A Spatial Analysis of Post Monsoon Surface Moisture Using MODIS Data in Haryana

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ABSTRACT

The spatial distribution of post-monsoon average surface moisture in Haryana was analyzed using MODIS data that provide critical insights into the region's ecological and hydrological dynamics. This study utilized a comprehensive dataset spanning multiple monsoon seasons to examine the variations in surface moisture across Haryana's diverse landscapes. The findings revealed significant spatial heterogeneity, with areas of dense vegetation such as forests and agricultural lands showing better moisture retention. In contrast, urban and arid regions exhibited lower NDMI values based on pixel, highlighting their vulnerability to moisture stress during the monsoon. These results underscore the importance of vegetation in mediating surface moisture levels and suggest that enhancing vegetative cover could play a vital role in mitigating moisture stress. This study offers valuable data for policymakers and environmental managers, aiding in the development of targeted water management and conservation strategies to ensure sustainable water resource management in Haryana.

Keywords: RS & GIS, MODIS, NDMI, NDVI, Haryana

INTRODUCTION

The accurate and timely measurement and monitoring of surface moisture is essential for understanding hydrological process, crop water reequipment and climate change Duda B. Balas et al. Haryana, situated in the north- western part of India, experiences generally lighter compared to many other parts of India. The state receives around 75% of its annual rainfall during southwest monsoon season typically from last week of June to first week of September. The state also receives a small amount of rainfall nearly 25 percent after monsoon through western disturbance. The moisture levels are not uniform across its diverse landscapes. Therefore, understanding the spatial distribution of surface moisture after the monsoon season is crucial for assessing agricultural productivity, water availability, and environmental conditions in Haryana, India. Surface soil moisture is very sensitive which varies with space and time [1].

The use of MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data provides an effective means to monitor and analyze surface conditions at a regional scale. MODIS data offer insights into parameters such as land surface temperature, vegetation indices, and potentially soil moisture content, which collectively contribute to understanding surface moisture dynamics. Spatial interpolation and GIS emerged as powerful tools in remote sensing technology demonstrating their capability to provide spatial continuous data required for environmental monitoring [2]. The present study is designed to know the spatial distribution of surface moisture after the rainfall season, i.e., in November. The study was conducted using MODIS-NDMI data to know the moisture level.

LITERATURE REVIEW

Haq et al. (2020) reported that Moderate Resolution Imaging Spectro-radiometer (MODIS) datasets can be used to investigate the geographical and temporal variability in land surface temperature (LST), snow cover, and normalized difference vegetation index (NDVI) in Himachal Pradesh between 2001 and 2017[3].

Krishnan et al. (2023) studied that soil moisture (SM) is a critical parameter for land-atmosphere interaction, measuring drought conditions in agricultural areas, and it can significantly affect surface water and agricultural production. Based on remote sensing observations, the temperature vegetation dryness index (TVDI) can be generated to evaluate SM at a large spatial scale [4].

Sharma et al. (2022) concluded that this study examines the trends in the MODIS/TERRA-derived Normalized Difference Vegetation Index (NDVI) and its correlation with land surface temperature (LST) and soil moisture (SM). The correlation between NDVI and LST (− 0.45) is higher than the correlation of NDVI with SM (r = 0.43) and precipitation (r = 0.341), suggesting NDVI is more sensitive to LST as compared to SM and precipitation. At the same time, SM shows a worthy positive correlation (r = 0.63) with the precipitation. Seasonally, winter (0.45 ± 0.02), monsoon (0.44 ± 0.04), post-monsoon (0.41 ± 0.02), and pre-monsoon (0.37 ± 0.04) are the periods with the highest NDVI values.

