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Water Detection using Satellite Images Obtained through Remote Sensing

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Abstract

Remote sensing (RS) using satellites images became a prevalent modern technology which is being used in numerous applications. Remote sensing is getting the data and information about any phenomenon or object without making physical contact with it. It is used in various fields including, land surveying, various Earth Science disciplines such as ecology, hydrology, etc. and in geography. One of the interesting areas of research is the use of Remote Sensing in water detection and management. In this paper, we will review the research that makes use of water detection techniques using the satellite images. We will review various technique and compare them to check their results against each other. It will help to come up with the best technique that can be used for our research.

Index Terms: Remote Sensing, Satellite, water detection.

I. INTRODUCTION

1.1. Overview

Water is one of the most important natural resources on the earth. It plays a significant role in our day-to-day life. There are numerous resources of the consumable water which include the rainfall, groundwater and the various surface water bodies such as ponds, rivers, lakes, etc. [1]. But there are numerous competitive sectors including the agriculture, infrastructure, domestic and industrial sectors. The major consumption of water is dedicated to the agriculture sectors [2].

Many approaches and techniques have been used to conserve the water. But none of them proved to be a complete way to get the sustainable growth [5]. Thus, there is a high requirement of some strategy in which resources can be utilized in the best way without degrading the quality of the water. Because of the lack of accurate data and information, evaluating the performance of the implemented water conserving approaches is not possible [8].

Apart from this, there are various water related issues which are being faced by many people in the World. Floods are one of those major issues that hinder the progress of happy life. Flood cause major damage to agriculture, people, and infrastructure. Thus there is a high necessity to look for some strategies through which the flood affected areas can be managed easily and quickly [10].

1.2.Remote Sensing

Remote sensing is the science and craft of getting data about, phenomenon, objects or areas through the recording instruments, for example, scanners, cameras, lasers, linear arrays situated on stages, for example, airplane or shuttles, without coming into physical contact with the items phenomenon or area under investigation [7].

Remote sensors are used for the remote sensing applications. Remote sensors detect the energy which is reflected from the Earth. The remote sensors can be mounted on aircraft or on satellite. These can be either passive or active type. The passive remote sensors respond to some external stimuli. They record natural energy which is transmitted or reflected from the Earth. The reflected sunlight is the main source of energy for the passive remote sensors [11].

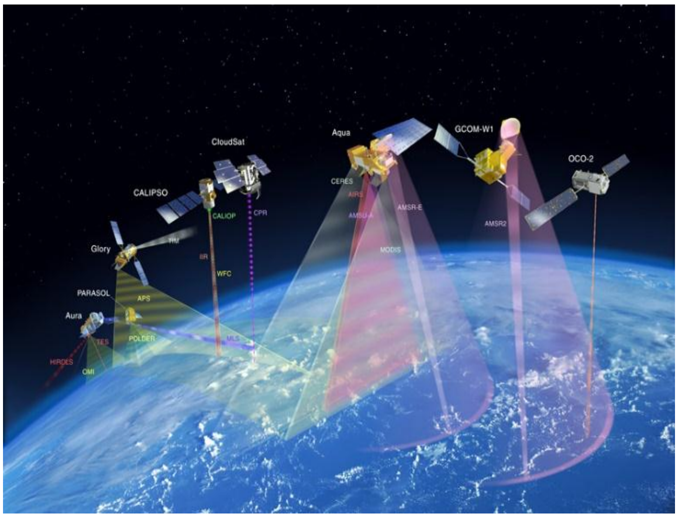

Figure 1: *Remote Sensing*

On the other hand, active remote sensors take help of some internal stimuli in order to retrieve information about the objects or phenomenon occurring on the Earth. For example, in the laser-beam remote sensing system, a laser beam is directed toward the Earth and the time taken by the beam to reflect back from the Earth is considered as the main measure [15].

There are numerous applications of remote sensing which include but not limited to the following:

1. **Coastal Applications:** There are various coastal applications that make use of the remote sensing. It includes maps coastal features, monitor shoreline changes and tracks a different kind of sediment transport [3].

2. **Ocean Applications:** The data and information can be obtained through the use of remote sensing about the ocean. For example, measure ocean temperature and wave height, monitor ocean circulation and current systems and track the ice present on the sea, etc. are examples of ocean application using the remote sensing technology. All of the data can be used to understand and manage the oceans in a better way.

