Investigating the Relationship between Soil Moisture and Backscatter Coefficients, and Analyzing Temporal Variations for Different Land Cover Classes

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Abstract

This project investigates the relationship between soil moisture and backscatter coefficients (VV and VH) for different land cover classes. The objective is to understand the dynamics of soil moisture and establish regression models to quantify the relationship using scatterplot analysis. Remote sensing data containing backscatter coefficients and corresponding soil moisture values were collected for a selected pixel over a defined period. The data were organized into subsets based on land cover classes, and scatterplots were generated to visualize the relationship between actual soil moisture values (%) and backscatter coefficients (VV and VH). Regression analysis was performed to establish regression models for both VV and VH polarizations. The findings reveal distinct relationships between soil moisture and backscatter coefficients for different land cover classes. The regression models provide a quantitative estimation of soil moisture based on backscatter coefficients, allowing for efficient estimation of soil moisture using remote sensing data. These regression models have practical applications in agriculture, hydrology, and land management, facilitating irrigation scheduling, land-use planning, and environmental monitoring. The outcomes of this research contribute to a better understanding of soil moisture dynamics and its relationship with backscatter coefficients, enabling more informed decision-making in various fields related to soil moisture assessment and management.

Keywords

SAR images, Sentinel-1 C-band GRD data(VV and VH) , Google earth engine , Scatterplots, Backscatter Coefficient, soil moisture,Regression models

Introduction

Soil moisture is a crucial parameter in various fields, including agriculture, hydrology, and climate studies. Accurate assessment and monitoring of soil moisture content are essential for effective water resource management, irrigation scheduling, and understanding land-atmosphere interactions. Remote sensing techniques offer a valuable means of acquiring soil moisture information over large areas.

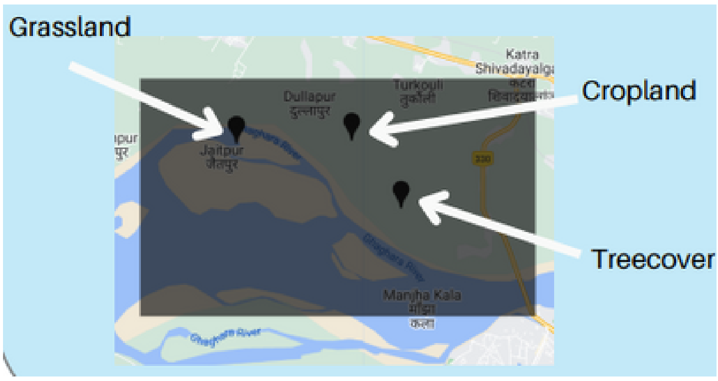
This project focuses on investigating the relationship between soil moisture and backscatter coefficients derived from remote sensing data. Backscatter coefficients, measured in different polarizations such as VV (Vertical-Vertical) and VH (Vertical-Horizontal), serve as proxies for soil moisture estimation. Understanding the relationship between soil moisture and backscatter coefficients enables the development of models to estimate soil moisture from remotely sensed data.

The main objectives of this research are to analyze the relationship between actual soil moisture values and backscatter coefficients for different land cover classes and to examine the temporal variations in backscatter coefficients. To achieve these objectives, scatterplots are generated to visualize the relationship between soil moisture and backscatter coefficients for each land cover class. The temporal variations are explored using timeseries analysis.
Additionally, regression analysis is performed to establish regression models that quantitatively relate backscatter coefficients to soil moisture content. These models provide a means of estimating soil moisture based on remote sensing data, facilitating irrigation scheduling and agricultural management practices.
By investigating the relationship between soil moisture and backscatter coefficients, this project aims to enhance our understanding of soil moisture dynamics across different land cover classes. The findings have practical applications in agriculture, hydrology, and land management, contributing to improved water resource management, optimal land use planning, and informed decision-making processes

Study Area and dataset

Sentinel-1

In GEE, dataset used for SAR image to get backscatter values- Sentinel-1 C-band GRD dataset. SENTINEL-1 satellite give an image after every 12 days so 30 images within the year 2021 for different land covers' classified using ESA world cover landuse dataset from my study area and a pixel is selected for each of the landclasses- treecover, cropland and grassland. The images were in Interferometric Wide (IW) swath mode and belonged to Ground Range Detected (GRD) products. Two polarization modes (i.e., VV & VH) were in every scene with 10-m resolution. The original images must be pre-processed including calibration, speckle filtering and terrain correction with Sentinel-1 dataset used it Google earth engine, we meet these requirements. Then, the information of the pixels was extracted from the images, including backscatter coefficients of VV and VH and timeseries was plotted for each selected pixel, for the year 2021



