Surface Water Detection Method for Water Resources Management

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ABSTRACT: Small significance earth dams during the dry period for locals at most semi-arid cannot be overestimated. Water stored in the same of these dams is little or no lack of domestic water and drinking water for residents during dry periods. The main limitation is the lack of knowledge of the storage quantities of small dams in the study area and knowing this form of field data regularly is costly and needs a long and arduous time. Remote sensing and geographic information systems (GIS) can be used in this study due to their ability to measure and analyze the amount of water stored in some small reservoirs. In this paper, the Water Natural Difference Index (NDWI) is used to detect the surface area as the base to estimate small reservoir storage capacities. The model equation created by this study provided a tool to know the amount of water available per day in the small reservoirs during the dry season and thus was able to obtain clear pictures of the water resources system by the planners. This method may help the planners and water managers will quickly make decisions on how to utilize and manage the available water given the various competing uses.

Keywords: area curve method - volume - altitude - remote sensing - geographic information system (GIS). Water Natural Difference Index (NDWI).

1. Introduction

Civilization is mainly based on the availability of water that has become a scarce resource with an exponential increase in the arid region[1]. However, large quantities of water are stored in these small reservoirs and the direction of the riverbed depends on the flow of this water, during periods of drought this water is rarely available in sufficient quantity [2]. Effective management and planning are overwhelmed with the knowledge of storage volumes [3][4]. This causes a lack of sufficient knowledge of small storage capacities and this is a hindrance in the process of decision-making that relates to design and managing current water resources. Determining the amount of water present and its knowledge is important to maintain water sustainability as well as help planners in sustaining customer demand.
The sustainability of the rainwater collecting is fundamental to the development of livelihoods in both socio-economic and biophysical conditions in arid and semi-arid regions [5]. Sustainability focuses on having a harvest in the consumption and use of natural water resources, through the rainwater harvesting uses. Where the existence of small reservoirs to provide ready and appropriate sources of water to be used in different communities of rural communities and that can become indispensable areas, which is very important in the development of livelihoods in the rural community[6].

For water resources evaluation it is necessary to know the adequate capacity of the respective reservoir. The volume of water in the reservoir must be measured to estimate the shape of the reservoir at the earliest [3]. And because the long and cross-sections of the reservoir are usually irregular, so it is not easy. A good way to estimate the amplitude is to consider the area around the lines at proportional intervals. After that, the volume can be calculated between two successive contours, after which these volumes are recorded and the total dam capacity can be obtained. In many cases, it is here to design small dams without the need for a full topographic survey. The management of water resources in arid and semi-arid regions faces many difficulties, as the areas are not eligible and do not have the infrastructure, and this makes transportation difficult, especially since its valleys have vast areas [7][8][9]. Therefore, it is imperative to manage the water resources in these areas with the necessary research.

In terms of the availability of remote sensing techniques, climate models, and information available, more detailed in it has new capabilities in detail models of small reservoirs to measure its surface area to know their storage capabilities. However, the latest developments are commuter devices it has the means to process larger spectral data arrays in remote sensing and to integrate this data with other geographic information[10]. Consequently, there are indications of and scope for improvement concerning research on small dams and the need to establish a model equation for reservoir estimation store capacity for small dams using their remote surface area sensor.

The discovery of bodies of water is the source of concern that has been followed since the first photos of Landsat were there in previous years [11]. The most popular and simple way to determine surface water using remote sensing data is to know the calculation of spectral indicators. Several indicators were then developed specifically to take advantage of the unique spectral signature of water compared to other land cover types [12][13][14][15][16][17][7][18].

Using remote sensing data, changes in the water level of small earthen dams can be assessed over time. Where many studies have used remote sensing data to assess the storage capacity of a small reservoir, such as the study in Ghana [11] where there is a relationship between depth, area, and volume of the reservoir, as well as the Limpopo River study to estimate the small size. Reservoir capacity using remote sensing surface area and storage volume in continental topographic climate [2]. Several studies have used GIS in calculating the storage capacity of rainwater harvesting structures mentioned in the literature [19][20][21].

