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# Estimating a Water Budget by Using Remote Sensing and GIS Technique for the Rabea Basin/Northwest Iraq

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**ABSTRACT**

*A water budget plan is an accounting of water put away inside and water traded among some subset of the compartments, for example, a watershed, a lake, or a spring. Water budget plans give a way to assessing accessibility and maintainability of water gracefully. The object of this search was to estimate water budget in Rabea basin and to know the recharge and discharge in the basin by using GIS and remote sensing techniques. The location of study area is in Nineveh Government (42° 00 '- 43° 00' East, and latitudes 36° 30' - 37°00' North) and covers about 3000 Km². GIS and remote sensing technique were used in research to convert raster formula to vector formula in applied water budget equation. The results included the totals for precipitation (596.98) m/year, actual evapotranspiration (164.84) m/year, surface runoff (98.43) mm. The study revealed the percentage of water surplus from precipitation to be 59.9% while the water deficit was 30.1% when compared to actual evapotranspiration.*

**KEYWORDS**: *Water budget, GIS and Remote sensing, Precipitation, Actual evapotranspiration, Surface runoff, and Soil moisture.*

## INTRODUCTION

Water is the exemplification of life. Its availability where and how animals and plants exist on earth. People necessity water for utilization, for food productions, and for industrial; simultaneously, all other living things on Earth require water for their food. Local plants in meadows and woods; wheat and corn crops in farming fields; creatures of land and water, and birds in wetlands; fish in streams and lakes; wild warm-blooded creatures and reptiles; and tamed pets and domesticated animals—all rely upon water.

Rivalry for water among people and other living things is the unavoidable result of blossoming populaces and a restricted source. Goals of contending needs require choices dependent on science just as cultural qualities. Educated choices are created with a comprehension of the hydrologic cycle—the procedure by which water moves from the air to land surface as precipitation, penetrating the subsurface or streaming along land surface to the seas, and in the long run coming back to the climate by evaporation. All water on Earth lives in one of the three compartments of the hydrologic cycle: the climate, the land surface, and the groundwater.

Groundwater plays a crucial role to the society and the nation as a whole. Therefore, evaluation of groundwater resources requires

a detailed study on the occurrence and behavior of groundwater. Understanding of groundwater behavior is also important for the proper management of this precious resource. This can be studied through careful monitoring of spatial and temporal variability of depth to water level, seasonal fluctuations of groundwater level, movement and flow pattern of groundwater etc. (Kataki, 2020).

A water budget is an accounting of water stored within and water exchanged among some subset of the compartments, such as a watershed, a lake, or an aquifer. Water budgets provide a means for evaluating availability and sustainability of a water supply. A water spending plan just expresses that the pace of progress in water put away in a zone, for example, a watershed, is adjusted by the rate at which water streams into and out of the territory. A comprehension of water spending plans and hidden hydrologic forms gives an establishment to successful water-asset and ecological arranging and management. Watched changes in water financial plans of a zone after some time can be utilized to survey the impacts of atmosphere inconstancy and human exercises on water assets. Correlation of water spending plans from various regions permits the impacts of components, for example, topography, soils, vegetation, and land use on the hydrologic cycle to be evaluated.

Human actions influence the normal hydrologic cycle from numerous points of view. Adjustments of the land to oblige agriculture, for example, establishment of seepage and water system frameworks, modify invasion, spillover, dissipation, and plant transpiration rates. Structures, streets, and parking garages in urban zones will in general increment spillover and abatement invasion. Dams decrease flooding in numerous territories. Water financial plans give a premise to evaluating how a characteristic or human-incited change in one piece of the hydrologic cycle may influence different parts of the cycle. Water financial plans as establishments for viable water-assets and natural administration of freshwater hydrologic frameworks. Maybe of most enthusiasm to the hydrologic network, the ideas introduced are additionally applicable to the fields of farming, environmental examinations, meteorology, climatology, nature, limnology, mining, water flexibly, flood control, repository the board, wetland studies, contamination control, and different zones of science, society, and industry. (Healy, et al. 2007).

