

Impact of Soil Moisture in the Cultivation of CO 51 in the Riverine Tract of Dakshin Dinajpur and SaraikelaKharsawan

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ABSTRACT

Soil moisture serves as an essential component for the Earth's terrestrial hydrological cycle. The parameter shows how much water remains trapped inside soil pores which helps scientists understand how different elements interact with each other. Soil moisture defines plant growth patterns which directly impacts agricultural output while also determining how water moves through different phases from ground infiltration to surface runoff and atmospheric moisture release. From a climate perspective it functions as the main factor which controls how energy flows between land surfaces and the atmosphere. The scientific community studies soil moisture because it connects to multiple research areas that focus on climate change and water scarcity and sustainable natural resource management. The majority of studies focus on examining different methods and tools. The study investigates different knowledge sources which extend from traditional point-scale methods to contemporary satellite remote sensing systems and land surface modeling techniques. The research team conducted an evaluation of riverine soil moisture conditions in riverine tract of Dakshin Dinajpur and SaraikelaKharsawan through Palmer Drought Severity Index (PDSI) calculations and its impact on the cultivation of CO 51 rice variety.

Keywords: Soil moisture, climate change, remote sensing, modeling, PDSI

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INTRODUCTION

The terrestrial ecosystem depends on water as its vital liquid resource which exists as a fundamental life requirement that needs to exist in soil. The common understanding of soil moisture defines it as the water present in the unsaturated zone which exists between the land surface and the water table but this definition fails to capture the actual complex and dynamic nature of the geophysical measurement [8-16]. The system creates a vital connection between the hydrosphere and lithosphere and biosphere and atmosphere. The importance of soil moisture extends beyond common understanding because it controls which vegetation types will grow in a specific location, between dense forests and productive agricultural land and empty desert areas [17-19]. The assessment of soil moisture requires a comprehensive understanding from soils experts. Soil scientists use it to study three hydrological processes which include water infiltration and surface runoff and underground water recharge. The scientific community uses it as a critical element which

controls weather patterns and climate changes because of its effect on latent and sensible heat flow. The resource functions as an essential element for ecological systems and agricultural scientists and their research on plant growth and ecosystem health and agricultural output [18-25]. Civil engineers and land managers use slope stabilization techniques to create protection against landslide dangers at construction sites. The combination of climate change and hydrological extreme events which include severe droughts and intense floods plus the rising demand for food and water resources throughout the world have made soil moisture a crucial element which drives worldwide sustainability initiatives within the last several decades.

This study provides an all-encompassing examination of soil moisture management. The research investigates how two essential processes move water through soil and retain it in soil while studying measurement techniques that range from field measurements to global assessments. The

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paper brings together existing scientific knowledge and ongoing research to explain why scientists need to study this unknown resource for effective environmental problem-solving in upcoming environmental challenges. The unsaturated zone contains water that exists in its soil moisture form because scientists need to measure this water for various scientific and operational applications. Soil moisture operates as a core hydrologic state because it includes solid states of water and liquid water and gaseous states with all their associated phase changes. Agricultural professionals depend on soil moisture information to determine the optimal irrigation time and predict their expected crop harvest. In climatology and meteorology, soil moisture acts as a critical variable that impacts energy transfer processes while providing information about long-term climatic patterns. Soil moisture affects plant water stress and carbon cycling processes which makes it an essential factor in ecological systems. The primary challenge to studying soil moisture stems from its unpredictable changes, which occur across both geographic areas and time periods.

