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Research Paper

Characterization of Biophysical Parameters of South Bihar using Satellite data

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ABSTRACT

In the present research work, an attempt has been made to characterize the biophysical parameters in the South Bihar region of eastern India using remotely sensed data and GIS techniques to understand the terrain conditions. The Landsat-8 satellite images has been used to measure vegetation cover, soil moisture, surface water and hydrogeomorphological parameters of the terrain and their conditions. All the terrain parameters were classified using the standard band combination to create the Indices which shown the density of land use/ land cover along with field hydrological and meteorological data to understand the rainfall distribution of the region. The primary findings from the present work shown important characters and distribution of all the biophysical parameters such NDVI, NDWI, NDMI , SAVI and rainfall provides very important information about the terrain for further detail investigation to see the long term impact if natural and manmade activity on climate and natural resources of the region.

Keywords: Characterization, Biophysical Parameters, GIS, Satellite images.

INTRODUCTION

Over the past three decades, land use and land cover changes have been recognized as one of the prominent driving forces to understanding global environmental changes, which explains the importance of characterization of biophysical parameters using satellite images in the present time. The characterization of biophysical parameters helps in the analysis of their potential, problems and stress environment to plan and execute site-specific landscape, agricultural, and irrigation management practices and maximize the productivity from each biophysical parameter (Reddy and Maji, 2004). The estimation of the biophysical attribute is of great importance nowadays because it plays a significant role in global climate change and ecosystem dynamics. Reliable information on biophysical units at river basin level with respect to their nature, extent, spatial distribution, potential and limitations is very useful for evaluation and optimal utilization of natural resources. Knowledge of the landforms and their groundwater prospects will improve our understanding of the biophysical processes. Apart from the other terrain features, the vegetative cover and their spatial distribution are considered to be important parameters in the analysis of environmental and biophysical processes (Anderson et al., 1976). The world's climate is changing and will continue to change into the coming century at rates projected to be unprecedented in recent human history. The risks associated with these changes are real but highly uncertain. Societal vulnerability to the risks associated with climate change may exacerbate ongoing social and economic challenges, particularly for those parts of societies dependent on resources that are sensitive to changes in climate. Risks are apparent in agriculture, fisheries and many other components that constitute the livelihood of rural populations in developing countries (Adger et al., 2003). Fluctuations or variations in climatic parameters are a recurring phenomenon in India. The effects of climate variability exacerbate existing social and economic encounters across the area. Over the last 115 years, the rainfall patterns in India have changed significantly. The most significant change is the shifting of the monsoon season altogether. It has been noted that the Sikkim region observed drastic rainfall pattern changes after 2001, because of which there was an increase in disasters like landslides and floods (Kakkar et al., 2022). Remotely sensed data is now commonly used for systematic analysis of various lithological, geomorphological, soil, hydrological and land use/land cover characteristics following the synoptic and multi-spectral coverage of a terrain (Saraf and Choudhary, 1998). A transformation technique is presented to minimize soil brightness influences from spectral vegetation indices involving red and near-infrared (NIR) wavelengths. Graphically, the transformation involves a shifting of the origin of reflectance spectra plotted in NIR-red wavelength space to account for first-order soil-vegetation interactions and differential red and NIR flux extinction through vegetated canopies. The SAVI was found to be an important step toward the establishment of simple "global" models that can describe dynamic soil-vegetation systems from remotely sensed data (Huete, 1988). The biophysical processes are interactions of climate, relief, landforms, water, soils and land use/land cover characteristics of the earth's surface (Baban and Yusof, 2002). The present study demonstrates that the generation of geo-spatial databases based on remotely sensed data in GIS and their analysis helps great extent in the characterization of biophysical land units and analysis of their stress environment for management for South Bihar in India. The study aims to evaluate the biophysical connections between vegetation, soil, water bodies and remotely sensed indices derived from Landsat 8 imagery (March-May 2021) and shall explore several socio-cultural characteristics, environmental conditions and human-environment relationships.