## LOCATIONOF STUDYAREA

Rabea basin is located in the Northwest IRAQ. In Nineveh Government with longitudes 42° 00'- 43°00' East, and latitudes 36°30' - 37°00' North , it covers about (3000) $Km^2$, bounded from the north and east by Tigris River from the west by the Iraqi / Syrian boundary, from the south Sinjar, Ashkft, Sasan and Alkasir anticlines; Topographically the basin is almost flat surrounded by the anticlines, the highest elevation of the area is 525 asl, and the lowest elevation is 250 asl, the most valleys gathered and drained its water in main valley which is locally named Al_Murr Valley (Figure 1).

## OBJECTIVE OF STUDY

The object of this study was to estimate water budget in Rabea basin and to know the recharge and discharge in the basin by using remote sensing and GIS techniques.

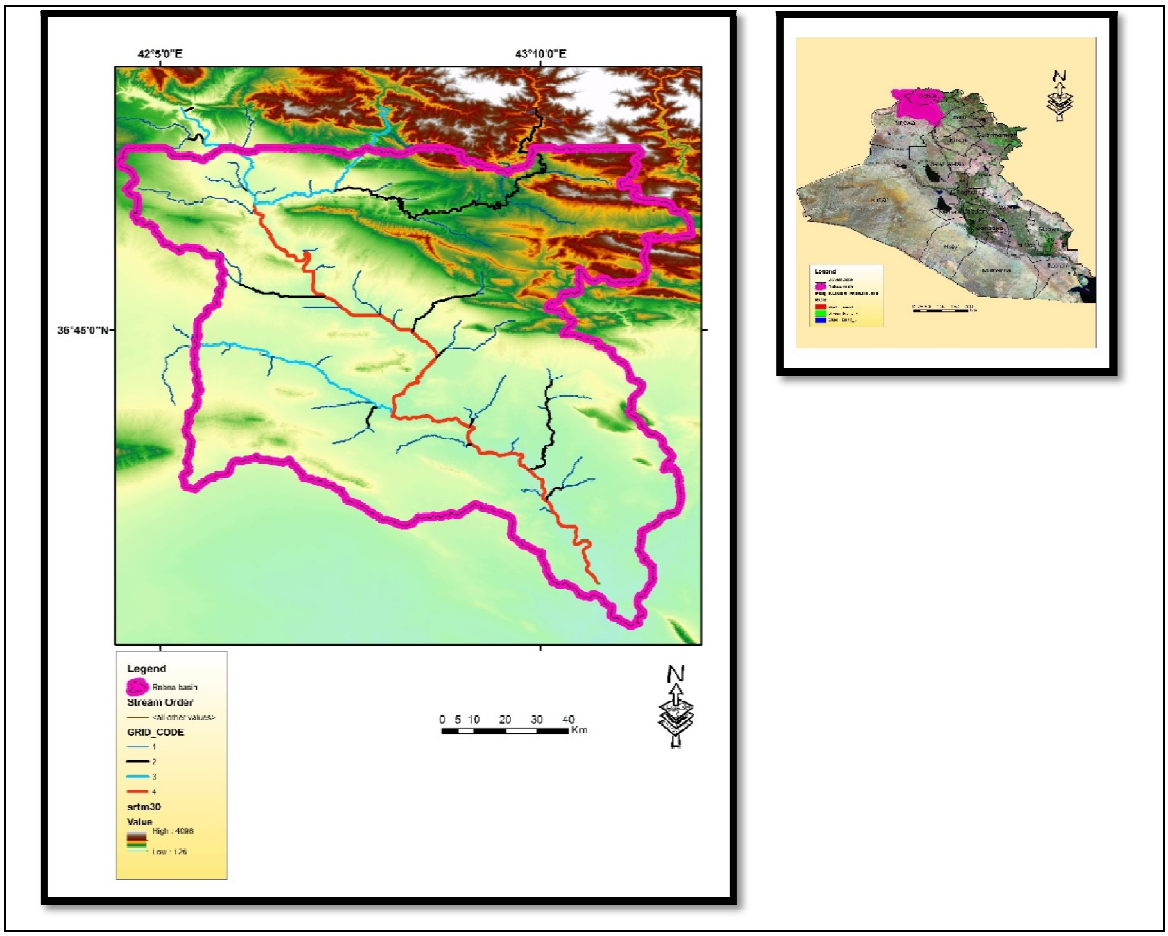


**Figure 1: Area of study region**

## PREVIOUSSTUDIESAND RESEARCHES

Rabeabasin, in general, has undergone many geological, hydrogeological, and soil studies as well as evapotranspiration studies that can be briefly reviewed: -