STUDY AREA

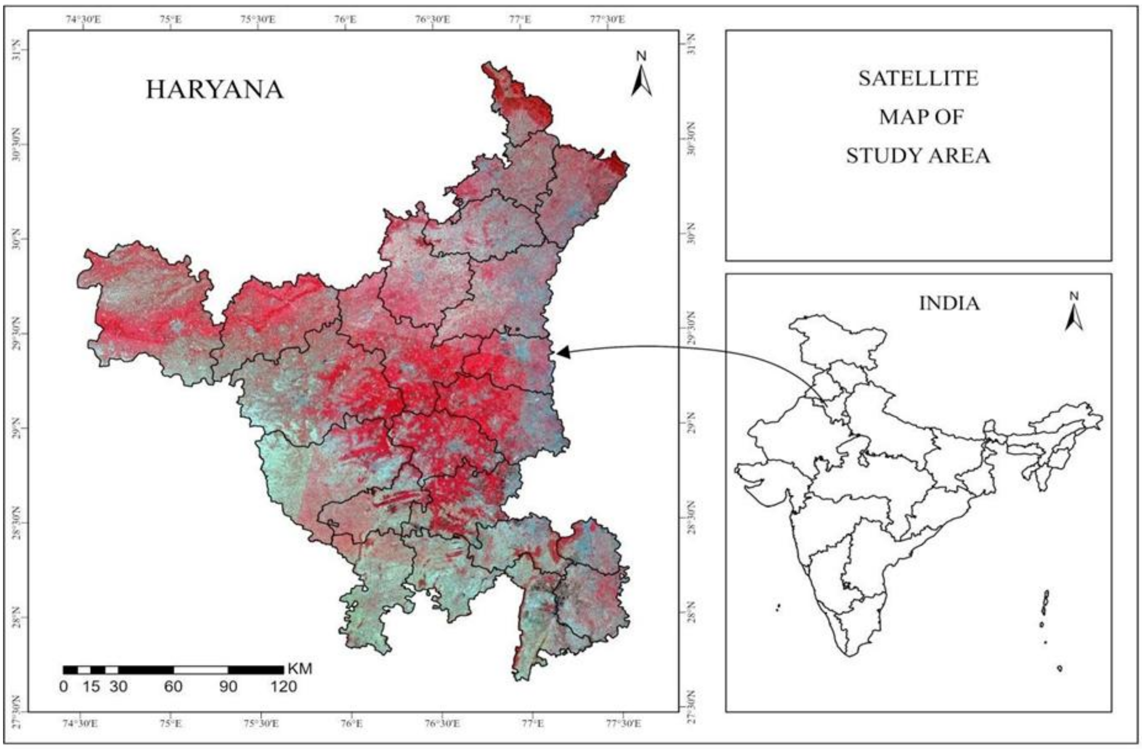


Fig 1.1: Location Map of Haryana

Haryana is a landlocked state in North –West India with 27° 39' and 30° 55' 5" N latitude and 74° 27' 8" and 77° 36' 5" E longitude (fig. 1.1), its capital at Chandigarh. The state's total geographical area is 44,212 square km, which is 1.34% of India's total landmass. Haryana's elevation ranges from 700 to 3600 feet (200 meters to 1200 meters) above sea level. Different terrain, ranging from Shivalik Hills in the North-East, alluvial plains in the center, and desert Aravalli in the southern areas.

The state is divided into three separate climate zones: hot semi-arid, hot desert, and hot sub-humid, and the average yearly temperature ranges between 1°C and 45°C. In the monsoon season, which lasts from the last week of June to first week of September, and the winter rains, due to western disturbance which last from December to February, the average annual rainfall of the state as a whole is 573 mm and below for arid and semi-arid regions [6]. The Yamuna and the Ghaggar are the state's most important rivers. Haryana has only 4% (compared to the national 21.85%) area under forests.

