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A Critical Assessment of High-Resolution Satellite Imagery for The Purpose of Extracting Water Body Areas

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Abstract

The property of water plays a crucial role in various aspects of daily life, including urban planning, commerce, industry, and agricultural production and so forth. The assessment of water bodies and accurate distinction of their characteristics is crucial for effective planning, particularly in regions such as India where land areas are predominantly occupied by water bodies. When capturing satellite imagery, there are instances where certain features, such as the shadows of prominent structures, do not accurately depict the distinct characteristics of water and non-water areas. The photograph of the water body was significantly disrupted by the presence of a skyscraper's shadow. This disturbance is noteworthy due to the disparity of the tranquil water surface, which promotes reflective properties, and the occurrence of wave echoes. The cost of water delivery can be relatively inexpensive. The potential for significant benefits to India's national development lies in the effective implementation of water transportation. The establishment of a connection between multiple territories involved in the transportation of water necessitates the usage of an appropriate navigational instrument. Hence, it is imperative to provide a concise delineation of the tranquil surface of water compared with the interplay of shadows cast by residential structures. In recent years, there has been a limited amount of research conducted to analyse the characteristics of the water system using a large number of multi-spectral satellite images. The primary objective of this paper is to advocate an effective approach for water body extraction using satellite imagery through the application of computer-based remote sensing techniques using PC television for laptop remote sensing. The Geographic Information System (GIS) and the Global Positioning System (GPS) have been acknowledged for their significant relevance to the field of remote sensing. Initially, there was a significant focus on conducting research related to water frame detection. Several methodological challenges associated with the utilisation of these techniques have been examined and identified through the analysis of summaries. The study presents the outcomes derived from empirical studies, specifically utilising water-frame extraction techniques. These consequences are systematically gathered and duly referenced.

Keyword- Feature extraction, remote sensing, and water body, satellite images.

1. INTRODUCTION

A watershed refers to a geographical region that directs the flow of precipitation and melted snow towards smaller water bodies like rivers, streams, and creeks, ultimately leading to larger bodies of water such as reservoirs, bays, and the ocean. The dimensions of a watershed, alternatively known as a drainage basin or catchment, are delineated across multiple levels, denoted as Hydrologic Unit Codes (HUCs), which are determined by the geographical characteristics that hold the utmost significance within the particular region. A watershed has the potential to encompass smaller geographical areas, such as a modest inland lake or a single county. A watershed refers to a comprehensive river system encompassing the region that is drained by a river and its associated tributaries. It is occasionally referred to as a drainage basin.[1] Watersheds can be characterized as both physical and abstract systems, exhibiting characteristics of openness and hydrological permeability while also being capable of being conceptually delineated as functionally distinct entities. Watersheds, as a whole, represent an intricate hierarchical system, thereby serving as a prime illustration of the interconnectedness and interdependence of ecosystems in terms of upstream and downstream dynamics.[2] Watersheds encompass a range of social actors, relationships, and institutions that are situated within their geographical boundaries.[3] In recent times, there has been a growing demand for the establishment of a field known as "watershed epidemiology". This field acknowledges the significance of geophysically defined landscapes as units of study that encompass the interconnections between water, land, and human health. The aim is to enhance our comprehension of the complex relationship between these elements.[4] The terms "watershed," "catchment," and "basins" are frequently used interchangeably. Remote sensing is the technology of using a tool to measure a target and its properties from a distance, without a physical connection between the measuring instrument and the target that is to be featured. The measurements are typically completed using a variety of techniques. The strategies encompass various forms of electromagnetic radiation, such as ultraviolet, visible light, reflective, thermal infrared, and microwaves, among others. The data pertaining to radiation that is either mediated or emitted by the goal and its surrounding structures is subsequently deduced from the signal that has been measured. One advantage of remote sensing is the ability to conduct measurements from a significant distance, such as several hundred or even several thousand kilometers in the case of satellite imagery sensors. This capability allows for the efficient coverage of large surface areas. The utilization of satellite imagery on personal computer devices allows for frequent and repeated examination of a specific target, often occurring multiple times within a single day. The task of classification has been extensively investigated in the field of remote sensing image processing. The software encompasses a range of stages, starting from land use evaluation and extending to object detection.[6]