3. **Natural Resource Management:** There are numerous natural resources which are being depleted day by day. There is a high necessity to save these natural resources so that they can be used for the long term with effective and efficient way. Map wetlands monitor land use, water detection and chart wildlife habitats are examples of such applications that make use of the remote sensing. All of the data and information obtained can be used for minimizing the damage that urban environment has on nature. Thus significant strategies can be investigated to protect these natural resources best.

4. **Hazard Assessment:** There are various applications of remote sensing in hazard assessment including the tracking of hurricanes, flooding, and earthquakes. Thus we can develop various strategies in order to prepare ourselves for the natural disasters.

1.3.Water Detection using Satellite Images

One of the significant application of remote sensing from the applications described in the previous section is the water detection on the Earth using the satellite images retrieved through remote sensing [16].

Identification and monitoring of different water surfaces have been a tough experiment for quite a while in remote sensing information processing. An extensive number of studies are accessible in the important literature dealing in water and wetness location and checking for land administration and protection. Various diverse sorts of RS (remote sensing) information are helpful for some sort of water discovery. However, the precision is exceedingly reliant on the info source, the processing methodology and specifically the mix of the two [17].

Thus, it is apparent that the reliable information about the spatial distribution of the surface water is necessary for numerous scientific disciplines. In simple words, assessment of present as well future water resources, river dynamics, agriculture suitability, river dynamics, wetland inventory, climate models, watershed analysis environment monitoring, surface water survey and management, and , flood mapping are some major areas that need information about the water.

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 in more rapid and easy manner. A tool is a set of various interactive steps to help in the analysis process. There are numerous analysis applications for flood, agriculture and fuel type assessment [5]. Similarly, we can use these strategies to detect the water on the surface of the earth.

1.4.Satellite Image processing

Till now, various image processing techniques have been introduced. These techniques help to identify the water features using the data from the satellite. There are single-band and multiband methods used for the image processing. Through the single-band method, only one threshold value is used to extract the features from the water. The error is common in the single-band method because of the mixing of water pixels with the different cover types. But it has been said that classification techniques provide a better result if used to extract the surface water than the single-band methods [18].

The main dataset includes the information retrieved through the satellite images. It is required to produce raw data from the previous images produced through several satellites with some specific resolution. After that these images need to rectify and corrected to measure the surface reflectance. It is necessary to organize the images spatially into 1 X 1-degree cell area. Obtained images are organized in a data tiles. In this way, through these data files a complete time series of observation for every single pixel which can be used for analysis. It is shown in figure 2 [1].

Pixel quality

The images and observations obtained from the satellite are subject to many issues especially the quality. The quality of observations from the satellite is associated with numerous problems including the instrument saturation, topographic shading, cloud shadows and instrument failure. Along with this, poor geolocation is also one of the main factors that lead to poor pixel quality of the observed data and images. Pixel saturation, band continuity, cloud shadow and terrain shadow are some quality indicators that helps to improve the quality of the image.

II. LITERATURE SURVEY

Mueller, N. et al. (2016) observed 25 years of Landsat imagery across Australia for accessing the information about the surface water. The tool used in the research named as WOfS (Water Observations from Space) helped to identify and to manage the surface resources water in Australia in a better way. A new way of information retrieval was possible through the maps generated using WOfS. The combination of large high-speed storage attached to supercomputer processors, and surface reflectance data in a standard grid arrangement has enabled the development of a single analysis that can be applied systematically through decades of data. Approximately 2 × 1013 observations and 184,500 scenes spanning over 27 years were used for the process. In this way, the continental map of the surface water was produced [1].

Klemas, V. and Pieterse, A (2015) proposed a technique for water resources detection in Arid and Semiarid Regions using the remote sensing. The condition of the soil degradation and desert areas was obtained through the internally consistent maps of arid regions. MCDM techniques were used to delineate potential ground zones. Satellite remote sensors and airborne sensors were used for the water detection [2].

Madhavana, S., et al. (2017) tried to improve the dust detection techniques. In order to do so**,** multi-sensor measurements using the Aqua (A), Terra (T) and MODIS images with OMI(Ozone Monitoring Instrument) were used. The identification of the dust pixels was a simple task with the use of OMI-based aerosol type [3].

