 100$

Specificity = $\frac{TN}{(TN+FP)} * 100$

Accuracy = $\frac{TP}{TP+FP} * 100$

VIII. IMPLEMENTATION AND DISCUSSION

Implementation of this work has been done in MATLAB 2015a, and the database selected is of the MODIS images which have high accuracy values and provide the better results after being used with various techniques. Hybrid approach is done using k-means clustering and morphological segmentation methods.

A. *Output of K-means Clustering Technique*

The image given below provides insight on the water area under study. The first image is the original image, and another is the segmented image.

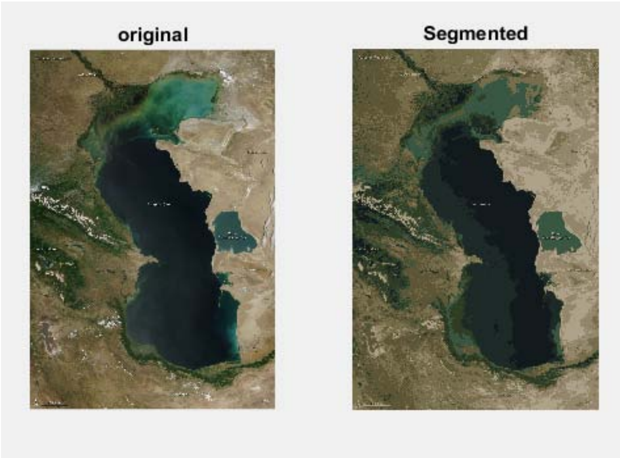

Figure 7: Original and segmental Image after K-means Clustering technique

B. *Final Output*

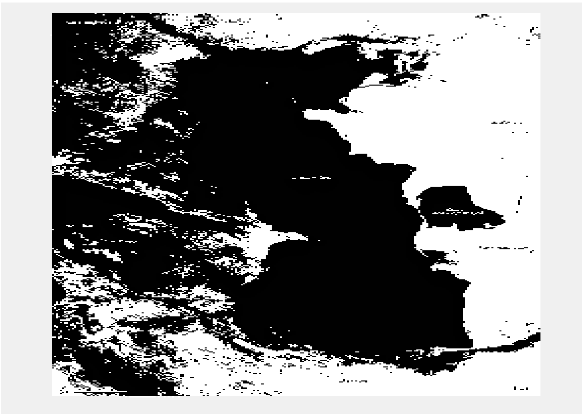

Figure 8: Final Output

C. *Water Area*

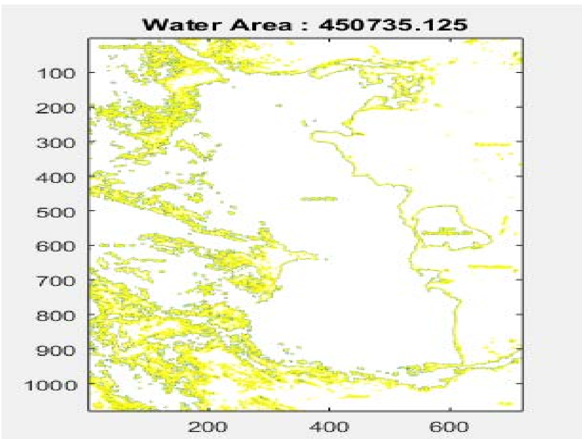

Figure 9: Water area under Study

D. *Resultant Values*

Table 2: Resultant values

Comparison Method	Morphological Alone	Morphological with K-Mean Clustering
FP	251624	22889
TP	119176	83747
FN	0	35553
TN	119176	212461

Table 3: Resultant Properties

	Morphological Technique only		**Morphological with K-means Clustering**	
	Sensitivity	**Specificity**	**Sensitivity**	**Specificity**
Base image	99.96	32.14	64.68	90.78
Image 1	99.99	43.96	77.68	91.14
Image 2	99.99	51.19	70.19	90.27
Image 3	100	55.96	84.82	93.16
Image 4	100	63.84	82.73	87.34

