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Estimation Of Surface Water Budget Using Geospatial Technique: Gravity Based, Imaging Spectroradiometer Satellite And Surface Observation Data

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Abstract: Present study has been carried out to determine the surface water discharge volume for entire India using the fundamental water budget equation. Population growth and economic development have impacted the capacity of water resources to meet demands in a number of arid countries. As far as India is concerned, irregular rainfall, high rate of population growth and unscientific/non sustainable agricultural practices are resulting in a dramatic depletion of groundwater resources. The components of the water budget are obtained from documented information and remote sensing data, using Gravity Recovery and Climate Experiment (GRACE) satellites to estimate changes in terrestrial water storage (TWS) and GIOVANNI (Geospatial Interactive Online Visualization and analysis Infrastructure) visualization interface, MODIS (Moderate resolution Imaging Spectroradiometer) satellite data to obtain precipitation (PPT) and evapotranspiration (ET) respectively. All thematic maps that influence water budgeting were processed and statistically analysed in QGIS. This study was conducted for the year 2021 and divided into pre and post monsoon season. The result shows major variations in the approximate seasonal discharge (in BCM) for both the seasons. Thus, the above analysis clearly demonstrated the capabilities of Remote Sensing and GIS technique in calculating the seasonal water budgeting. Recommendations for further research of the terrestrial water monitoring based on GRACE data are also suggested.

Index Terms: **Water Budget, GRACE, GIOVANNI, MODIS, QGIS, Imaging Spectroradiometer, Evapotranspiration.**

I. INTRODUCTION

The atmosphere receives water through evaporation and loses it as precipitation; mostly in the form of rain or snow. The average residence time for water in the atmosphere is about 10 days Some rainfall never reaches land surface; instead, it evaporates as it falls and returns to the atmospheric reservoir **[1]**. The average residence time for water in free-flowing rivers ranges between 16 and 26 days. Streams that run through reservoirs can have substantially longer residence times. Not all surface water flows to oceans. Some lakes and wetlands have no surface drainage. It losses water into evaporation and to groundwater. Water moves much more slowly in the subsurface than in the atmosphere or on land surface. Water that infiltrates the subsurface can remain in the unsaturated zone where it will most likely be returned to the atmosphere by evaporation or plant transpiration.

The water budget equation describes the exchange of water between the land, ocean and atmosphere. It accounts for rate of water movement and change in water storage in all parts of atmosphere, land surface and sub-surface. The advances in observation techniques: satellite sensors, a number of data products are available that represent the components of water budget both in space and time **[2]**. An understanding of water budgets and underlying hydrologic processes provides a foundation for effective water-resource and environmental planning and management.

Observed changes in water budgets of an area overtime can be used to assess the effects of weather and climate variability, human activities, rock type, geological structures and other geological factors on water resources. Slightly different approach that serves the study objective has been selected which upholds the originality of the water budget equation:

$$\Delta S_W = PPT - ET - TWSC$$

Here, ΔS_W is the change in surface water storage, P is precipitation, ET is the evapotranspiration and TWSC is the terrestrial water storage change from GRACE.

1.1 STUDY AREA

India is situated between 8°4' N to 37°6' N latitude and 68°7' E to 97°25' E longitude with a total area of 3,287,590 square kilometers. The southwest monsoon is most intense and brings abundant rains in most part of the country and some areas are affected by the retreating monsoon in the later part of the year **[4]**. The mean air temperature in 2021 was 0.44° C above normal. Also, the country last year witnessed a rise in the annual rainfall, which was 105% of its last 50 years average.