Soil moisture shows extreme fluctuations across meter distances because of variations in soil texture and vegetation cover and topographic features and because of precipitation and evaporation and drainage which change throughout the day. The variable nature of soil moisture components requires a comprehensive approach that involves multiple research methods. The soil moisture data collection process requires multiple techniques because no single method can deliver accurate results across all spatial scales that range from pore to globe and all time scales that extend from minutes to decades and all underground depths that reach from surface to root zone. The process of soil moisture analysis employs various methods which each have distinct theoretical foundations and different strengths and weaknesses. The PDSI calculation process at Google Earth Engine developed the fundamental method for measuring soil moisture in the Atreyee and Punarhaba river regions of Dakshin Dinajpur, and Subarnarekha river basin of Saraikela Kharsawan. The natural variability of soil moisture research requires that research methods should include multiple research elements. The method of finding soil moisture through a single technique fails to deliver complete soil moisture information across all spatial dimensions which extend from pore to globe and all temporal dimensions which range from minutes to decades and all depth dimensions which span from surface to root zone. Different methods exist to study soil moisture because scientists require various research methods which combine different scientific theories which create unique strengths and weaknesses for each approach. The purpose of this paper is to provide a systematic and thorough investigation into all the methods of soil moisture assessment. We want to avoid just a list of methods to include an assessment of their principles, how they operate, sources of error, and their area of application. The way the paper is organized follows the measurements from direct to point scale with the ultimate scale they apply to

being land surface modelling and data assimilation. The systematic findings create a fundamental basis which researchers and practitioners can use to develop their own soil moisture monitoring strategy that fulfills their specific requirements. Most modern soil moisture sensors operate according to their fundamental electromagnetic characteristic which detects water's high dielectric permittivity that exists between soil particles and air. Dielectric permittivity (ϵ) serves as an indicator for how well materials can store electrical energy within an electric field. At electromagnetic frequencies relevant to soil moisture sensing (ranging from MHz to GHz), the relative dielectric permittivity (ϵ_r) of liquid water is high (~80 at 20 °C), while the ϵ_r of soil minerals will generally be low (~3-9) and air $\epsilon_r = 1$. The bulk dielectric permittivity of the soil mixture will exhibit strong sensitivity to the water content present within the soil matrix. The physical relationship between water content and soil moisture detection represents the essential mechanism used by most electronic soil moisture sensors.

2.0 Materials and methods

2.1 Palmer drought severity index (PDSI)

Drought stands as the most complicated natural disaster which produces the greatest destruction because it affects agricultural production and water supply systems and natural habitats and human communities. Drought differs from floods and cyclones because its definition and measurement create challenges which arise from its gradual development together with its dependence on extended periods of rainfall deficiency which generate changes in soil moisture and evapotranspiration rates throughout different times. To fill the need for a common measurement of drought severity, Wayne C. Palmer (1965) developed a PDSI that is now one of the most widely used meteorological drought indices in the world [23]. The PDSI system uses precipitation and temperature data together with soil water holding capacity information to create a continuous system which shows how wet or dry a location is at any given time. The PDSI system originated from Palmer's work in central United States climate but its design enables application across different climatic regions. The PDSI system presents numerical values which usually fall between -6 and +6 although

extreme situations can produce values beyond these limits (Table 1).

Table 1 PDSI range
+4.0 or more: Extremely wet
+3.0 to +3.9: Very wet
+2.0 to +2.9: Moderately wet
+1.0 to +1.9: Slightly wet
0.5 to -0.4: Near normal
-1.0 to -1.9: Mild drought
-2.0 to -2.9: Moderate drought
-3.0 to -3.9: Severe drought
-4.0 or less: Extreme drought

PDSI is computed as:

$$X_i = 0.897 \cdot X_{i-1} + \frac{Z_i}{3}$$

Where:

X_i = current month's PDSI value; X_{i-1} = previous month's PDSI value; Z_i = current month's Z-index and 0.897 = persistence factor (drought/wet conditions).

Results and discussions

PDSI provides a basic system which measures multiple degrees of soil moisture and drought conditions. PDSI functions as a primary drought measurement tool which most frequently operates as an index to assess drought conditions in different areas throughout the United States. Wayne Palmer created this index in 1965 to measure the intensity of both meteorological and agricultural drought conditions. PDSI measures long-term droughts which last from weeks to months while weather events exist as temporary phenomena. PDSI uses a permanent soil structure which creates difficulties when assessing areas with uneven and shallow soil conditions. The system functions as a predictive tool which analyzes agricultural and water supply drought conditions. The map displays a PDSI measurement obtained through Google Earth Engine for the river areas of the two districts. The map has been accessed from the dataset USGS_GFSDAD1000_V1 and illustrates a range of drought conditions through both the representation of their environment by topography and colours. PDSI intensity measurements show higher values close to main river paths while lower values occur at locations which are farther from those rivers (Fig. 1).