Arvinda, C. S., et al. (2016) used MODIS images in order to analyze the flood affected areas. Mean shift and SOM techniques were utilized for the flood assessment. The SOM algorithm was used before, during as well as after accessing the flood affected area images. The flooded and non-flooded regions were differentiated through the ROC performance evaluation parameters. At last, the result of the study shows that proposed method is effective enough to provide a clear view of the flood affected areas [4].

Baeye, M. et al. (2016) detected shipwrecks using ocean color satellite imagery in turbid water. They demonstrated that wrecks generate SPM (Suspended Particulate Matter) concentration signals that can be detected by using high- resolution ocean color satellite data like Landsat-8. Surface SPM plumes extended downstream for up to 4km from the wrecks, with the concentration ranging between 15 and 95 mg/l. Surface SPM plumes with fully submerged shipwrecks were observed by them, and they describe them regarding wrecks size and its geometry. So, SPM plumes were indicators that a shipwreck was exposed at the seabed and certainly not buried [5].

Gierach, M. M., et al. (2016) detected wastewater diversion plumes in Southern California. They examined the capabilities of multi-sensor satellite data to detect the 2006 HTP and 2012 OCSD wastewater diversions and their impact on water quality in the SCB. Data included ocean color from MODIS-Aqua and SST from ASTER-Terra. 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 [6].

Ovakoglo, G., et al. (2016) used MODIS satellite images for detailed Lake Morphometric. They presented a methodology for easy updating the bathymetry of a lake with large water level fluctuations using high temporal resolution satellite image. It seemed to be possible to produce the lake DDM, using a time series of shorelines digitized on the near-infrared band of MODIS satellite images. Two versions of the DDM were produced to access the influence of seasonal water fluctuation. Their evaluation was small and attributed to seasonal water ponds and vegetation as well as natural sedimentation process. 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 [7].

Rokni, K. et al. (2015) gave a new approach for surface water change detection. They introduced a new approach based on Integration of image fusion and image classification techniques for surface water change detection. 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. In the end, the suggested approach has been proven to be effective3 in detecting the water surface changes of Lake Urmia, Iran [8].

Gupta, R., & Panchal, P. (2015) concentrated on cloud detection algorithm using Discrete Wavelet Transformation (DWT) and realization of data on NOAA, VIRR and MODIS datasets with double threshold values, applied in the visible region of electromagnetic spectrum using pixel to pixel processing. The radiation in the microwave region is low and maximum at the visible region. Therefore in this paper, computation is done in the visible region. DWT is STFT (Short Time Fourier Transformation). Equation (6) to Equation (12) show the mathematical operations of proposed algorithm. In this paper, images are categorized into different ecological surfaces such that water, soil, vegetation, snow. The proposed method can differentiate the cloud from clear regions. The comparison is made between existing method based on the color model, and proposed method was found to be better. Limitation of proposed method is that it face some difficulties to differentiate between thick clouds and snow/Ice [9].

Sarp, G., & Ozcelik, M (2016) represented the changes that occurred in the Lake Burdur from the year 1987 to the year 2011. The images were obtained from the Landsat TM and ETM+ for detecting the changes. Support Vector Machine (SVM) classification and indexing, including the Normalized Difference Water Index (NDWI), Modified NDWI (MNDWI) and Automated Water Extraction Index (AWEI) were used to extract surface water from images. Overall SVM followed by MNDWI, NDWI and AWEI got the best result among all the techniques [9].

III. TECHNIQUES

In this section, we will review the various techniques used in the satellite image processing for retrieving the information about the water. Various techniques have been adopted to get the high quality of pictures in order to get better information about the presence of water.

Standard supervised maximum likelihood classification

After obtaining the MODIS images from the NASA website, the images covering the Sindh province were classified. The standard supervised maximum likelihood classification was used for the images. In this way desired inundated class was translated into a shape file. Next, the visual interpretation was utilized for the inundated areas. To exert a different kind of info-layers, the shape file was intersected with the topographic maps [15].