This study aims to estimate small reservoir storage capacities as a function of their remotely sensed surface areas during the dry season to assess the sustainability of water storage in small earthen dams.

2. Study area

The study area was chosen as Wadi Houran in Anbar, in the western desert of Iraq, about 450 km west of Baghdad, as shown in Figure (1). Wadi Houran is the largest valley in the Anbar desert, where the length of the valley is 458 km from the city of Al-Baghdadi, where it meets
the Euphrates River until the border between Iraq and Saudi Arabia, as the geographical location of the Wadi Houran ranges between 39°00'00" to 43°00'00" in the east and latitude 32°00"00', to 43°30'00" north [22]. The difference in slope between the start and the end was 600 meters, and the valley catchment was about 11,370 square kilometers. The Wadi Houran region is cold in winter and hot in summer, so it is considered an arid region. The month of January is the coldest and July is the warmest month [23]. The valley temperature ranges between (0-48) degrees Celsius. The annual rainfall is about (75 - 150 mm). About 49% of the precipitation is in winter., 15% in autumn, 36% in spring, and summer without rain [24]. Flooding occurs in the valley in short periods and the weather is dry most of the year. Maximum evaporation of destinations in the valley in July and August [25] the extent of evaporation ranges from (1600-1900) mm, and the range of relative humidity of the valley varies from month to month, and the annual rate ranges between (19% -82%).

We notice the levels of deep groundwater in the study area and that the water of most of the wells is salty, as we note that the small earth dam is the ideal technology for freshwater. Wadi Houran contains four small earth dams, which are Al-Rutbah Dam, Al-Ubailah Dam, Houran Dam 2, and Houran Dam 3 as shown in Figure (1). The maximum storage of four dams is about (46) million cubic meters of water, as shown in Table (1).

The Wadi Houran site is in a part of a fixed rack of the Arab platform and the valley area is almost flat. The Sheikh Al-Aas formation appears in Wadi Houran and downstream of about 35 km. The Sheikh Alas formation is made of white, cream, and porous limestone. In an area near the Euphrates, the Euphrates formation along the Wadi Horan reveals most of the exposed rocks in the valley from hard limestone [26]. It provides a good base for terrain, social economy, hydrology, soil, and agricultural engineering [27]. Wadi Houran is a very important area in the Western Desert, as it receives large amounts of rain in the rainy seasons. Therefore, it is essential to optimize these quantities of water by storing the optimum amount of runoff [28][4].

Figure 1. Study area
Table 1. Small Dams in the study area (Ministry of Water Resources, 2015)

| No. | Name of Dam | Completion Date | Height of Dam (m) | Storage capacity (Mm³) |
|-----|-------------|-----------------|------------------|------------------------|
| 1   | Rutbah      | 1981            | 19               | 32                     |
| 2   | Horan 2     | 2007            | 15               | 5                      |
| 3   | Horan 3     | 2003            | 15               | 5.3                    |
| 4   | AL-Ubailah  | 1973            | 11.5             | 4                      |

3. Methodology

The methodology started to collect the area volume elevation curve for AL-Rutbah dam, Horan 2 dam, Horan 3 dam, and AL-Ubailah dam. To define the maximum dimensions of the reservoirs employing remote sensing data, which are represented by their largest surface area, the acquisition time should be as close as possible to the end of the rainy season, when the tanks are filled until the maximum full supply capacity and losses (evaporation) and drawdown, leakage) is minimal.

The procedure for estimating the surface areas used from the satellite imagery is image acquisition. However, the images were selected based on the images captured in this study every 16 days to make the storage capacity of the reservoir and define them in a surface area based on the area volume elevation curve. The Landsat 8 satellite image was imported into the Arc GIS 10.07 and projected UTM zone 37 north. Images were taken geographically and upon changing the pixel size to a resolution of 30m x 30m were combined into a single image strip.