MATERIALS AND METHODS

STUDY AREA

The South Bihar region is located in eastern India in Bihar state and comprises 17 districts. The population of the South Bihar region is 38,551,925 as per details from the 2011 Census. The geographical area of this region is 41828 km^2. South Bihar region lies in-between the coordinate's 24°30′00″–25°30′00″N latitude and 83°62′00″–87°30′00″E longitude, located between Kaimur district in the West to Banka in the East. The region is bounded by West Bengal on the East, Jharkhand on the South, Uttar Pradesh on the West and North

Bihar region on the North. The main rivers are the Son River and the Ganges, supplying most of the water to the region and other rivers are mostly seasonal, water flows during the monsoon period. A major part of the land is flat with some mountains in the southern part. The soil is mainly young loamy and portrays an undulating topography. In terms of climatic conditions, Bihar embodies the general climatic pattern of the Indian sub-continent, which is sub-tropical. The soil is deficient in phosphoric acid, nitrogen and humus, but potash and lime are usually present in sufficient quantity.

The main source of income of this state is through agriculture, following rainfed agriculture practices. Bihar is one of the largest producers of fruits and vegetables in the country. Bihar accounts for 71% of India's annual litchi production. Makhana cultivation is done in about 5000 hectares in the entire country and produces 90% of the world's fox nuts. In fruit cultivation, the third largest producer of pineapple, as well as a major producer of mango, banana, and guava. Few Bihari Farmers are turning to strawberry cultivation for better economic returns. Also, the better economic return has attracted the farmers to cultivate Kamalam (dragon fruit). Corrigendum one of the world's costliest crops are now under cultivation in Bihar by a few farmers. The location map of the study area is shown in Fig. 1.