Historically, lessons of interest have been chosen from various geographical regions, including city regions, farmland, wooded areas, and river/lake regions. The utilization of remote sensing imagery for the analysis of water bodies has gained significant importance in recent years due to two main factors:

1. There is a pressing global need to assess the current state of water resources and changes in water availability due to the escalating water scarcity and associated challenges.
2. The phenomenon known as "climate change" is directly influenced by and has a direct impact on the water cycle.
3. The study of water bodies can potentially contribute to the development of water supply routes, either by utilizing existing ones directly or by connecting them through the construction of canals to extend the length of the water route.
4. Timely information regarding water accumulation in hills and mountains can also aid in devising strategies to mitigate the occurrence of flood disasters. The utilization of remote sensing techniques, along with the integration of geographic information systems, has a widespread impact on the implementation of practical tasks.[1234]

The software applications encompass a wide range of disciplines including business, ecology, engineering, forestry, geography, geology, city and local planning, water assets management, transportation engineering, and environmental technology. Remote sensing provides a means to observe and analyze various phenomena, such as flood disasters and changes in land use.

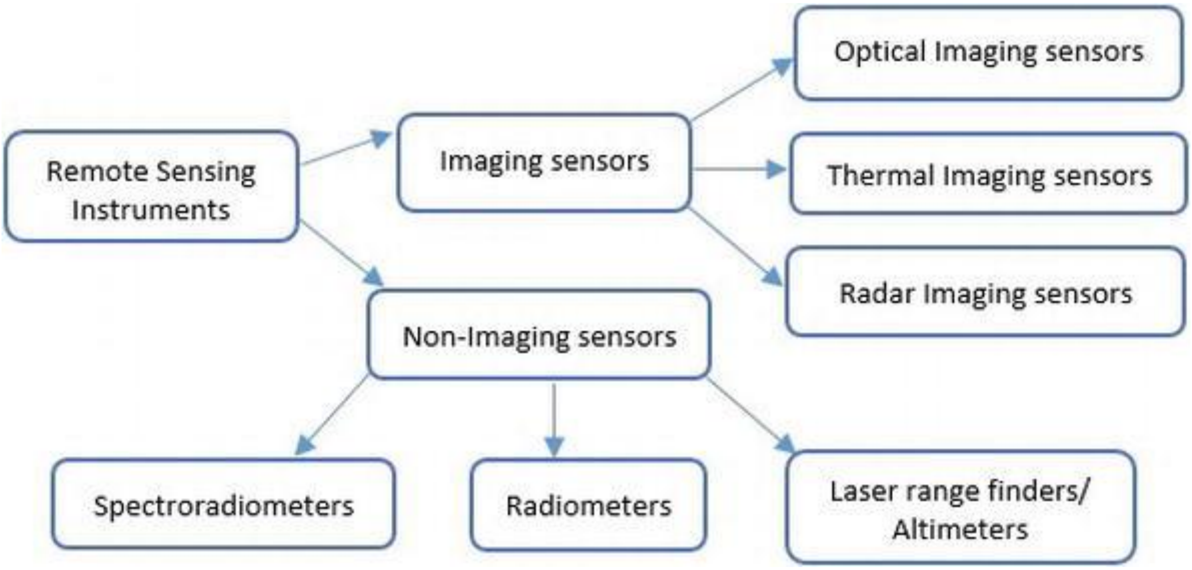
There is a close interrelationship among the interconnected domains of remote sensing, Geographic Information Systems (GIS), Global Positioning System (GPS), digital image processing, and environmental, transportation, and urban planning. The ability to delineate the extent of unconfined groundwater is an essential component in various hydrological and agricultural models, wildlife management programs, as well as recreational and natural resource studies. The evaluator analyzed X-band HH polarized airborne Synthetic Aperture Radar (SAR) imagery in order to assess the capability of SAR data for mapping open water areas on 1:100,000 USGS topographic maps.[7]