METHODOLOGY

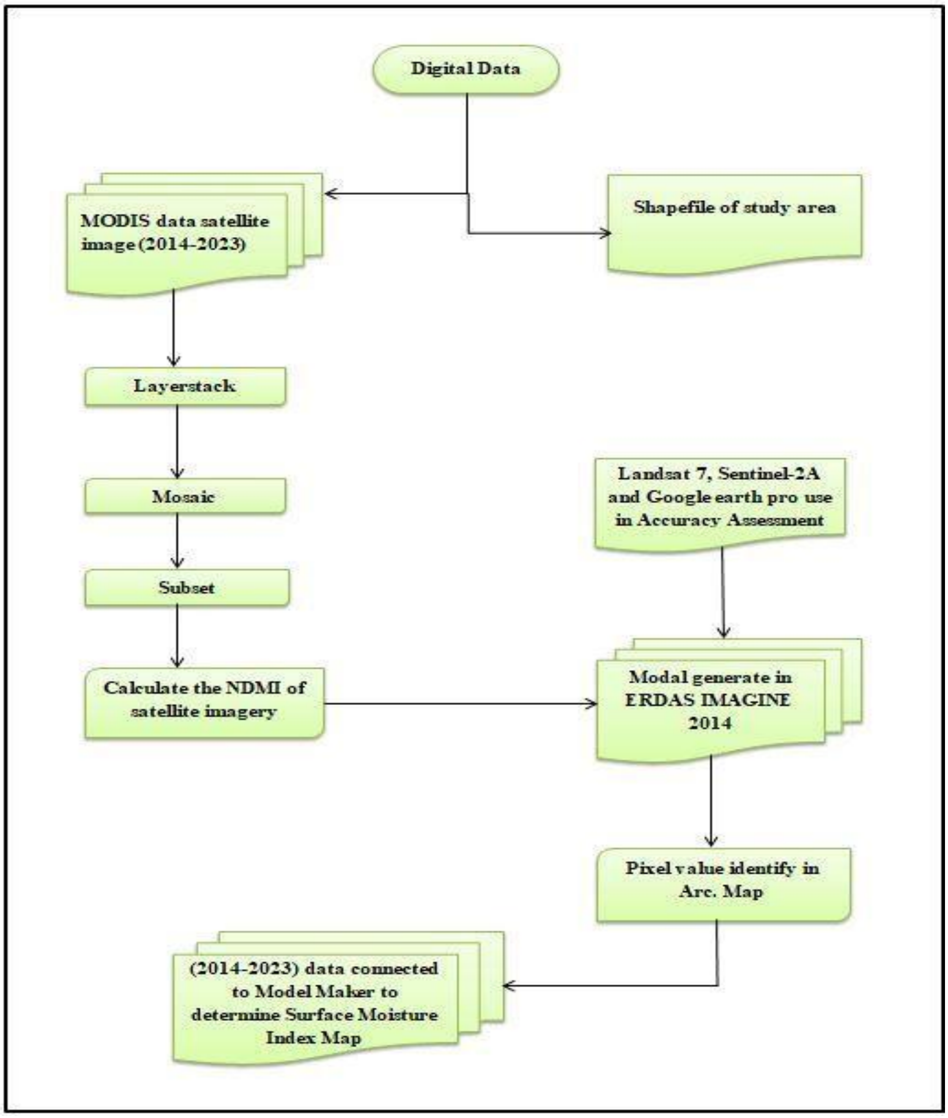


Fig 2.1: Methodology flow chart

The traditional method used for measurement of moisture content in water bodies, vegetation and surface required more time and cost. Therefore, remote sensing offers valuable tools for analyzing surface moisture using electromagnetic radiation. The remote sensing techniques rely on the relationship between surface moisture and amount of radiation reflected by surface. The raw data download for the site was improved in the image formed (.img) using ERDAS IMAGINE 2014 software. The Universal Transverse Mercator (UTM) projection system was used to pre-process and project all the data.

Table: 1

Details of satellite data used in the present work:

Name of satellite	Resolution	Date of acquisition
MOD13Q1	250m	09.11.2014
MOD13Q1	250m	11.11.2015
MOD13Q1	250m	08.11.2016
MOD13Q1	250m	10.11.2017
MOD13Q1	250m	07.11.2018
MOD13Q1	250m	09.11.2019
MOD13Q1	250m	24.11.2020
MOD13Q1	250m	22.11.2021
MOD13Q1	250m	12.11.2022
MOD13Q1	250m	15.11.2023