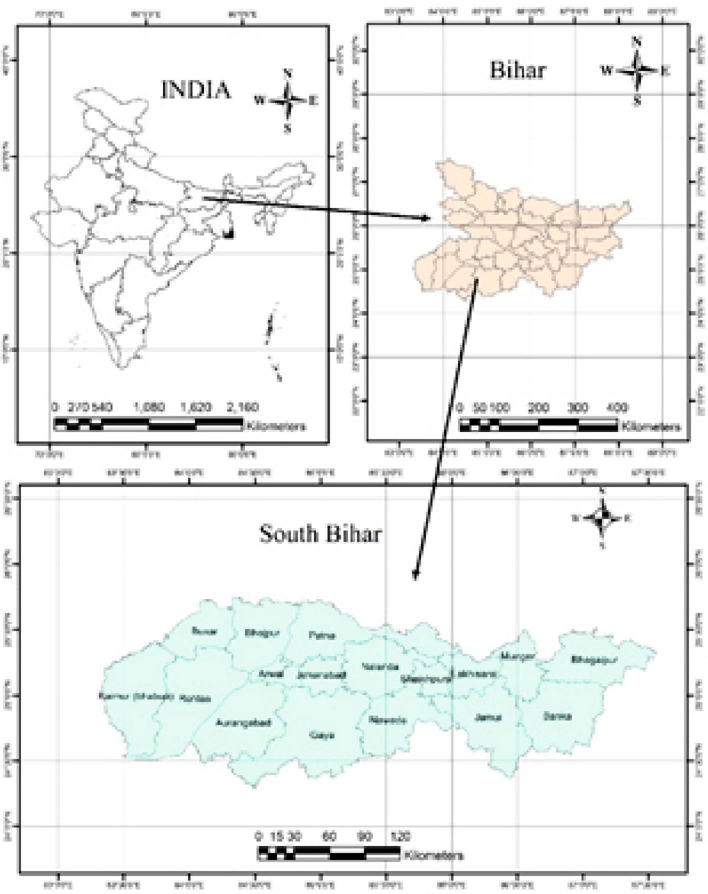

Fig. 1: Location of the Study Area

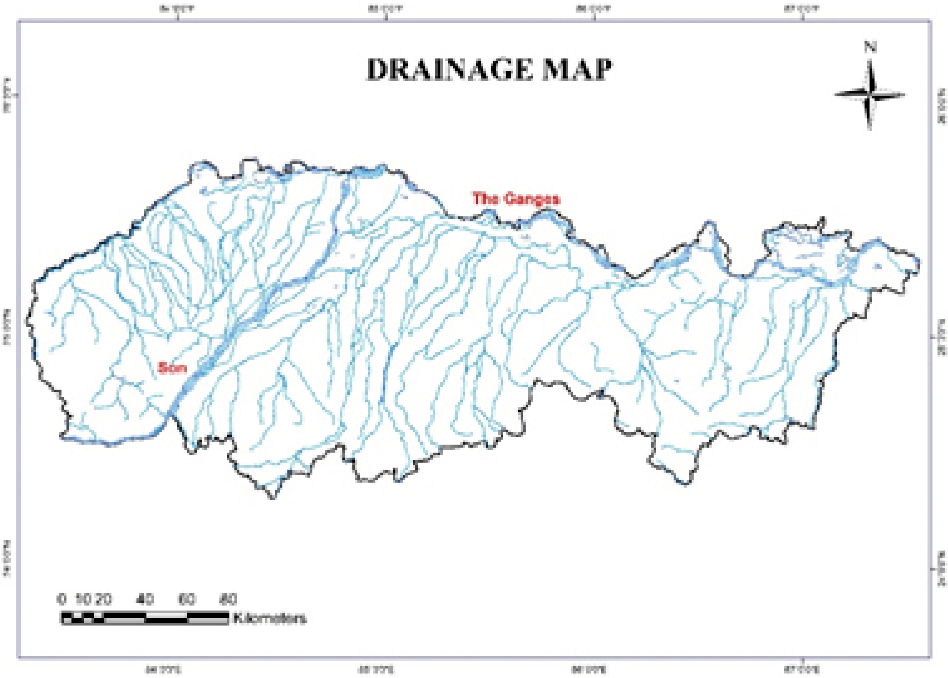

Fig. 2 : Drainage map of the rivers of South Bihar

GENERAL GEOLOGY AND GEOMORPHOLOGY OF SOUTH BIHAR

In the eastern part of India, Bihar is a landlocked state. The geology of Bihar corresponds to the balanced picture of the term geology because it consists of younger (Tertiary Period) and older formations of rock (Pre-Cambrian period), and the plain was formed by filling up of a vast trough by the heavy loads of detritus carried by swiftly flowing rivers down the Southern slopes of newly uplifted Himalayas .The basement succession is Granitic Gneiss of Archean age and the topmost succession is younger alluvium of Gangetic plain. Bihar is divided into three physiographic units based on physical and structural conditions i.e. **Shiwalik Range, Bihar Plain Southern Plateau Region.** The southern plain is narrower than the northern plain of Bihar and triangular because many hills are located in this region such as the hills of Gaya, Rajgir, Giriak, Bihar Sharif, Sheikhpura, Jamalpur and Kharagpur hills. It is located between Kaimur districts in the West to Banka in the East. It is made up of hard rocks like gneiss, schist and granite. This region is blessed with many conical hills which are made up of batholiths like Pretshila, Ramshila and Jethian hills.

DATA USED

To get the terrain information of South Bihar. Various types of primary and secondary data were used for the assessment of biopsychical parameters. In this study, LANDSAT-8 satellite imagery and meteorological data are used to generate the biophysical parameters such as NDVI, NDWI, NDMI, and SAVI. High-resolution gridded datasets were used for calculating average annual rainfall in the study area (Table 1)

Sl. No.	Type of Data	Description	Source	Year
1.	Shape Files	State and District Shape File of India	https://geographicalanalysis.com/gis-blog/download-free-india-shapefile-including-kashmir-and-ladakh/	2021
		Water lines and Water areas	https://www.diva-gis.org/	
2.	Landsat 8	30-meter spatial resolution	https://earthexplorer.usgs.gov/	2021
3.	Geological Data	Regional Geology and Geomorphology of the study area	https://www.gsi.gov.in/webcenter/portal/OCBIS	1970-2018
4.	Rainfall Data	High-resolution gridded datasets	https://crudata.uea.ac.uk/cru/data/hrg/legacy	2011-2020
5.	Population Data	Indian Census	https://www.census2011.co.in/	2011

METHODOLOGY

All the biophysical parameters were generated and reclassified by using classification tools in ArcGIS and ERDAS Imagine software for the characterization of biophysical parameters. Finally the maps were classified for the biophysical parameters of the South Bihar Region. The Flow chart of the methodology is given in Fig. 3. All the parameters were given below sections.