A watershed refers to a geographical region that is demarcated by a well-defined topographic boundary and serves as a drainage basin for water. The geographic region referred to as the watershed is characterized by the concentration of hydrological features such as bodies of water like oceans, seas, lakes, rivers, or reservoirs. These features serve as outlets through which the watershed's water is drained. Within the confines of a topographic boundary or hydrological divide, the watershed encompasses a diverse assemblage of soils, landforms, vegetation, land uses, and land configurations. The terms watershed, catchment, and basins are commonly regarded as identical.[8]

The term "far-off sensing," which refers to the technological capability of using a device to measure a target and its properties from a far-off location, without a link between some of the measuring instrument and the target, is to be included. The measurements are typically carried out using a variety of techniques. Electromagnetic radiation (G. Ultraviolet, visible light, reflecting, thermal infrared, microwaves, and soon.) are such methods. The instrument collects the radiation that is reflected off of the object, and its components are then deduced from the measured sign.[6, 7]

1.1 Usage of a satellite sensor

Numerous earth observation satellites have been deployed and remain in orbit around the planet, facilitating the regular acquisition of imagery capturing its surface region. A considerable number of satellites possess the capacity to furnish significant data for the assessment of erosion; however, only a limited proportion of these satellites have been utilized for this specific objective. This section provides a concise overview of the space-based sensors utilized in research pertaining to the extraction of water bodies. Optical instruments are utilized for the purpose of quantifying the reflection of sunlight within the visible and infrared regions of the electromagnetic spectrum, alongside the measurement of thermal infrared radiance. Conversely, imaging radars operate by actively transmitting microwave pulses and subsequently recording the resultant received signal.[5]



Source 1:A Review: Remote Sensing Sensors

1.2 Satellite acquired images

A diverse array of satellite images obtained from multiple locations were examined and integrated to present datasets. The generated maps proved to be valuable for a diverse set of users who required prompt identification of natural and artificial features, accurate and quantitative assessment of flood severity, determination of flood impacts and behavior, and efficient dissemination of findings to a wide viewer. The utilization of maps extends beyond mere representation, as they can serve as a valuable tool for monitoring temporal variations, delineating the characteristics of flooding events, pinpointing vulnerabilities in flood control infrastructure, contributing to the formulation of flood plain analysis strategies, and facilitating the dissemination of pertinent information regarding post-flood restoration efforts to both the wider populace and governmental decision-makers.

Source 2:

2. The current methodology

The mean shift algorithm has been demonstrated to be a highly efficient tool for picture segmentation. The algorithm iteratively moves to the kernel smoothed centric for each data point. The algorithm's quadratic computational cost presents a substantial challenge to its scalability in real-world scenarios. The fast Gauss transform (FGT) has significantly accelerated the kernel density estimation process in low-dimensional scenarios, leading to a linear time complexity. However, the expenses associated with employing the FGT for addressing challenges in higher dimensions exhibit exponential growth in correlation with the number of dimensions. Mean shift segmentation was employed to partition the picture into homogeneous regions. Subsequently, the primary aquatic extent was selected, which included the establishment of an initial perimeter along the water's edge. The ultimate coastal boundary, established through localized adjustments within the potential areas neighboring the initial shoreline. Skeletonization is a method employed to eliminate a significant number of pixels from a given pattern while preserving the pattern's fundamental shape. In an alternative formulation, it is imperative that the underlying pattern remains identifiable even subsequent to the removal of individual pixels.[11] The resulting skeleton must possess the following characteristics:

- Utmost level of thinness.
- Appropriately Allied.
- Right Positioning.