Table 4: Accuracy Comparison

Input Images	Morphological Alone	Morphological with K-Mean Clustering
Base Image	51.1959	80.1293
Image 1	55.9680	83.7029
Image 2	43.9602	78.5354
Image 3	63.8343	88.4048
Image 4	32.1402	62.9063

Frst image Area is 6.549739e+01 % Shrinked

Second image Area is 7.327280e+01 % Shrinked

Third image Area is 5.359891e+01 % Shrinked

Fourth image Area is 7.842888e+01 % Shrinked>

Figure 10: Results based on area of images

E. *TP Rate vs. FP Rate Plot*

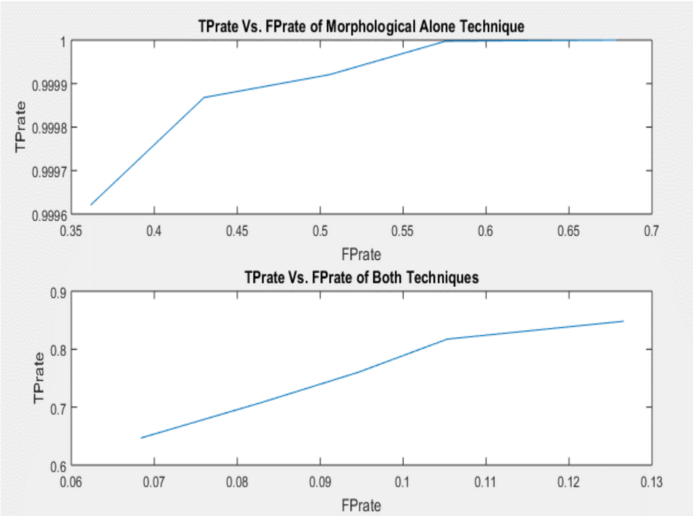

Figure 11: Comparison of TP Rate vs. FP Rate Plot

F. *Sensitivity vs. Specificity Plot*

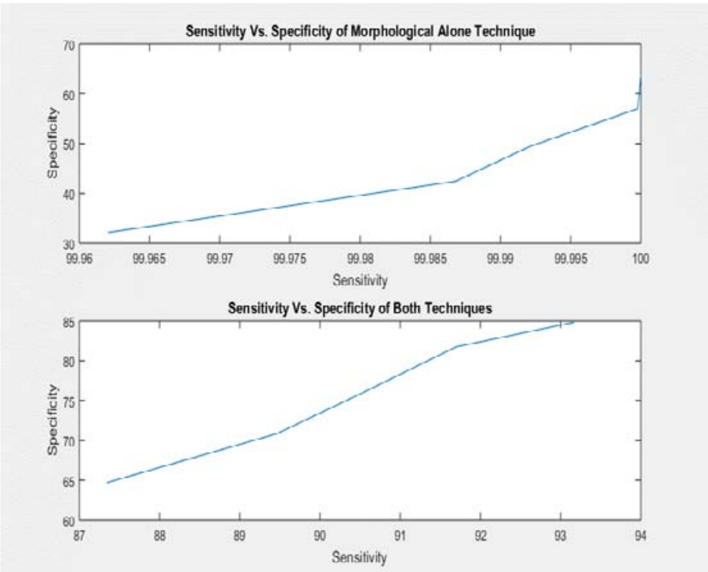

Figure 12: Comparison of Sensitivity vs. Specificity

IX. CONCLUSION

Water resources are limited on the Earth, and the rapidly increasing population is another drawback associated with it. Remote sensing offers detection of water resources for better water management in the coming future. Remote sensing through satellites is an effective way to help the disaster management authorities to locate and recognize the affected areas and population. High Accuracy values have been obtained using this hybrid methodology. Instant information retrieval helps them to implement the possible control measures as soon as possible. In this research, we proposed a Hybrid method which consists of k-means clustering and morphological segmentation techniques for water detection. The results of the proposed technique provide better results in detecting the water with accuracy as compared to the previous research.

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