Normalized Difference Vegetation Index (NDVI)

The NDVI indicates vegetation cover information on the land surface and is calculated as a ratio between the Red (R), which vegetation absorbs and Near Infrared (NIR), which vegetation strongly reflects in Landsat 8-9. It is calculated by using the following equation.

$$\text{NDVI} = \frac{\text{Near Infrared (NIR)} - \text{Red (R)}}{\text{Near Infrared (NIR)} + \text{Red (R)}} \quad ....(1)$$

NDVI always ranges from '-1 to +1'. The negative values highly indicate water. The value close to +1, shows the high possibility of dense green leaves. But when NDVI is close to zero, there aren't green leaves and it could even be barren land or an urbanized area (Tucker et al., 2001).

Normalized Difference Water Index (NDWI)

The NDWI is used to highlight open water features in a satellite image. This parameter uses Green and near-infrared bands to calculate values. The NDWI value varies from '-1 to +1' and can be calculated as

$$\text{NDWI} = \frac{\text{Green (G)} - \text{Near Infrared (NIR)}}{\text{Green (G)} + \text{Near Infrared (NIR)}} \quad ...(2)$$

Normalized Difference Water Index (NDWI)

The NDWI is used to highlight open water features in a satellite image. This parameter uses Green and near-infrared bands to calculate values. The NDWI value varies from '-1 to +1' and can be calculated as

$$\text{NDWI} = \frac{\text{Green (G)} - \text{Near Infrared (NIR)}}{\text{Green (G)} + \text{Near Infrared (NIR)}} \quad \ldots(2)$$

Normalized Difference Moisture Index (NDMI)

The NDMI is aimed at investigating the soil moisture content. It is calculated as a ratio between the NIR and SWIR values in the traditional way and is represented as given below.

$$\text{NDMI} = \frac{\text{Near Infrared (NIR)} - \text{Short wave Infrared (SWIR)}}{\text{Near Infrared (NIR)} + \text{Short wave Infrared (SWIR)}} \quad \ldots(3)$$

The high values of NDMI indicate the existence of more soil moisture under massive water bodies and low values denote the low soil moisture content.