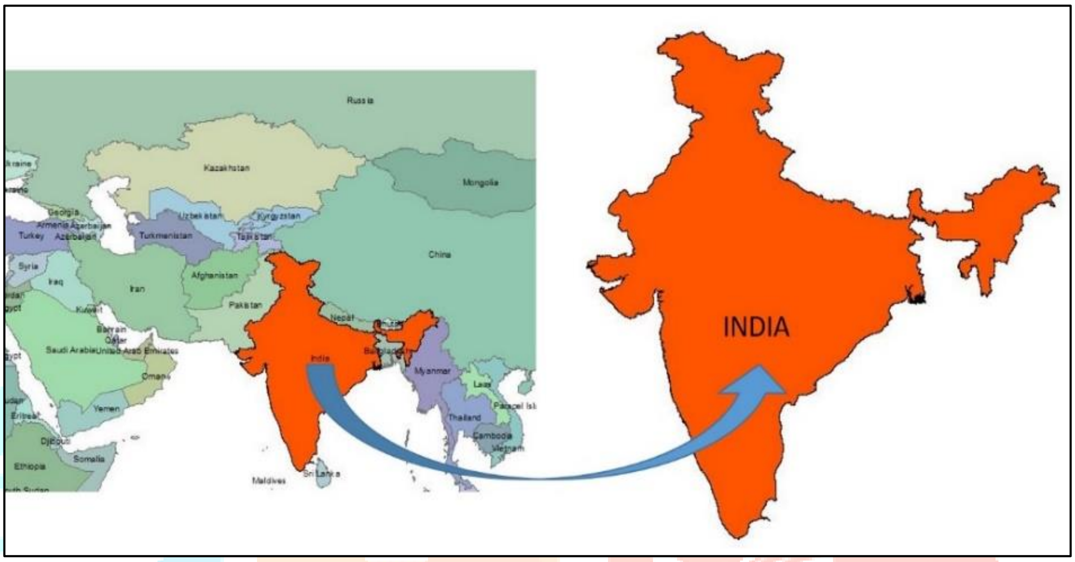


Fig 1. Study Area

II. RESEARCH METHODOLOGY

2.1 Data sets and Processing Platform:

GRACE: GRACE gravity satellite program was jointly developed by the National Aeronautics and Space Administration (NASA) of the United States and the German Aerospace Centre (DLR) with the objective of providing spatiotemporal variations of the Earth's gravity field. Terrestrial Water Storage is the most direct hydrological parameter obtained by GRACE monitoring. The main goal of GRACE satellite is to monitor the Earth's gravity field variations; early researches were focused on the feasibility and accuracy of TWS retrieval from GRACE data. This GRACE data is available monthly in 1° grid and .tif format.

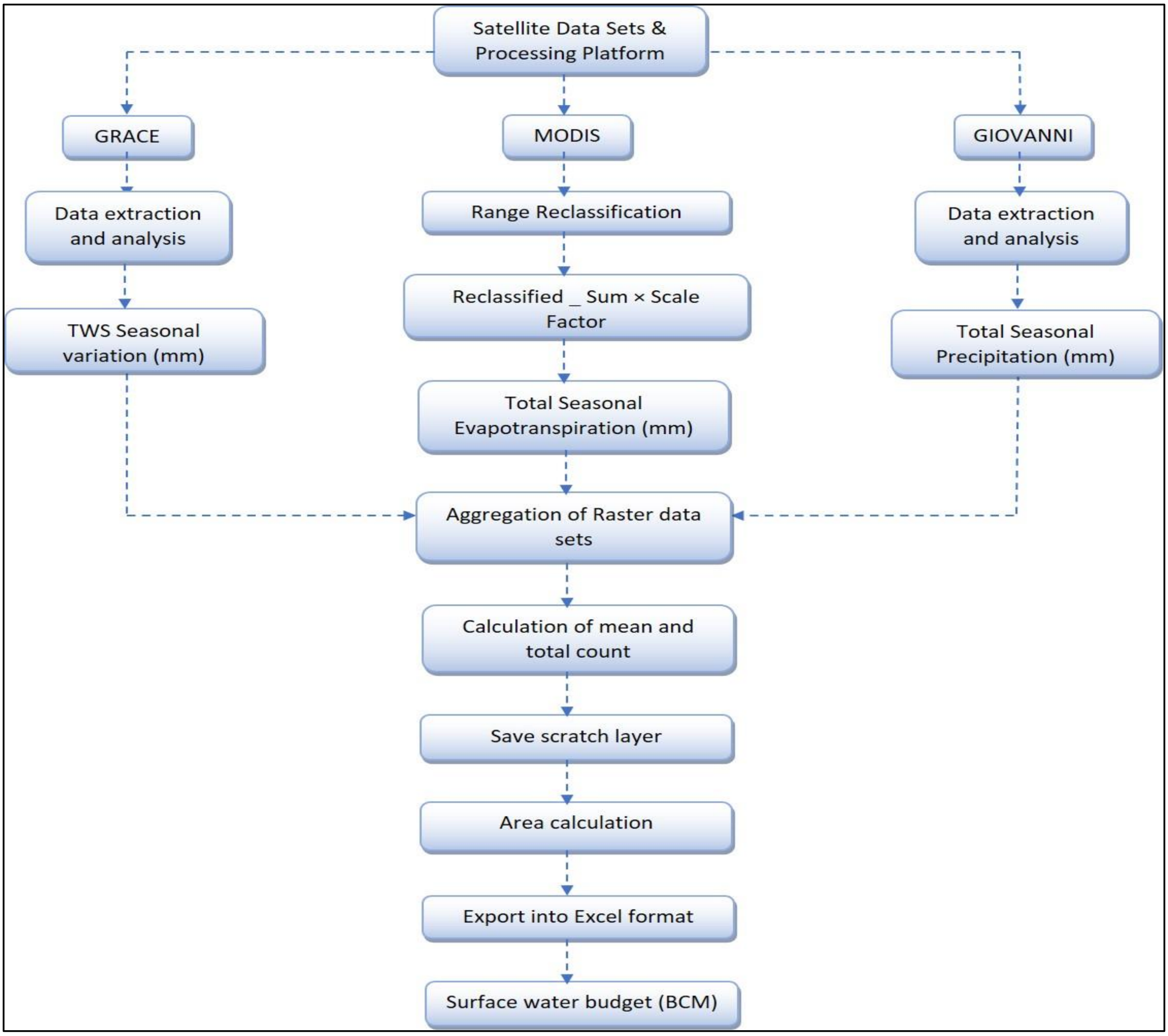
MODIS: This project is part of NASA/EOS project to estimate global terrestrial evapotranspiration from earth land surface by using satellite remote sensing data. The product to be used is MOD16A2 level 4 data from TERRA instrument. The spatial resolution of this data is 500m and temporal resolution is 8 days. It includes evaporation from wet and moist soil, evaporation from rainwater intercepted by the canopy before it reaches the ground, and the transpiration through stomata on plant leaves and stems.