### Hydrogeological Studies

- Parsons study, 1957, which included a general survey of groundwater resources focusing on the geological and hydrogeological status of the area.
- Ingra studies, 1967, in which its final report / Part Two / Mosul Lewa that 14 wells were drilled within the project area.
- The study of Al-Jawyad and Hawa, SadiqBaqir, Abd al-IlahJamil, 1982/ a hydrogeological study of the Rabea area, which is an evaluation of the renewable resources of groundwater from the confined and semi-confined aquifer of the Rabea Plain using field-collected hydrogeological and climatic data prevailing in the region.
- Hydrogeological investigations of the section 8 / Rabea project / 1989 / study carried out by the groundwater ground water department in Al-Furat State Company for studies and structures of water system ventures. The study included drilling many of exploration wells for the Rabea basin area and doing pumping test operation for wells. Then evaluation G groundwater sources and areas encouraging for investments.
- A study carried out by the Groundwater Department for studies and designs of

irrigation projects on the reasons for high concentrations of salts in the unconfined aquifer in Rabea plain, 1992, and from the results of this study is that the unconfined aquifer in Rabea plain the depth to water near to the surface and it reach 1.65 Meters, which makes it vulnerable to evaporation in the summer and washing in the winter.

**Soil Survey Studies**

- Al-Nifestudy (2016), Aiserabed Al-Azez, (2007), Groundwater uses evaluation for irrigation of a part of Al- Jazerah irrigation project north part in Rabeaarea, the highest affected areas were found to be located at the second irrigation stage area were the classical irrigation method is used.

**Evapotranspiration Studies**

No local evapotranspiration can be found regarding actual evapotranspiration (ETa), but there are many global can be found mention some.

- "Senay, et al. (2013). Operational Evapotranspiration Mapping Using Remote Sensing and Weather Dataset, he used a new technique depends on the Simplified Surface Energy Balance (SSEB) model, which is presently defined for operational applications, renamed as SSEBop. The inventive part of the SSEBop is that it utilizes predefined limit conditions that are one of a kind to every pixel for the "hot" and "cold" reference conditions. The SSEBop model was utilized for processing ET. Utilizing the MODIS and Global Data Assimilation System (GDAS) information streams".
- "Senay, et al. (2019). Long-Term (1986–2015) Crop Water Use Characterization over the Upper Rio Grande Basin of United States and Mexico Using Landsat-Based Evapotranspiration, they conclude that the rich document of Landsat archive joined with the Operational Simplified Surface Energy Balance (SSEBop) model was utilized to gauge map ETa over inundated fields for recorded portrayal of water-use elements".

## MATERIALS AND METHODS

In this research Digital Elevation Model (DEM) with 30 m resolution, Precipitation raster for annual 2018 were collected, Evapotranspiration raster for 2018, soil moisture raster image for 2018 as well as geological map 1:1000000 is used to examination and extraction of seepage systems. Arc GIS 10. Excel software's were utilized to get special maps.

## RESULTS

Water request is expanding a result of environmental change and quick populace development (Schewe et al., 2014). Iraq is a rural nation wherein the interest for water has been developing for increasingly agrarian creation to ensure food security. The primary irrigation of water system is streams. Adjusted water balance is the procedure whereby water transitions (Actual ET, precipitation, groundwater revives, surface and subsurface overflow) and capacity changes (soil–water stockpiling changes, and supply stockpiling changes) are adjusted in a given hydrological basin (watershed). The technique is otherwise called the inflow–outpouring or mass parity approach; it tends to be applied overlarge coordinated zones that comprise of water and diverse land spread sorts (Allen et al., 2011).