Several indices are used to analyze moisture level in different context. The NDMI (Normalized Difference Moisture Index) is used in present study. The NDMI is an index used to monitor the change in water content in water bodies, vegetation and surface. NDMI index derived from remote sensing data using near-infrared (NIR) and short-wave infrared (SWIR). NDMI values range from -1 to +1, with higher values showing higher moisture content and lower values suggesting lower water content.

$$NDMI=(NIR-SWIR)/(NIR+SWIR)$$

The NDMI values were computed from MODIS bands sensitive to water content (Near Infrared and Green Bands). High NDMI values Indicate areas with high moisture content, such as water bodies and dense vegetation. Water bodies or waterlogged remain around 0 values as observed rather than interpretation (Fig 2.1).

Fig 2.2 Google image using Google Earth Pro

Result and Discussion

Moisture content (in canopy) is an important factor for agricultural analysis in Haryana. The data used in this paper is suitable for agricultural areas and has useful applications for agricultural management (irrigation, pasture, and grassland) and drought monitoring in Haryana. Time series analysis is one of the most important tools for analyzing and forecasting future trends in moisture. The following image shows NDMI images in the post-monsoon period (in November) for different years. (As shown in Figs. 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, and 3.10). The November months of (2014, 2016, and 2017) had higher NDMI values while November months of (2018, 2019, 2020, 2021) had a medium value (10-20). in the eastern part of the state. The north-western part of Haryana for November month of 2015, 2022, and 2023 had a low value (0-9), showing low moisture content