GIOVANNI: It is a web interface that facilitates to explore and analyses global Earth science data: NASA's gridded data from various satellite and surface observations. In the context of our study, we are using the Global Precipitation Measurement (GPM) mission product. The product used is the Merged satellite- gauge precipitation estimate (GPM_3IMERGM v06). The temporal resolution of this dataset is one month and spatial resolution is 0.1°. The unit for this data is mm/month.

2.2 Processing of data

After downloading all the datasets, we have to processed them separately in GIS environment. In our study, we are using QGIS for all the processing and calculations. Firstly, for GRACE data, we have to clip the global dataset according to our study area and determine the seasonal change value using Raster calculator for both pre and post monsoon period. The difference is then converted into mm. For ET data, the Modis dataset needs to be reclassified under 'Reclassify values(range)' and the resultant reclassified grid data is saved in .sdat file format. The final data needs to be multiplied by the scale factor as well. For precipitation data, GIOVANNI data set is to be clipped for the study area and used in further processing.

All three dataset needs to be processed under the 'Zonal Statistics' tool in QGIS. It allows to calculate several values of the pixels of a raster layer with the help of a polygonal vector layer. This plugin generates output columns in the vector layer with a user-defined prefix and calculates for each polygon, statistics on pixels that are within. It creates additional fields in the vector layer using a user-defined prefix to hold the calculated statistics which include the minimum value, maximum value, mean value, count, and sum. The area is calculated of the study area using the field calculator. The attributes of this layer are exported in csv format for estimating the water budget. The output values are converted in billion cubic meters (BCM).