The water-body feature is derived from satellite imagery through the utilization of a dual process. The process encompasses the extraction of boundaries and skeletonization from color imagery through the utilization of a color image segmentation algorithm, a crust extraction algorithm, and a novel skeleton extraction algorithm.

2.1 Non-Definite Methodology

The dimensionality of multispectral data collection has significantly increased due to advancements in sensor technology for Earth observation. Furthermore, the utilization of multisource data will provide a substantial amount of data with a significant level of dimensionality. The advent of high-dimensional data will have a significant impact on processing technology across various domains i.e.

- There will be an increased capacity to categorize additional classes.
- High-dimensional data requires more computer power.
- Dimensionality and class count will increase processing time significantly.

The examination of remotely sensed data is typically conducted through machine-centric pattern recognition methodologies. Classification based on maximum likelihood (ML) assuming Gaussian distributions of classes is a highly prevalent pattern recognition technique. The Gaussian maximum likelihood classification encounters a significant issue pertaining to extended computational duration. The extended duration of processing contributes to an increase in computational time, thereby resulting in escalated computational expenses. The issue of computational cost may pose a significant concern in scenarios where the analysis of remotely sensed data for a vast geographical region is required or when the processing hardware has limited capabilities. The emergence of advanced sensors in the future is expected to exacerbate this issue. Therefore, it is imperative to prioritize the extraction of comprehensive information from datasets with a high number of dimensions, while simultaneously minimizing processing time to a significant extent.[11]

3. Definite Methodology

When examining the period between 1989 and 2017, it is possible to observe the changes in the water levels within the Reservoir. This study presents a methodology and showcases different satellite-multiband datasets, such as the Normalized Difference Vegetation Index (NDVI) [21], Normalized Difference Moisture Index (NDMI), Normalized Difference Water Index (NDWI) [22], and Modified Normalized Difference Water Index (MNDWI). These indices were employed to identify and extract surface water bodies from Landsat imagery, as depicted in Table 2. Therefore, four distinct extended periods of satellite imagery (specifically Landsat-5 data from 1989, 1997, 2007, and Landsat-8 data from 2017) were utilized to extract surface water bodies using various classification techniques (including NDVI, NDMI, NDWI, and MNDWI).[21]

The Normalized Difference Water Index (NDWI) is utilized to identify and distinguish surface water bodies based on a predetermined threshold value. Water bodies have positive limit values, while non-water bodies have negative edge values. The Modified Normalized Difference Water Index (MNDWI) has been developed as an effective tool for identifying and extracting surface water bodies. The band5 (center infrared) has been replaced by the band4 (near infrared). The reflectance values of band 5 exhibit greater contrast compared to band 4.[17]The Modified Normalized Difference Water Index (MNDWI) is commonly employed to mitigate errors arising from vegetation, soils, and urbanized areas. The advantages and disadvantages of the Modified Normalized Difference Water Index (MNDWI) are applicable to both aquatic and non-aquatic entities. The Normalized Difference Vegetation Index (NDVI) has primarily been employed for the purpose of distinguishing green vegetation from other surface areas within wetlands. As a result, the Normalized Difference Vegetation Index (NDVI) exhibits a superior ability to distinguish surface water compared to the Normalized Difference Moisture Index (NDMI) approach. Furthermore, the NDVI's capacity to quantify water is indicated by negative values.[21]