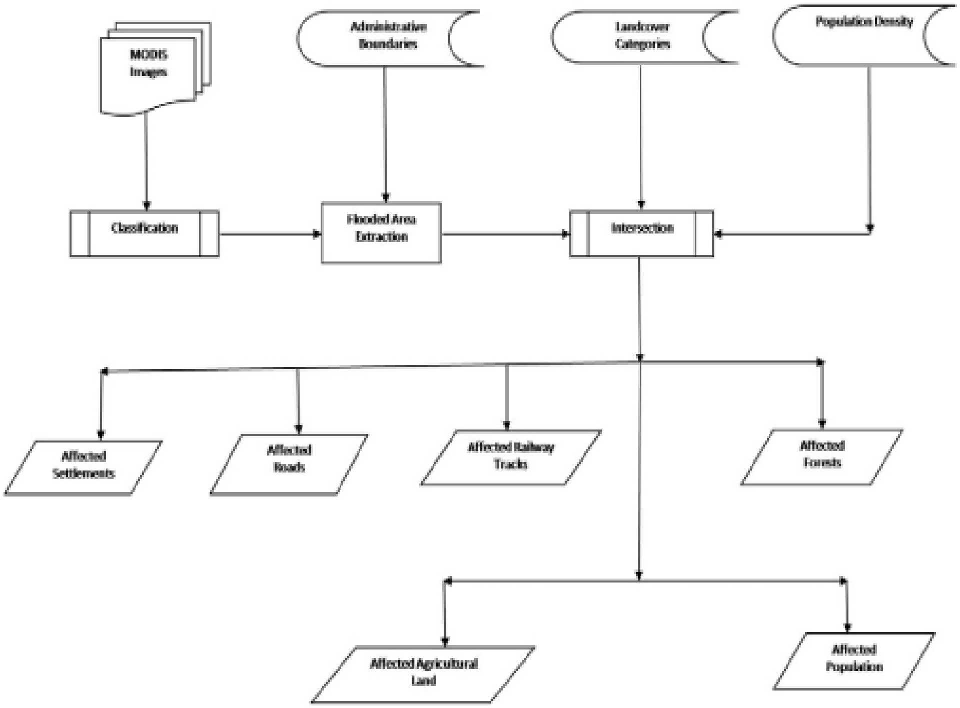

Figure 2: *Flow chart of the adopted methodology [Source: A. Shakoor, A. Shehzad, & M. Asghar, 2012]*

The study areas used for the Research was the southern part of the Australia with an area of 140915 Km ranging 442 km from east to west and 579 km from north to south. Numerous data sources and software were used for the research. Information about the different info-layers was observed from the topographic maps. It includes the data from the railway track, rivers, boundaries, vegetated area, etc. The MODIS (Moderate Resolution Imaging Spectroradiometer) images were used with resolution comprising bands 1,2, and seven were retrieved and used as the main input to map the area which was affected by flood [15].

The main technique which was used for estimating the number of affected people and the data obtained from the Pakistan, Federal Bureau of Statistics was District wise population density.

Image Pre-Processing

The image pre-processing technique was used to prepare the images as an input for the satellite. The main pre-processing steps used in the techniques include atmospheric correction, co-registration, mosaicking, radiometric calibration, and resampling. The images were translated to the at-satellite radiance for the atmospheric correction and radiometric calibration. After that, each image was transformed to at-satellite reflectance. The images containing the sun elevation and data acquisition rate were obtained from the Landsat header satellite. At last, the images were converted to surface reflectance from the at-satellite reflectance using the DOS (Dark Object Subtraction) method [18].

The new images were then obtained by mosaicking to cover the entire study area. One image was used as a reference for the co-registration of multi-temporal images. Root Mean Square Error (RMSE) was used to co-register the images. At last nearest neighbor method was utilized to resample the dataset as that of the size of the study area [18].