PDSI serves as an essential instrument which enables researchers to identify different geo-physical environments while assessing their effects on soil moisture potential. The PDSI values show their lowest readings in areas which mostly experience agricultural activities together with their most vulnerable regions. The maximum values of PDSI exist near rivers while the lower PDSI values extend beyond the river banks throughout the high and low and medium PDSI segments. PDSI indicators in understanding various geo-physical environments slow movement strategies and vulnerability when they depict lower PDSI values. The scientific community has reported PDSI through multiple testing scenarios which consist of experimental work described in research articles [7-14] as an effective method to assess drought conditions and track soil moisture fluctuations. The group of studies reviewed overall reaffirmed that PDSI and its derivatives are effective at identifying drought and measuring soil moisture variability, across different geographical and climate conditions. PDSI generates water balance climate assessment results because its system uses temperature and precipitation data for environmental analysis. Agricultural planning and climate change adaptation and water resource management all require PDSI as their operational tool.

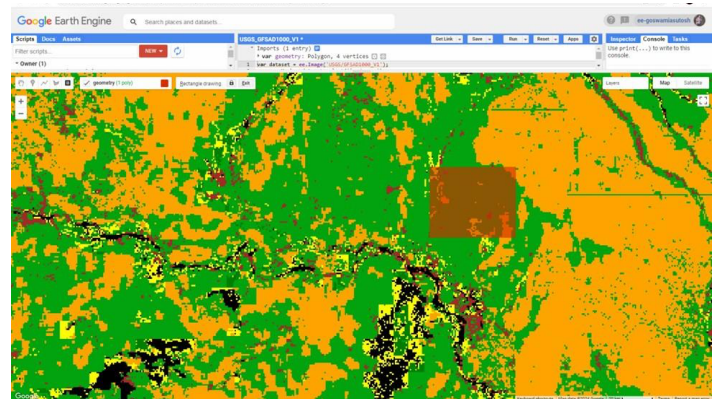


Fig. 1 Map of Palmer Drought Severity Index

The present study has computed a theoretical and actual curve for the purpose of validation (Fig. 2). The observations are directly coinciding the theoretical diagonal line indicating the higher significance of the result.

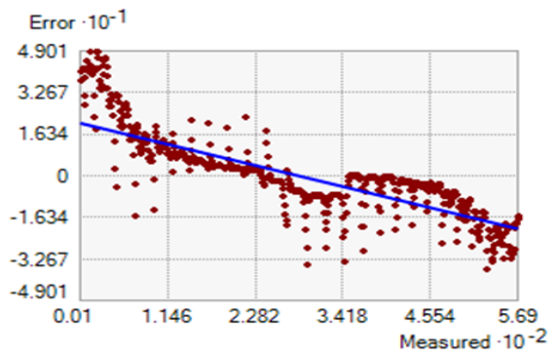


Fig. 2 Model validation

Conclusion

The PDSI index enables permanent moisture assessment through its measurement of temperature and precipitation patterns. The PDSI values show stronger elevation through the complete area which extends from natural river channels because these regions hold both groundwater and moisture from floods and different types of water movement. The regions establish better total soil moisture levels which result in healthier plant growth of CO 51 and create successful agricultural systems. The PDI values decrease in river-adjacent areas which become more drought-affected because they experience less rainfall and more arid conditions. The low PDSI value regions in food production become more vulnerable to drought because they suffer various soil moisture shortages which result in crop difficulties and decreased agricultural production, leading to food insecurity. Drought-prone regions find themselves without enough irrigation systems, which forces them to depend completely on rainwater, thus making them more vulnerable to climate variations. The combination of persistent environmental conditions and low PDSI patterns leads to reduced soil productivity, decreased groundwater reserves, and delayed essential

agricultural activities, which result in diminished agricultural output. The identification of these drought-prone areas using PDSI mapping becomes necessary in regional drought prevention, resource priorities, and farm planning for sustainable agricultural systems which apply to semi-arid or arid zones where water scarcity presents a major risk.

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