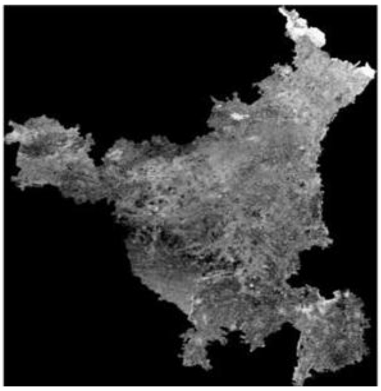


Fig 3.1
MODIS data NDVI Nov. 2014

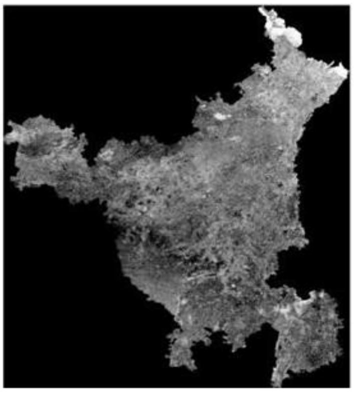


Fig. 3.2
MODIS data NDVI Nov. 2015

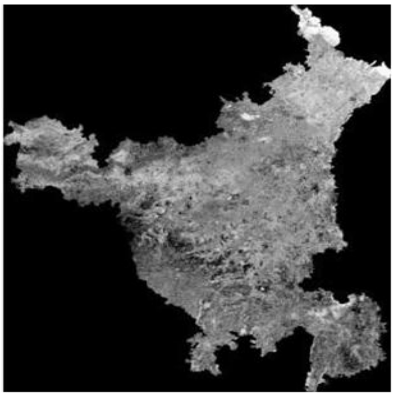


Fig. 3.3
MODIS data NDVI Nov. 2016

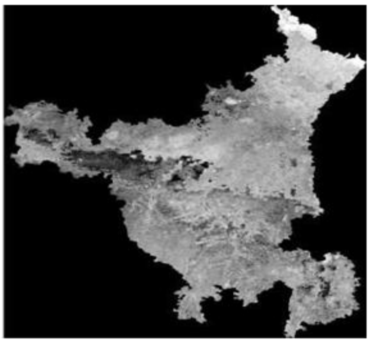


Fig 3.4
MODIS data NDVI Nov. 2017

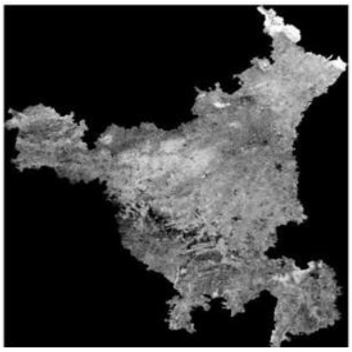


Fig. 3.5
MODIS data NDVI Nov. 2018

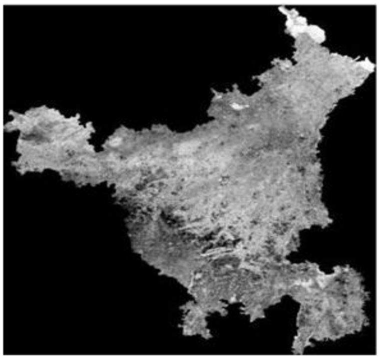


Fig. 3.6
MODIS data NDVI Nov. 2019

Fig 3.7
MODIS data NDVI Nov 2020

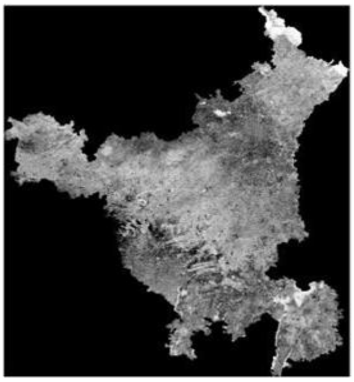


Fig. 3.8
MODIS data NDVI Nov. 2021

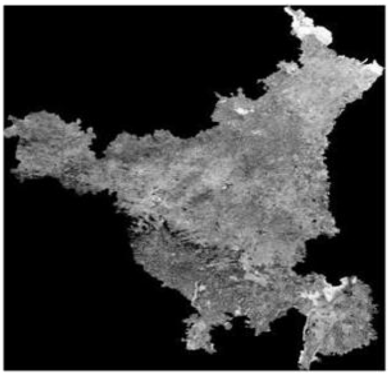


Fig. 3.9
MODIS data NDVI Nov. 2022

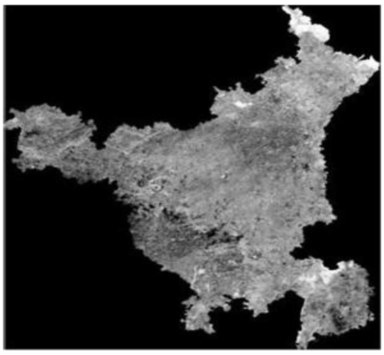


Fig 3.10
MODIS data NDVI Nov. 2023

Based on the 10-year MODIS data and using NDMI (Normalized Difference Moisture Index) as an indicator, the post-monsoon average surface moisture was analyzed by adding all the images in ERDAS imagine software. The image was further coded as under (as shown in Fig. 4.1). The year with good/normal and heavy rainfall should have higher moisture content over the region. Each year, NDMI is categorized into three levels based on NDVI values shown in values in Table 2.