The primary application of the Normalized Difference Moisture Index (NDMI) is the retrieval of vegetation and water content. Nevertheless, when it comes to the identification of water bodies, it is comparatively less efficient in comparison to alternative indices such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Modified Normalized Difference Water Index (MNDWI). Consequently, the NDMI strategy produced inadequate outcomes with regards to the extraction of water bodies. The noteworthy aspect of the Normalized Difference Moisture Index (NDMI) lies in its positive value limit for water. Within the framework of these evaluations, it has been noted that the MNDWI methodology has demonstrated comparatively enhanced efficacy when compared to alternative approaches such as NDWI, NDVI, and NDMI. The study aimed to identify and apply the most efficient methods for extracting water bodies in order to analyze the spatiotemporal fluctuations of the Nagarjuna Sagar Reservoir between the years 1989 and 2017.[22] In order to differentiate and segregate reservoir surface water bodies across four specific years, namely, 1989, 1997, 2007 (captured by Landsat-5) and 2017 (captured by Landsat-8), the utilization of corresponding images is imperative. The period from 2007 to 2017 witnessed the most significant fluctuations in the separation of reservoir surface water regions during four-year examinations. Various precision examinations were conducted to assess the efficacy of identifying and extracting surface water regions. Through the application of precision evaluation investigations, the computation of various metrics can be achieved, including overall accuracy, producer's accuracy, user's accuracy, and kappa coefficient. The delineation of those boundaries was conducted based on the changes observed in the water body from 1989 to 2017.[21-22]

Once the essential satellite data is obtained, additional image processing procedures are implemented for further analysis and manipulation. The investigations were conducted before implementing water-based techniques and after implementing water-based strategies, resulting in the obtained outcomes. Various satellite-based multiband water detection methods, such as NDVI, NDMI, NDWI, and MNDWI, were employed to identify and extract surface water bodies from Landsat-5 (1989, 1997, and 2007) and Landsat-8 (2017) datasets. The Reservoir water region is subjected to four water detection strategies, namely NDVI, NDMI, NDWI, and MNDWI, in order to highlight the differentiation between water and non-water entities. Among the various techniques used for water detection, the Modified Normalized Difference Water Index (MNDWI) demonstrates a superior approach in isolating water bodies when compared to other established techniques such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Moisture Index (NDMI). In general, water regions exhibit positive attributes, while vegetation regions tend to display negative attributes. Firstly, calculate the surface water area and the altered surface water area for four distinct years using a selected reservoir. [21-22]

4. Evaluation and Barriers

In order to effectively implement a command using discernment, the first step involves defining feature vectors by identifying the descriptors that represent characteristics of a water body. These descriptors can be either pixel-based or object-based. Only pixel-based data is currently utilized in the existing concentration. Once the vector highlights have been characterized, the subsequent step involves the installation of loads for each vector. The magnitudes of these loads are dependent on the spatial and material characteristics of the objects. The reflectance exhibited by a water body during the summer season differs from that observed during storm season (specifically flood periods) due to factors such as increased water levels, sediment deposition, and the presence of various pollutants.[23-24]

Thus, there is no common motivation for the burdens associated with each descriptor, and the best qualities may change by circumstance. Load values vary from 0 to 1, with 0 indicating no distinguishing attribute and 1 indicating the desired property. A weighted aggregate was calculated from component vectors and loads. Weighted totals determined the outcome. The work produces a demanding threshold that combines capacity and a limit value during grouping. Vectors and loads determine edge esteem. We calculate the largest possible weighted sum for a water body pixel. Extreme values determined this value. Classification is completed by comparing the weighted sum for each pixel to the edge value. This data is binary, precisely zero. Zero is turned to zero and 1 to 1. Linearization assigns 1 to all water pixels and 0 to all non-water pixels, which has two benefits. These tools help determine yield output thresholds. When constructing the weighted aggregate, negative qualities must be minimized.