The computation should be possible at any scale (hours to years) and any spatial scale (plots to enormous watersheds) at which the transitions and capacity changes are known. Basin water adjusts can be lumped by considering the entire area as a unit or appropriated by computing the water balance at the degree of sub-units of the basin. The water balance condition for basin under characteristic conditions is settled for actual evapotranspiration ET from the accompanying water balance condition. (Senay, et al., 2011).

$P - ET - Q = \Delta\Theta$ --------1

Where
P= Precipitation
ET=Evapotranspiration
Q = River Flow
$\Delta\Theta$ is a change in water storage.

**Precipitation (P)**

The term precipitation signifies all types of water that arrive at the earth from the climate. The typical structures are precipitation, snow fall, hail, timberland and dew, of all these, lone the initial two contribute huge measures of water, precipitation being the transcendent from of interest causing stream (Subramanya, 2008).

Precipitation raster images were supply from (https://giovanni.gsfc.nasa.gov/giovanni/). For the year 2018 and processed in Arc GIS to get the results of sum (596.98) as in Figure 2.

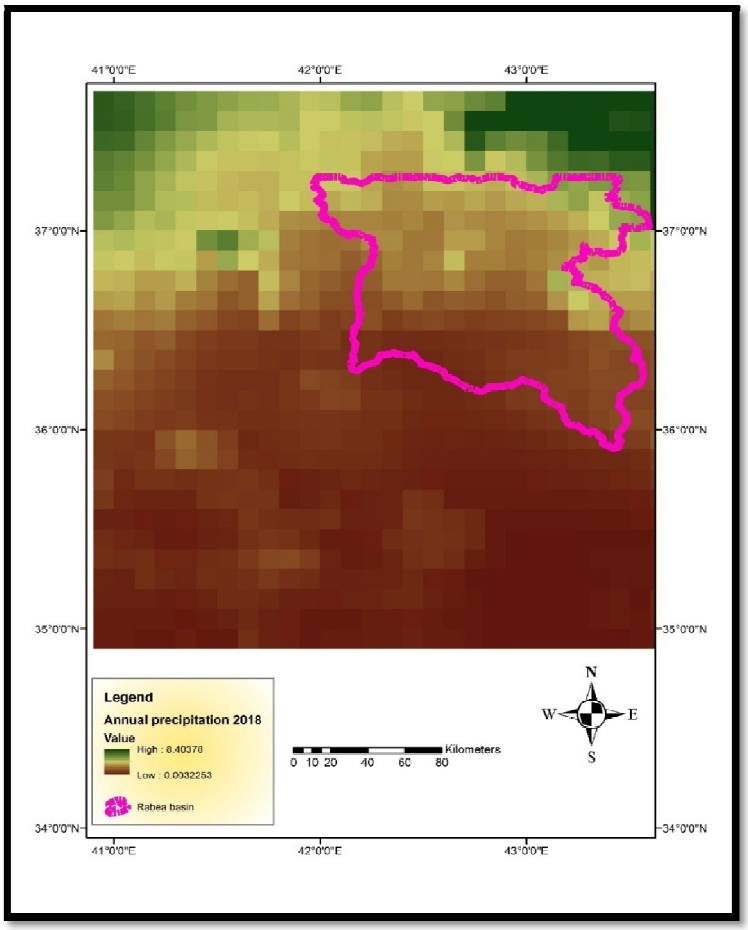


**Figure 2: Annual precipitation for Rabea basin 2018**

**Actual Evapotranspiration (PEc)**

Remote sensing-based evapotranspiration (PEc) can be inferred utilizing different strategies, from soil wetness compute to vegetation-indicator based ways to deal with straightforward and complex surface vitality balance procedures. Because of the intricacy of completely speaking to and defining PEc sub-forms, various models will in general wander in their estimations. Nonetheless, most models seem to give sensible estimations that can meet client prerequisites for occasional water use estimation and dry season observing. Notices a portion of these models are the Operational Simplified Surface Energy Balance (SSEBop), Mapping Evapotranspiration at High Resolution with Internalized Calibration (METRIC), and Surface Energy Balances Algorithm for Land (SEBAL). (Senay, 2013). The raster picture was utilized from https://earlywarning.usgs.gov/fews. And we get the raster for annually 2018 for modis satelliteprocessed in Arc GIS to get the results of sum (164.84) as in figure 3.