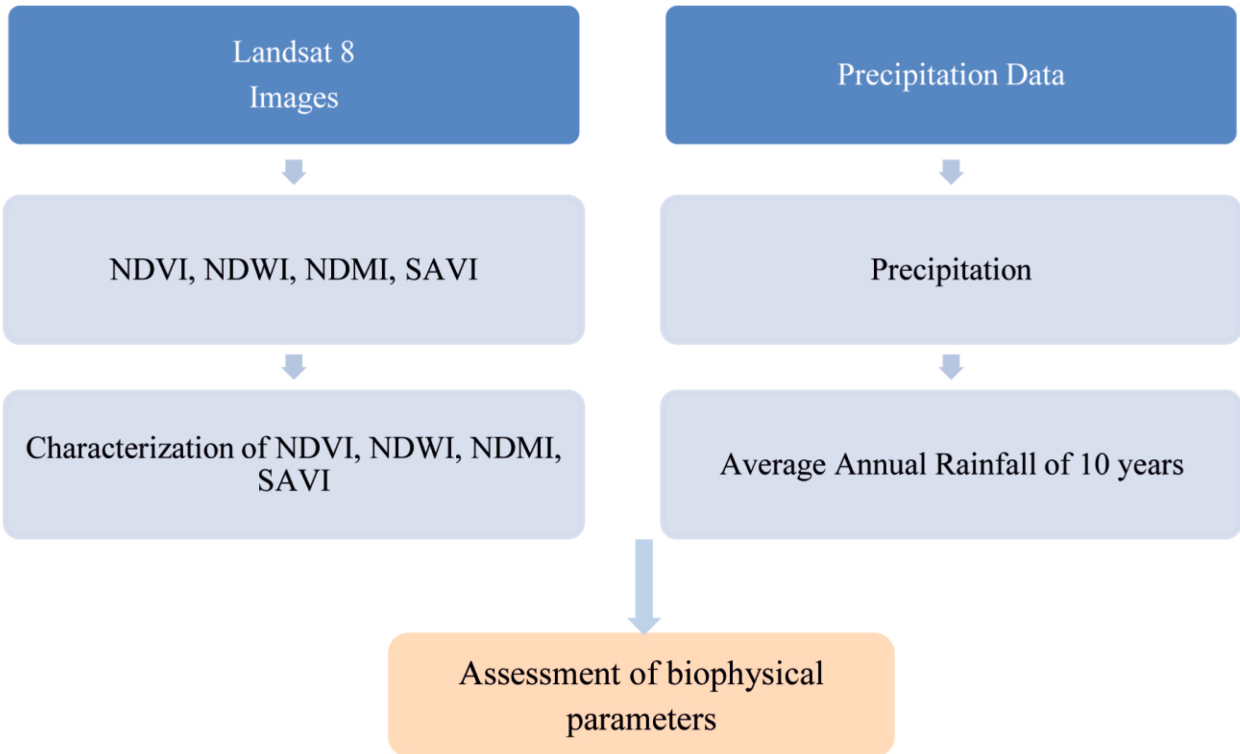

Fig. 3. Flow chart of Methodology

Soil-Adjusted Vegetation Index (SAVI)

The SAVI is a transformation technique that minimizes the soil brightness influenced by spectral vegetation indices involving Red and Near-Infrared (NIR) wavelengths or is used to correct NDVI for the influence of soil brightness in areas where vegetative cover is low. Landsat Surface Reflectance-derived SAVI is calculated as a ratio between the R and NIR values with a soil brightness correction factor (L) defined as 0.5 to accommodate most land cover types. This is determined by the given equation.

$$\mathrm{SAVI} = \left\{\frac{\mathrm{NIR}-\mathrm{Red}}{\mathrm{NIR}+\mathrm{Red}+\mathrm{L}}\right\} \times (1+\mathrm{L}) \qquad \ldots(4)$$

L is the amount of green vegetation cover and varies on the amount of green vegetative cover. Generally, in areas with no green vegetation cover, it is 1 and for moderate green vegetative cover, and very high vegetation cover, it is 0.5 and 0, respectively. SAVI result output values range between -1.0 and 1.0.

RESULTS AND DISCUSSION

All the terrain biophysical parameters and density of the land cover along other characteristics were given in the figures 4. All the biophysical parameters are shown low to high concentration for NDVI , NDWI, NDMI and SAVI of the region.