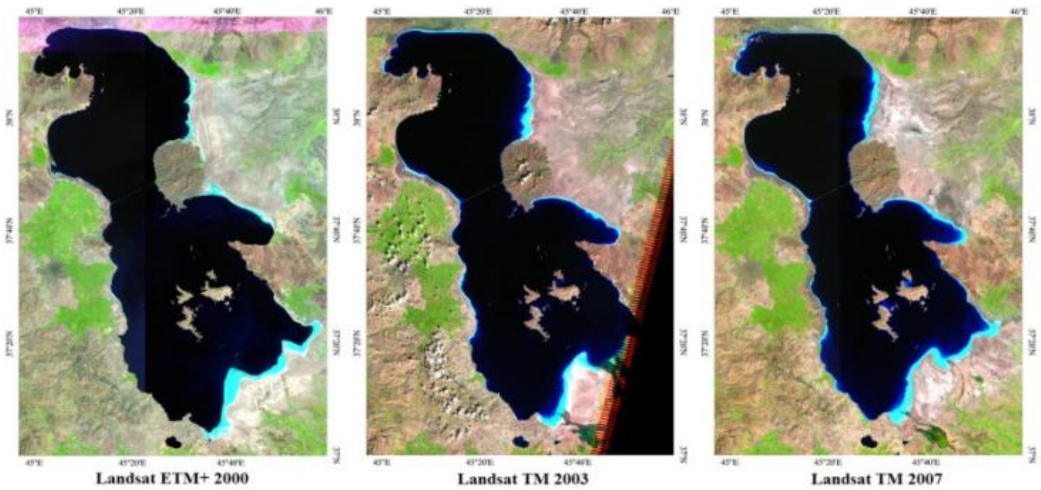

Figure 3: Data after pre-processing [source: K. Rokni, A. Ahmad, A. Selamat, & S. Hazini]

Index/overlay GIS-based model

K. Khodaei, & H. R Nassery in the paper studied the semi-arid area. They delineated the potential groundwater zones through identification of the porosity indicators. It includes the vegetation, drainage pattern, drainage density, lineaments, etc.

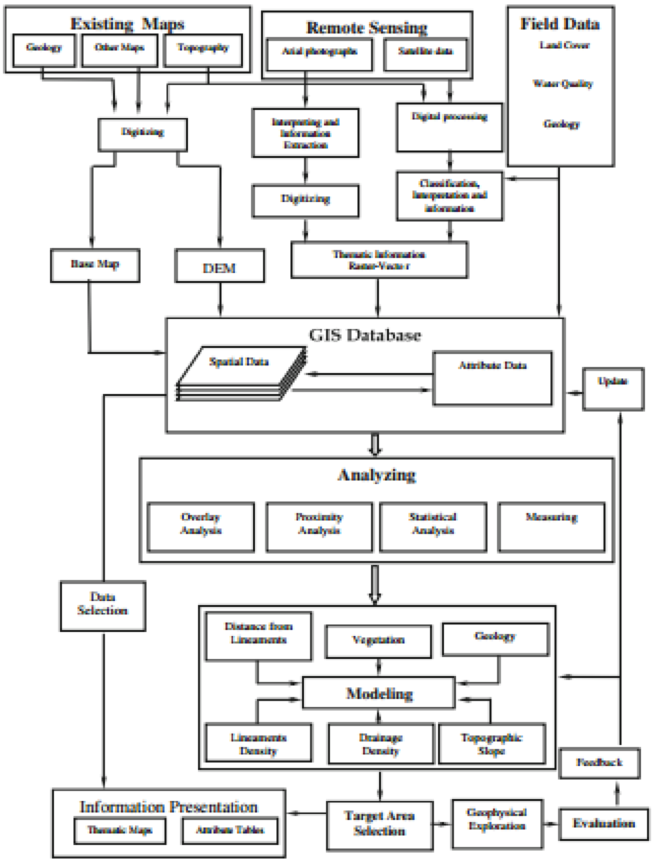

Figure 4: *Flow chart for Groundwater target area selection [source: K. Khodaei, & H. R. Nassery, 2011]*

The tone, drainage pattern and texture characters were used to prepare the lithological map of the study area from the images obtained from Landsat TM. Various digital image processing techniques including the false color composite, band rationing, principal component analysis, filtering, and classification were applied to obtain high quality of images [20].

Water Classification

The water classification technique was utilized to analyze the areas of water. In this technique, N observations for each tile which is stored in AGDC were taken. The code 1 was used to define the pixel as water and code 0 to define the pixel as not water.

The regression tree classification was used to obtain the water classification. The regression tree classification that uses normalized difference rations (NDI) and Landsat Spectral bands [1].