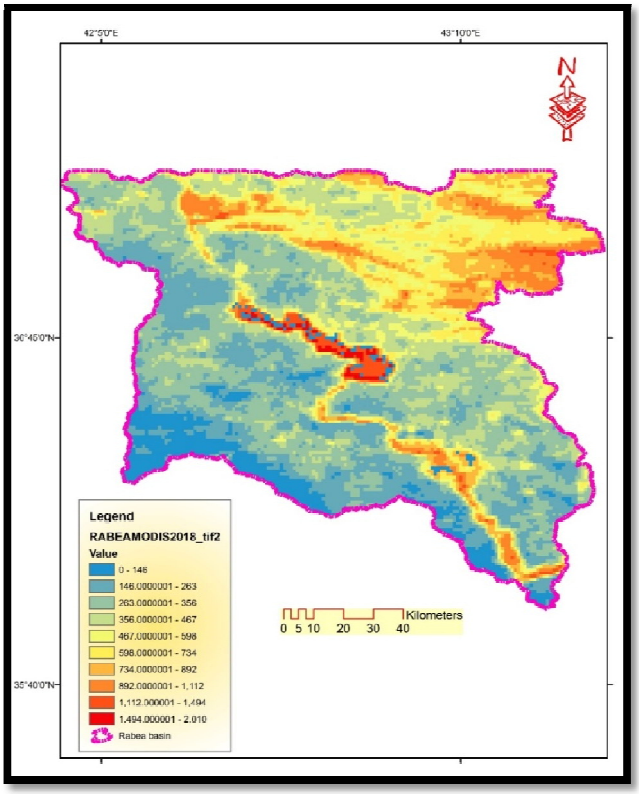


**Figure 3: Annual ET modis satellite for Rabea basin 2018**

**Surface Runoff**

That piece of the precipitation, snow liquefy, or water system water that shows up in uncontrolled (not managed by a dam upstream) surface streams, waterways, channels or sewers. Overflow might be grouped by speed of appearance after precipitation or dissolving snow as immediate spillover or base overflow, and as per source as surface spillover, storm interflow, or groundwater spillover. The surface runoff which realized from Water Surplus in the study area was calculated using the following mathematical formula (Dandekar & Sharma, 1989):

$R_\circ = (P-17.8)\, P / 254$ ..... (2)

P=Rainfall (cm)

$R_\circ$=Runoff

By applying the equation above, the surface runoff is (98.43) mm.

**Soil Moisture (SM)**

Soil dampness content is characterized as the water that might be vanished from soil by warming at 105°C for a steady weight. The decision of as far as possible is discretionary, and clayey soils hold an impressive amount of water at this temperature. Water in the soil is held by the powers of union and bond in which surface strain, capillarity, and osmotic weight assume a critical job. There are two sorts of powers following up on soil wetness. Positive powers are those that improve soil's partiality for water (e.g., powers of attachment and bond), while interestingly, some negative powers that remove water from soil incorporate gravity, effectively developing plant roots, and evaporative interest of the air. (Dekker, 2004), Soil moisture raster images was supply from (https://giovanni.gsfc.nasa.gov/giovanni/). For the year 2018 and processed in Arc GIS to get the results of sum (74.66) as in Figure 4.