The detection and delineation of open surface water bodies using Landsat images were best done with imagery from the infrared and visible parts of the spectrum. The best method for detecting and determining the characteristic spectral reflection curve of water with increasing wavelength shows an overall decrease in reflection, such that the reflection of clear and deep water in the near-infrared is nearly zero [11].

Spectral water index methods, such as the normalized difference water index, namely, and specifically, NDWI McFeeters [12], which are computed from a green band image and a single NIR-band image, and modification of the normalized difference water index, namely, [29], which is computed from a single green-band image and one SWIR-band image, extracting water body information more accurately, quickly and easily from general feature classification methods.

NDWI was defined by McFeeters [12] as:

\[
\text{NDWI} = \frac{\rho_{\text{Green}} - \rho_{\text{NIR}}}{\rho_{\text{Green}} + \rho_{\text{NIR}}} \tag{1}
\]

where \(\rho_{\text{Green}}\) and \(\rho_{\text{NIR}}\) are the reflectance of the green and NIR bands, respectively.

The NDWI from McFeeters (1) using green wavelengths to maximize the reflection of a water body, (2) low reflectance filtering in NIR of water bodies, and (3) the extent to which high reflectance in NIR makes use of vegetation and soil characteristics [30]. As a result, water surface information and background information (vegetation and soil features) will be
restricted in the McFeters' NDWI images. By applying a border to NDWI images from McFeters, means that bodies of water can be identified.

In the year 2020 for dry periods (May-October) one image per 16 days is captured. The spectral band of Landsat used (B3&B5) these bands are merged through an equation (1) and get surface area accurate. After digitizing the surface area was estimated. The three-step analysis of this information and linked with the area volume elevation curve and formulate the relationship between storage capacity and days in the dry period.

4. Results

In the study, through an inventory of satellite imagery, four small reservoirs from the western desert of Iraq were visually identified. In each case, a reservoir has its area-volume curve and depth-area curve. Thus, according to the NDWI, the remotely sensed surface area of a reservoir, the volume storage can be estimated for each reservoir.

The main findings on the data obtained in the study are table (2) represents the relationship between three parameters were the date of imagery taken, surface area, and volume storage in the dry season.

To establish the model equation, a method used for quantitative estimation, an examination of "informal modeling" was performed through which the basic premise is that the variable (storage capacity) is affected by an independent variable (number of days). From the regression equations, a regression curve was constructed for each dam. The regression curve gives a formula in which the storage capacity of each reservoir is estimated, given the number of days.

Satellite images may be used to assess changes in water levels in small dam over time. In this case, the reservoir studied was evaluated to see the changes, which took place in storage capacity in the dry season as a result of the various activities that take place around the reservoir and most importantly the watering of the livestock. Since the capacitance is a function of the surface area, we have provided expected changes in surface areas such as selected by remote sensing of the studied reservoir.

Graphs 2,3,4 and 5 show the relationships between volume storage and the number of days in the dry season for studied reservoirs Al-Rutbah, Horan 2, Horan 3, and Al-Ubailah dams.

**Table 2.** Surface area and the estimated storage volumes for Al- Rutbah, Horan 2, Horan 3, and AL-Ubailah dams.

| Date    | Name of Dame | Surface area(m²) | The volume of storage (Mm³) |
|---------|--------------|------------------|-----------------------------|
| 15/5    | Horan2       | 800021.31        | 1.6                         |
| 2020    | Horan3       | 440302.5         | 0.33                        |
|         | Al-Ubailah   | 361121.32        | 0.35                        |
| 31/5    | Horan2       | 775996.8659      | 1.45                        |
| 2020    | Horan3       | 420505.7         | 0.3                         |
| Date   | AL-Ubailah | AL-Rutbah | Horan2   | Horan3   | AL-Ubailah |
|--------|------------|-----------|----------|----------|------------|
| 16/6   | 322313.13  | 460002.321| 733218.1048 | 0.3      | 21.8       |
| 2020   | 400312.1   | 300136.34 | 637004.0287 | 0.28     | 0.25       |
|        | 4451230.321| 4362130.114| 583273.5375 | 19.5     | 1.1        |
| 18/7   | 300136.34  | 4362130.114| 349831.0949 | 0.2      | 0.1        |
| 2/7    | 275432.05  | 186325.44 | 501070.5999 | 0.17     | 0          |
| 3/8    | .................. | 4000012.001| 222734.0346 | 19       |           |
| 19/8   | 4221034.457| 4351258.298| 461606.2597 | 0.65     | 1.1        |
| 4/9    | 275432.05  | 4362130.114| 255826.8981 | 0.15     | 0.17       |
| 20/9   | 186325.44  | 4362130.114| 133657.7756 | 0.12     | 0          |
| 6/10   | 300136.34  | 4362130.114| 305214.046  | 0.4      | 0.09       |
| 2020   | 95789.3254 | 4362130.114| 104688.2052 | 0.1      | 0          |
5. Discuss Results