Workflow Diagram

2.3 Thematic Maps

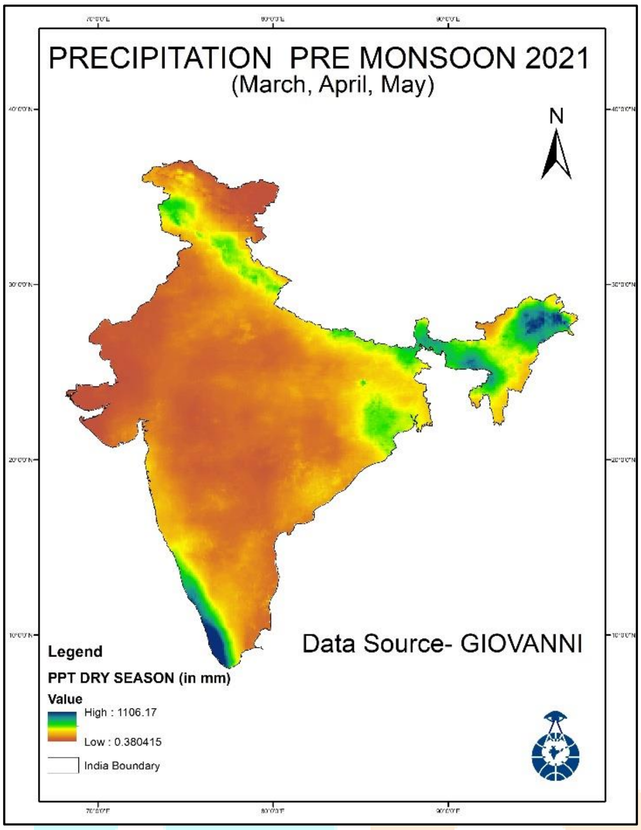


Fig. 2 Precipitation Pre-Monsoon

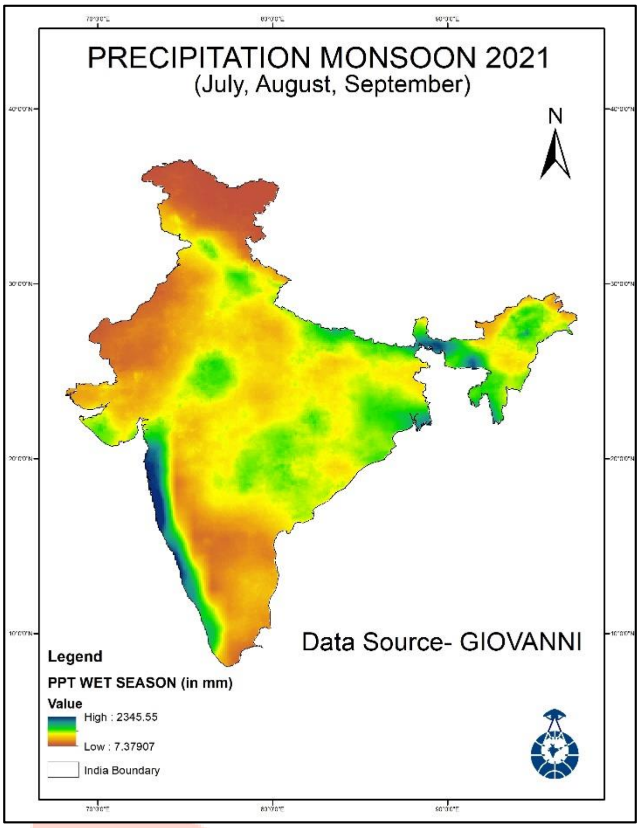


Fig. 3 Precipitation Post-Monsoon

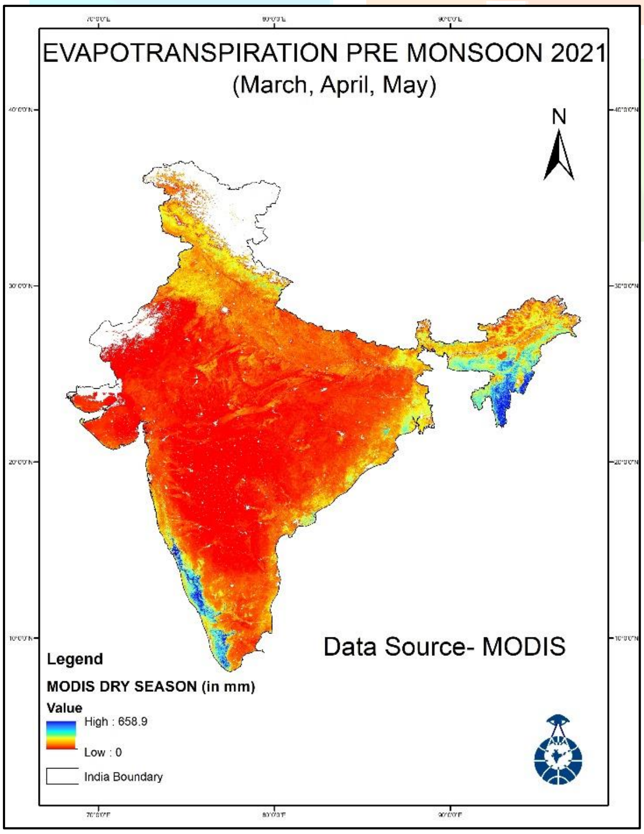


Fig. 4 Evapotranspiration Pre-Monsoon

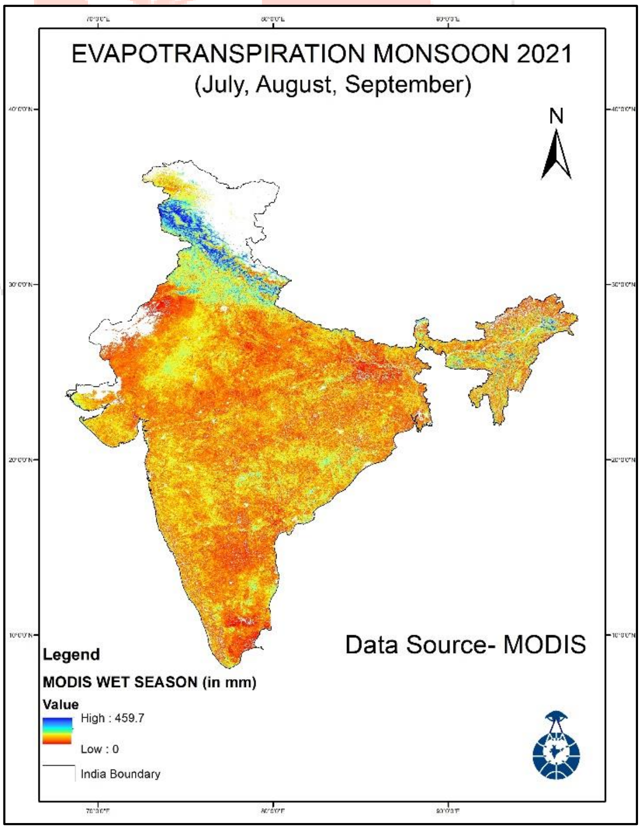


Fig. 5 Evapotranspiration Post-Monsoon

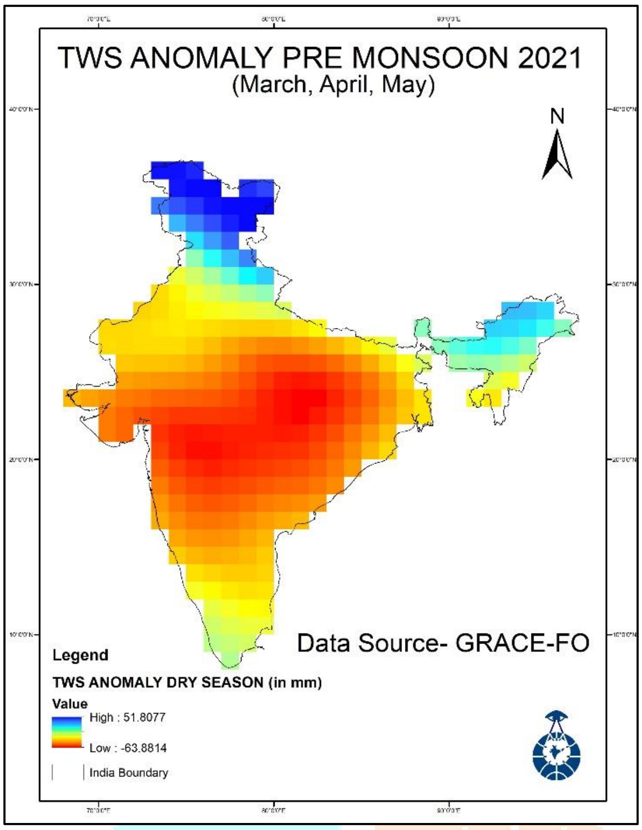


Fig. 6 TWS Anomaly Pre Monsoon

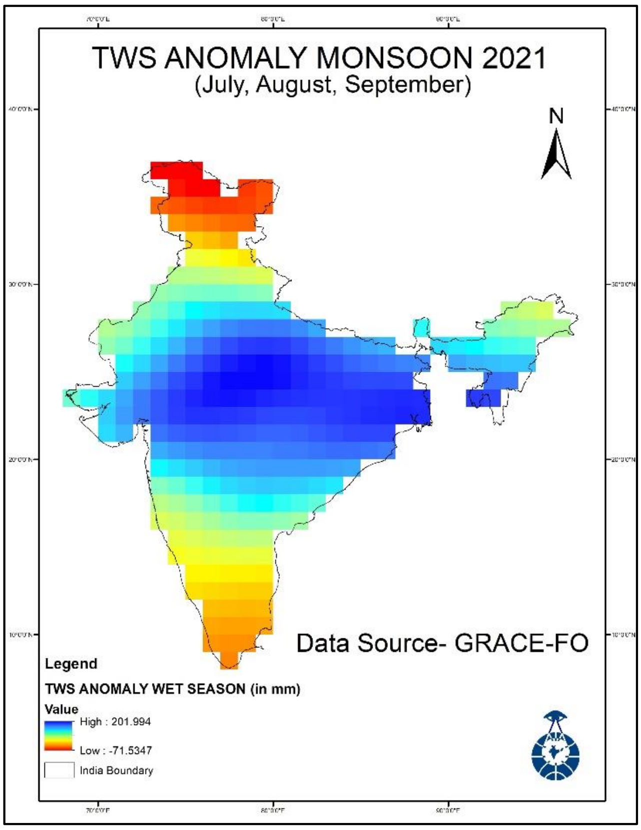


Fig. 7 TWS Anomaly Post Monsoon

III RESULTS AND DISCUSSION

3.1 Results of statistics derived from GIS environment

Table 3.1: Descriptive Statistics

Area (km^2)	PPT dry (BCM)	PPT wet (BCM)	ET dry (BCM)	ET wet (BCM)	TWS dry (BCM)	TWS wet (BCM)
3,287,590	520.9520	2265.6004	186.9490	253.5518	-102.0203	357.0545

Table 1

Table 3.2: Calculation based on statistics derived from satellite datasets

Surface Water Budget (ΔS_W = PPT- ET-TWS) (in BCM)	
Surface Water Budget DRY	436.0233
Surface Water Budget WET	1654.9940

Table 2