The soil moisture (SM) of the top soil in the Rabea basin equal (74.66) mm, therefore, the equations (3) and (4) will be as follow:

WS=P-PEc-SM: P>PEc…….…….. (3)

WD=PEc+SM-P: P <PEc …….…... (4)

WS= Water Surplus

WD= Water Deficit

In this case (P >PEc)

Then

WS= 596.89 – 164.84 -74.66

= 357.39mm

Then the Water Surplus is (357.39) mm. This Water Surplus divides to runoff and groundwater recharge. Surface runoff equal (98.43) mm its percentage from rainfall equal 16.5%, and the groundwater recharge is (258.96) mm, and its percentage of rainfall equal 43.4%. In general, the percentage of water surplus from rainfall is equal 59.9% and water deficit is equal 30.1% through evapotranspiration.

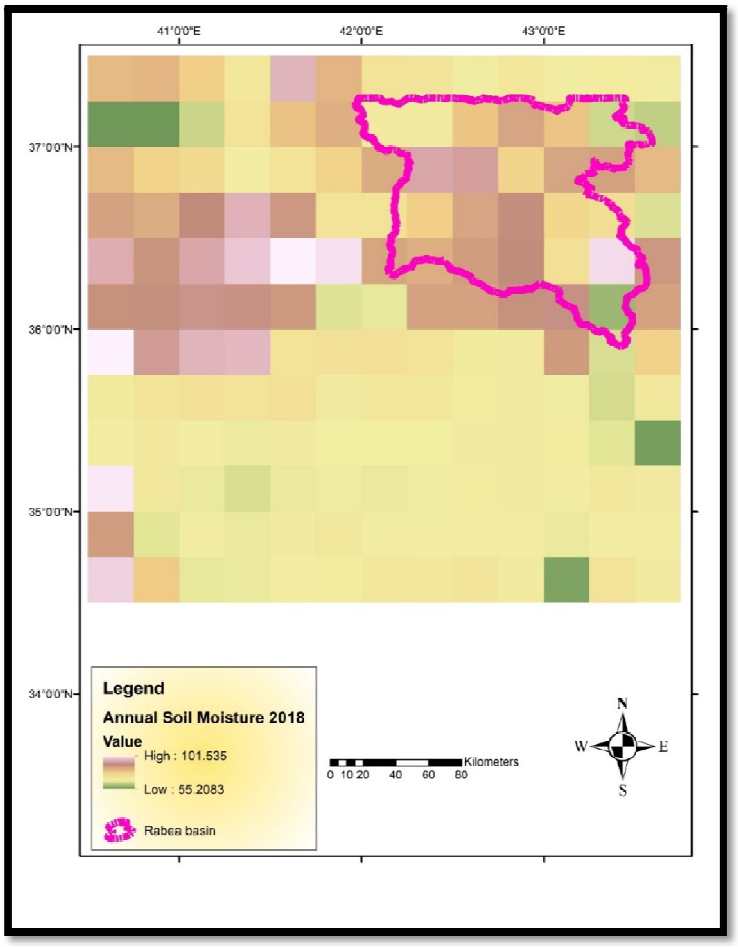


**Figure 4: Annual Soil moisture satellite for Rabea basin 2018**

## DISCUSSION AND CONCLUSIONS

The hydrogeological situation has been affected by two main factors (Al-Jawyad, et al, 2008), namely the prevailing and previous climatic conditions; the geological situation represented by stratification of the sedimentary column and the structural geology which containmany articular areas that connect these different systems of joints and faults (Al-Saedi, 2020).

Most hydrological studies include field data such as wells data and field visits. The current study uses remote sensing and GIS technique to calculate water budget in Rabea basin. This approach is very vital to improve accuracy and processing time of results and can be used

for not only one year, but for a longer time series, as long as datasets are available. The approach was compared with results from a recent study by Al-Nife (2016) for Rabea basin and it shows semi-identical results. All the raster's used in the study obtained from different reliable satellite images, all the raster's was processed in the environments of Arc GIS with precipitations 596.89 mm, the Actual Evapotranspiration 164.84 mm/year as well as Soil Moisture (SM) was 74.66 mm, While Al-Nife study the recipitations equal 365.5 mm, the Actual Evapotranspiration 151.93 mm and Soil Moisture (SM) equal 82.35 mm. The increase of precipitations lead to an increase of water surplus and then increase of runoff and groundwater recharge.

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