However, it is necessary to test the model's accuracy and performance by taking into account factors such as objective, duration of satellite data, as well as land use and land cover patterns around water bodies, which have not been examined in the present study. The study employed data from the Enhanced Thematic Mapper (ETM) for a specific time period and had the capability to accurately represent water bodies. The matter should be thoroughly examined with regard to diverse transient data and multiple seasons for a comparable sensor, namely the Enhanced Thematic Mapper (ETM). Similarly, it is imperative to assess the efficiency of the proposed computation by utilizing satellite data obtained from various sensors. Moreover, in terms of ETM (Enhanced Thematic Mapper) information, the review has considered a significance value of 2 as the most effective in distinguishing between different bodies of water. It is important to normalize this value considering the diverse spectral and spatial resolutions of satellite data. The investigation of the potential suppression of authentic positive attributes due to a threshold value of 3 must be conducted by employing multiple satellite datasets to establish a standardized threshold for extracting water bodies. The proposed technique demonstrated its effectiveness in effectively distinguishing larger water bodies, highlighting the necessity to further develop the model by emphasizing a universal threshold that can also detect smaller water bodies. This is particularly crucial in light of the ongoing global water crisis. The objective of information is of utmost importance in accurately delineating the boundaries of water constraints. The suggested model should be tested using high-resolution spatial data sources, such as IKONOS, which are preferred by experts due to their superior accuracy in land feature mapping. The sequence of satellite data analysis begins with testing, and if the proposed model proves to be effective, it enables more precise and expedited extraction of information regarding water bodies.[25-26]

5. Program

In order to reach the conclusion, the performance of the proposed techniques This code is used to extract water bodies from Lands at images:

```
clear all; close all;clc;
QCALMAX=255;
QCALMIN=1;
d=0.99253;
THETA=48.77438778;
l_lambda =
zeros(7201,7981,6);rho=zeros(7201,7981,6);
y=zeros(6);
ndwi=zeros(7201,7981);
img_final = zeros(7201,7981);awei_nsh =
zeros(7201,7981);awei_sh =
zeros(7201,7981);DN(:,:,1)=imread('Image_1.tif');
DN(:,:,2)=imread('Image_2.tif');
DN(:,:,3)=zeros(7201,7981);
DN(:,:,4)=imread('Image_4.tif');
DN(:,:,5)=imread('Image_5.tif');
DN(:,:,6)=imread('Image_8.tif');
LMAX=[191.6196.5152.9241.131.0610.8];
LMIN=[-6.2-6.4-5-5.1-1-0.35];
ESUN=[19701842154710442225.782.06];
for i=1:7201for j=1:7981forl=1:6
ndwi(I,j)=(y(2)-y(5))/(y(2)+y(5));
awei_nsh(I,j)=4*(y(2)-y(5))-(0.25*y(4)+2.75*y(6));
awei_sh(I,j)=y(1)+(2.5*y(2))-(1.5*(y(4)+y(5)))-
(0.25*y(6));
ifDN(I,j,4)<45&&DN(I,j,4)>10&&DN(I,j,5)<60&&DN
(I,j,5)>10&&
ndwi(I,j)<0.8&&ndwi(I,j)>-
0.3&&awei_nsh(I,j)>0&&awei_sh(I,j)>023
img_final(I,j) = 1;end
endend
imshow(img_final);
```

6. Conclusions

The process of water body mining is contingent upon the land use and land cover of the landscape under investigation, in addition to the utilization of satellite data. The present investigation employed the landscape structure of the urban setting in the rapidly expanding city of Hyderabad. It is imperative to assess the efficacy of the proposed methodology in relation to various landscape configurations, such as the presence of water bodies within densely forested areas, or in rural settings characterized by the intermixing of water bodies within agricultural lands featuring diverse crops, as well as water bodies situated adjacent to sizable rivers and streams. The significance of landscape lies in the variation of land use classes surrounding water bodies across different landscapes. Water bodies are typically separated by distinguishing between water and non-water features, which serve as boundaries for the water bodies. However, the act of segregating these features may hinder the natural flow of elements and disrupt the overall ecological balance. Considering the aforementioned points, future research holds significant potential for investigating the application of perceptron models in designing and developing a promising strategy for analyzing diverse satellite data and accurately identifying water bodies, including those of smaller sizes.

Furthermore, there is a need for enhancement in the water body extraction algorithm to ensure automation of the system for handling various types of sensor images. This integration with other tools will facilitate the provision of accurate data pertaining to flood conditions and the availability of underground water. The aforementioned perspectives constitute a fundamental concern in developing nations. Collecting data manually can often be tedious and uninteresting.

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