Table 2

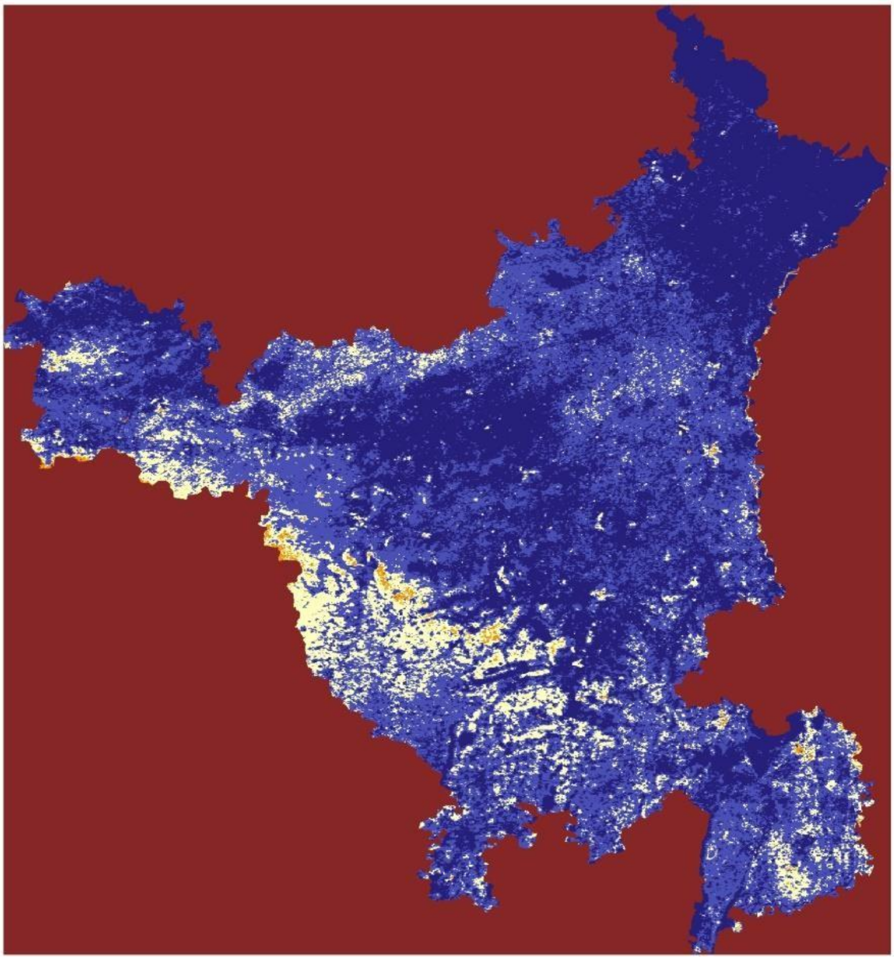
Coding for NDMI images

Code	NDMI value
1	<0.1-0.3
2	<0.3-0.6
3	>0.6

The analysis indicated that the post-monsoon surface moisture levels, inferred from NDMI trends over a decade of MODIS data, exhibit significant variability and regional patterns. This information can aid in understanding ecosystem dynamics, agricultural productivity, and water resource management in the studied regions.

The (fig.4.1) shows coded images for composite analysis. These 10 images were summed up to get the average moisture status of the data during the post-monsoon. This image explained normal effective rainfall over the state, where higher values showed higher moisture content with 21 to 30 NIR Pixel values in the northern and middle parts of the state covering the districts of Panchkula, Ambala, Kurukshetra, Kaithal and Jind. The above central part of the state has a low-lying area that is often waterlogged after the monsoon period resulting higher moisture level. The western and southern parts of state covering the district of Hissar, Bhiwani, Mahendergarh and Sirsa districts showed lower moisture content with 0-10 NIR Pixel values. The dry and semi -arid surface with patches of sand dunes lack moisture content. Moreover, the state experiences a dry to semi-arid climate with variation in rainfall across the state, ranging from 300 mm in south -west to 1100mm in the north-east

Haryana
Composite Analysis Image
MODIS Data November Months 2014-2023



Index

Code	NDMI value	Map's color
1	0 -9*	
2	10-15	
3	16-20	
4	21-25	
5	26-30	

* NIR absorbance on Pixel value

. Fig 4.1

CONCOLUSION:

The spatial distribution of post-monsoon average surface moisture, derived from a decade of MODIS data, reveals significant insights into regional ecological and hydrological dynamics.

The analysis highlights marked variations in surface moisture across different landscapes and over periods, indicating areas of both resilience and vulnerability to climatic changes. Regions with dense vegetation cover, such as forests and wetlands, consistently show higher NDMI values, reflecting greater surface. Conversely, arid and semi-arid zones exhibit lower NDMI values, underscoring their susceptibility to moisture stress post-monsoon. Additionally, the data suggests that targeted water management practices are essential in regions identified as high- risk for moisture deficits. Overall, the ten-year MODIS NDMI dataset provides a robust framework for understanding surface moisture dynamics, aiding in the formulation of effective environmental management and conservation policies.

The higher NDMI value coincides with a higher canopy water structure that can be correlated with good rainfall, whereas the (0–9) lower NDMI (south-western Haryana) value has low moisture conditions that may be the impact of rainfall in agriculture.

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