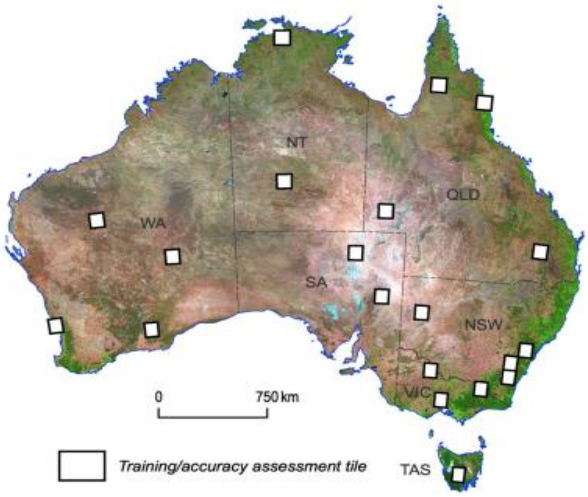

Figure 5: *Cells and 20 tiles used to develop training data for the model [N. Mueller, A. Lewis, D. Roberts, S. Ring, R. Melrose, J. Sixsmith and A. Ip]*

The figure shown above represents the 20 training tiles used as samples for the regression tree. The each tile was broken into an object for obtaining the training samples. After that objects were classified manually into 26 different classes representing a different kind of water and non-water targets. The objects were selected based on the principle that only includes pixels of necessary class [1].

The adopted technique shows the positive result as it was able to clearly differentiate between the water and non-water bodies based on the water classification technique.

Groundwater Potential Model (GPM)

Weighted overlay technique was used for implementing the GIS (Geographical Information System). The technique was used to determine the potential groundwater value. Each scale value of reclassified layer was multiplied by its weight to determine the potential groundwater value for a given area [19]. At last, all the resulting cell values for were added to produce a final output representing the study area. The greater potential for groundwater was defined with the higher sum values.

The presence of groundwater was classified into three categories including the low, moderate and high potential for the groundwater [19].

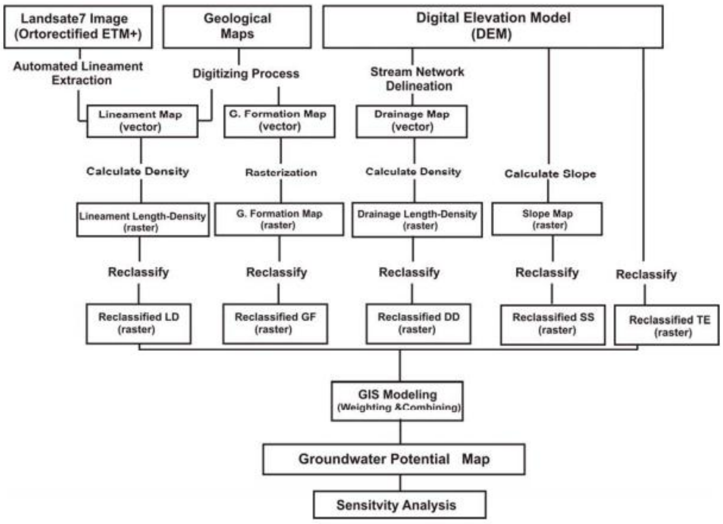

Figure 6: *Flow Chart representing different input, processing, and outputs during the study [source: N. Hammouri, A. El-Naqa, & M. Barakat]*

IV. RESULT AND DISCUSSION

This section provides insight into the findings of the research and the discussion about the various results obtained from the techniques used by the researchers shown in the previous section.

The following table provides insight into the algorithms and technique used along with the input and the results.

Year	Researchers	Algorithm/Method	Input	Results/ Solution
2012	M. Haq, M. Akhtar, S. Muhammad, S. Paras, & J. Rahmatullah	MODIS images with topographic map information retrieval were used to determine the affected people	Topographic map and MODIS images	The applied technique is effective in providing an overview of the flood affected area.
2014	K. Rokni, A. Ahmad, A. Selamat, & S. Hazini	Principal Components of multi-temporal NDWI (NDWI-PCs)	Landsat 5-TM, 7-ETM+, and 8-OLI images	The surface area of Urmia Lake decreased to one-third in 2013 when compared to the surface area of water in 2000.
2011	K. Khodaei, & H. R Nassery	Groundwater target area selection using GIS and Remote sensing procedure	Landsat 5-TM data and images	E (Excellent) and VW (Very Well) groups have been proposed as the target area

2016	N. Mueller, A. Lewis, D. Roberts, S. Ring, R. Melrose, J. Sixsmith and A. Ip	a decision tree classifier algorithm	Images obtained from Landsat 5 and Landsat 7	Developed clear map of the water present across the Australia
2012	N. Hammouri, A. El-Naqa, & M. Barakat.	A groundwater potential model	drainage and Lineament and densities extracted using an ortho-rectified Land-Sat 7 ETM+ and digital elevation model (DEM)	7% of study area found to have a high potential for groundwater. Apart from this, 79% and 14% area have moderate and low potential for groundwater.