The values generated of Precipitation for Dry season ranges from 0.3 to 1106 mm and for Wet season it ranges from 7 to 2345 mm. For evapotranspiration, the value for Dry season ranges from 0 to 658 mm and for Wet season, it ranges from 0 to 459 mm. The TWS anomaly for pre monsoon period ranges from -63 to 51 mm and for Post monsoon period, it ranges from -71 to 201 mm. After estimating the groundwater component, the second step focuses on the water budget equation itself. All water inputs are introduced in the equation and the evapotranspiration is estimated from it. The surface water budget estimated for dry and wet season in the year 2021 are approximately 436 and 1654 BCM respectively. The purpose of the study was to quantify the surface water storage and to assess the effects of both human and natural stressors on water resources. This study has provided an enhanced understanding of the water budget components in the India and may serve as a base for future studies in the region. Further research might investigate new ways of modelling these water inputs and outputs and how to account them in the water budget.

In this study, the efforts are put to assess the components of the water budget and gain better understanding of the availability of water resources in the India. We have also presented a new estimate of the water budget, with the main terms computed from recent data, including precipitation over land, evapotranspiration data and gravity anomaly data **[6]**. These values depend somewhat on the period used for the data, and hence the challenge is to be able to compute this monthly, or more often, for river basins and watersheds. The assessments of socio-hydro inter-linkages through the analysis of remotely sensed data have proven to be effective in this research. This study also demonstrated the benefits of remote sensing approaches in quantifying groundwater variability. All together the study concedes that although the results are restricted to theoretical stances, there is an advancement in understanding socio-hydrological linkages through this approach and can be used in other catchments or large study areas.

IV. ACKNOWLEDGMENT

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