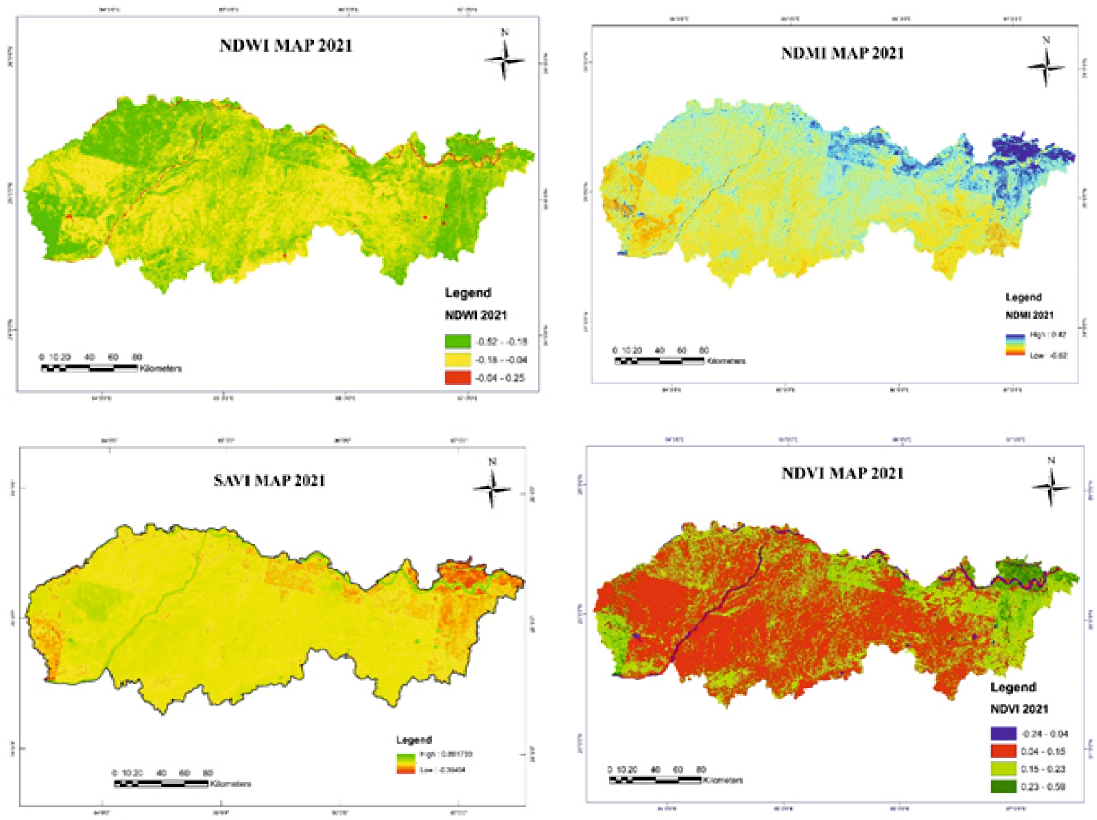

Fig. 4 Biophysical Parameters such as NDVI, NDWI, NDMI, SAVI along with their concentration

RAINFALL DISTRIBUTION OF THE REGION

The spatial rainfall distribution map (Fig. 5) generated under GIS environment from the raster layer of precipitation data from Research Unit dataset i.e., CRU TS v. 4.05 (A gridded time-series dataset). The average annual precipitation for ten years of the study area, from 2011 to 2020 has been used and interpolated to generate the annual rainfall.

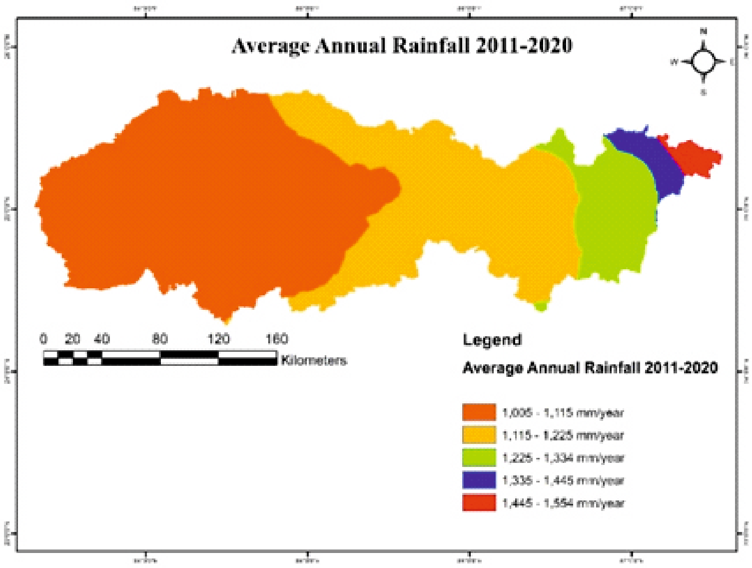

Fig. 5 Average Spatial distribution of Rainfall in the region.

CONCLUSIONS

The finding from the present work clearly indicated the utility of space borne satellite images for generation of biophysical parameters of the complex terrain and their application in land and water resources management. The study also present the current spatial density of vegetation cover and other indices which provides very important data on assessment climate change and their impact on natural resources and environment of the terrains. The NDWI indicates surface water bodies is very low in the South Bihar region. Soil moisture content is comparatively high in neighbouring areas of The Ganges and Son River watercourse. The soil type of almost all the districts of the South Bihar region is quaternary alluvial-clay to sandy clay tending to be porous but barely permeable. Less vegetation cover in the area indicates surface runoff takes place during rainfall which affect groundwater recharge. The trend of the average annual rainfall pattern of the last decade indicates the districts in the western part of the map i.e., Buxar, Kaimur, Rohtas, Aurangabad, Gaya, Bhojpur, and Arwal received the lowest precipitation. Whereas Bhagalpur, Banka, and Munger districts received more precipitation.

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