Standard supervised maximum likelihood classification

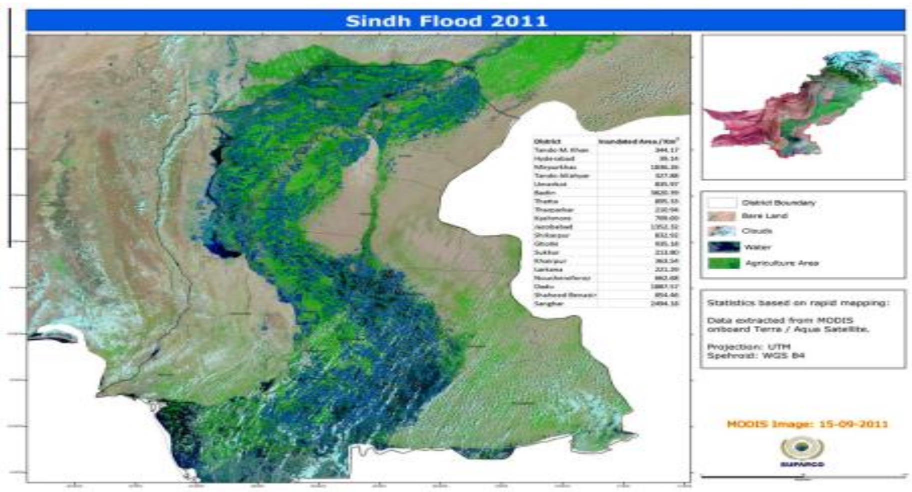

Figure 7: *Inundated area representation through MODIS image [source: A. Shakoor, A. Shehzad, & M. Asghar, 2012]*

As shown in the above diagram, the selected technique is effective enough in providing the information about the flood affected area. Remote sensing and Geographical Information system (GIS) helped to detect the flood affected area as well as the land cover features [15].

Image Pre-Processing

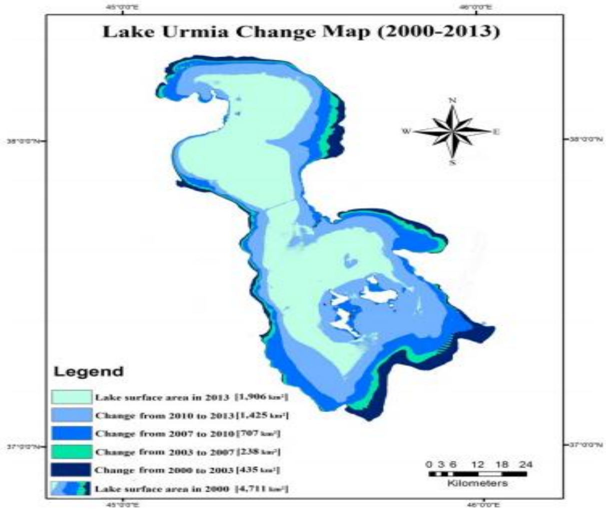

Figure 8: *Map of Lake Urmia surface area changes [source: K. Rokni, A. Ahmad, A. Selamat, & S. Hazini]*

The above figure provides a clear insight into the changes that occurred in Lake Urmia from the year 2000 to 2013. In 2000, the total area of the lake was 4711 km which remain only 1906 km in 2013 [18].

Index/overlay GIS-based model

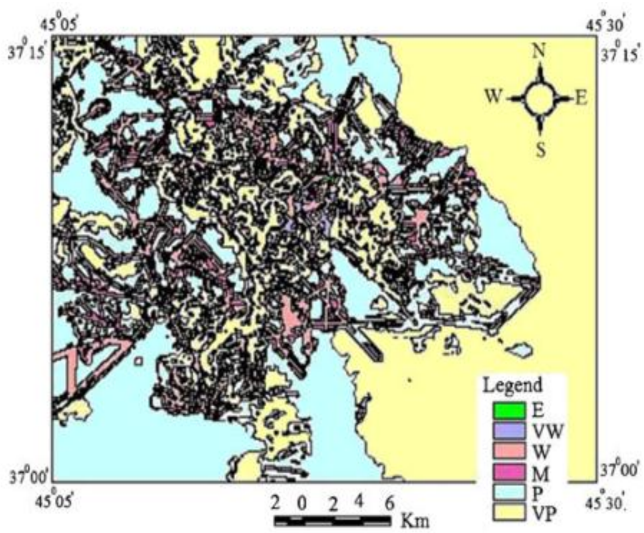

Figure 9: Final Groundwater Potential map [source: K. Khodaei, & H. R. Nassery, 2011]