We see water described as the most precious natural resource in the Western Desert of Iraq. It is undoubtedly the most vital and thus the need to effectively plan and manage water resources. The storage capacity and the number of days in dry season relationships are built for the four small earth dams in the Western Desert of Iraq. The cost of this method is less labor and less cost.

The general curve shapes represent expected curves of small reservoirs as shown by common designs of small reservoirs. This is because reservoirs were very different in shape, depth, and nature. It was found that all equations have a higher value of the coefficient of identification ($R^2$) higher (0.958%). The difference in $R^2$ is explained by the different properties of the dam. However, from the results given in Figures 2, 3, 4, and 5, the summarized equation gives a better assessment of storage ability as compared with the height.

From a comparison of the tables of remote sensing areas 2, 3, 4, 5, the Al-Ubailah dam is less than others. According to the regression analysis performed in this study of generalized equations for storage capacities of small reservoirs in the Western Desert of Iraq is due to their surface area, evaporation, dam shape, and water extraction.

There was evidence of local communities using small reservoirs to conserve water for irrigation in the dry season. The differences in the storage capacity of the reservoir located in the Western Desert of Iraq over the years due to the change in precipitation and the various uses during years depending on whether or not the year of drought. Due to the amount of rain it receives during the period, the estimated surface area is small in 2020, so its storage volume is low compared to other years. This information is necessary regarding the management of small dams, and storage estimation. Over time, depending on the time of acquisition of the images and with the introduction of precipitation and disposal of silt, Storage capacities will vary, and therefore benefit from using data to satellites to managing water levels in reservoirs. So a clear picture was drawn of what the reservoirs could carry at any time. Demonstrating this, water can be taken and allocated in larger reservoirs based on the variation of smaller reservoirs.

Note that through measured capabilities, water managers and planners will make rapid decisions about how to manage available water under different competing uses. Hence, from the results of this study, using remotely sensed surface areas it is possible to estimate the storage capacities of small reservoirs of dams. Remote sensing and geographic information systems can be used in this study due to their ability to storage and retrieval the hydrological data needed for planning and developing reservoirs and can measure and analyze the amount of water stored in a small volume reservoir. However, the general estimation of water volume in this study using a GIS procedure was based on a simple relationship dependent on surface area and depth. Instead of measuring all parameters, the GIS technique makes usage of the reduced levels to calculate storage volumes in a way that represents a basin that is emptied over time. This process allows for the estimation of storage changes in water levels over time.
Figure 2. Relationship between volume of storage and number of days for Al-Rutbah dam.

Figure 3. Relationship between volume of storage and number of days for Horan 2 dam.
6. Conclusions

The main limitation is the lack of knowledge of the storage quantities of small dams in the western desert of Iraq and knowing this form of field data regularly is costly and needs a long and arduous time. The integration of GIS and remote sensing data has been developed to estimate small reservoir volumes using remotely sensed surface area. The model equation created by this study provided a tool to know the amount of water available per day in the small reservoirs during the dry season and thus was able to obtain clear pictures of the water
resources system by the planners. It can conclude that the use of satellite images and the obtained small reservoir capacities have a significant effect on water resources planning and management in the basin.

7. Reference

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