As shown in the above figure, the areas were divided into different legends. The results of the study show that E (Excellent) and VW (Very Well) groups have been proposed as the target area where groundwater exploration is possible [20].

Water Classification

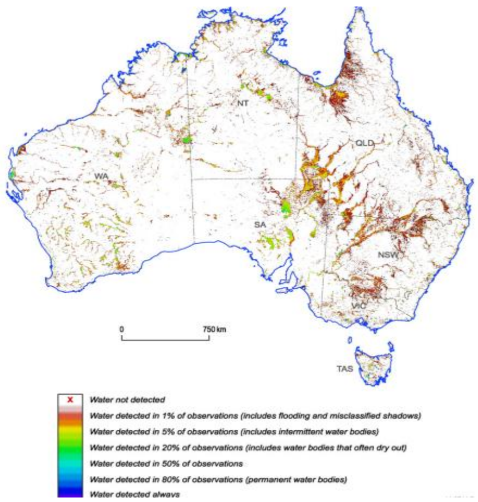

Figure 10: *WOfS filtered summary product for Australia [source: N. Mueller, A. Lewis, D. Roberts, S. Ring, R. Melrose, J. Sixsmith and A. Ip]*

Above is the map which is generated using the WOfS product. It provides a source of information about the flood plains in Australia. Along with this, it is the data source for analysis and visualization of the surface water in Australia [1].

Groundwater Potential Model (GPM)

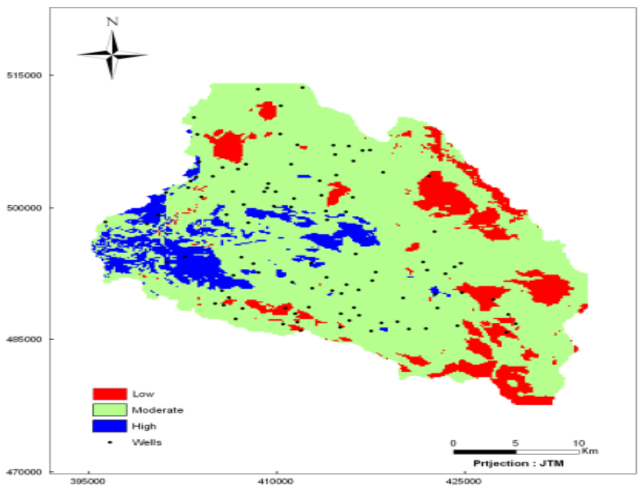

Figure 11: Groundwater potential Area Map [source: N. Hammouri, A. El-Naqa, & M. Barakat]

As shown in the above diagram, the result was classified into three different categories. These classes include the low, moderate and high groundwater potential area. It was found that 7%, 79% and 14% of the study area have high, moderate and low potential for groundwater respectively

The Excellency of the results of all the described techniques is clear from the images obtained from the study area. Technique 3 is not effective enough for representing the water detection in an appropriate way because of the unclear boundary lines and use of weak image processing techniques. Among all the techniques, technique 1 shows clear view of the water detection area. Also, the technique 5 demonstrated a clear view of the potential ground water using three classifications. We will use technique 1 and technique 5 utilizing the MODIS images with GIS and RS for detecting the water under the study area.

V. CONCLUSION

Water is one of the most important natural resources which is key to our life. Though most of the Earth area is filled with water, only small amount of water is available for the drinking purpose. Various water conservation techniques have been used till now. But management of water resources is necessary for accomplishing this task in an effective way. Water detection through satellite images is one of the promising areas for conserving the water through proper management. In this paper, we have reviewed various water detection techniques implemented by the researchers. Image processing is one of the significant parts of every remote sensing technique to get effective results. The research review will help us to implement an effective technique for our research.

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