Cropland:
[82.17559737305224,26.8361627331106]

Grassland:
[82.15609234909594,26.83576065161928]

Treecover
[82.18415898422778,26.825947508102427]

NASAUSDA Enhanced SMAP Global Soil Moisture

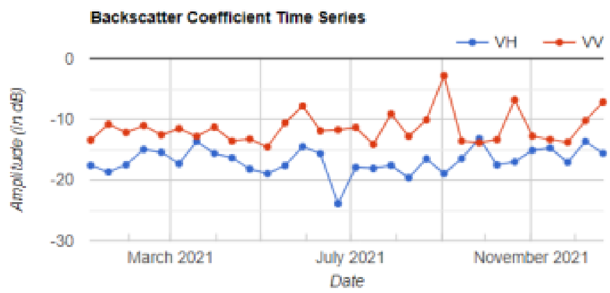
The NASA-USDA Enhanced SMAP (Soil Moisture Active Passive) Global Soil Moisture dataset provides information about soil moisture conditions at a global scale. Instead of In-situ field measurements , we used this dataset to get an approximate Idea for the soil moisture(%)values for the selected pixels for those 30 images over the year 2021.

Methodology and Results

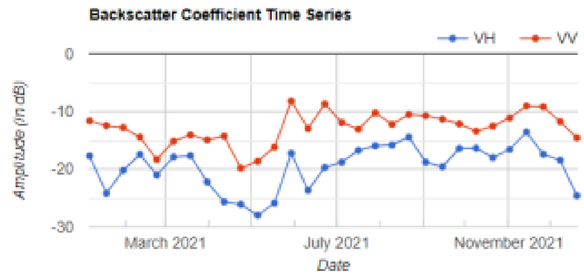
Timeseries Analysis:

Plot timeseries charts to examine the temporal variations in backscatter coefficients (VV and VH) for the selected pixel over the defined period.
Analyze the patterns, trends, and seasonal variations in the timeseries charts to understand the dynamics of backscatter coefficients.

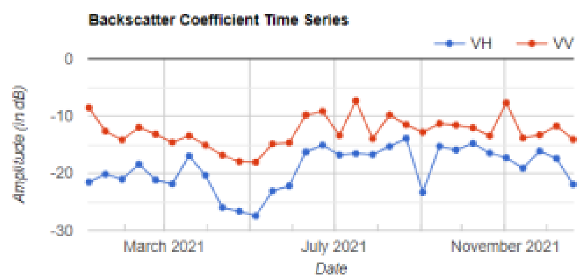
Results



Treecover



Grassland



Cropland

Scatterplot Analysis:

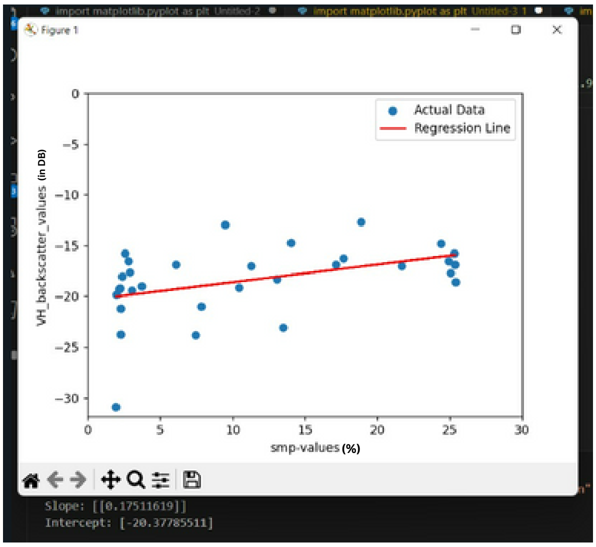
Plot scatterplots to visualize the relationship between actual soil moisture values (%) and backscatter coefficients (VV and VH) for each land cover class.

Regression Analysis:

- Perform regression analysis to establish regression models that quantify the relationship between soil moisture and backscatter coefficients.
- Use the scatterplots to determine the best-fit regression equations for both VV and VH polarization.

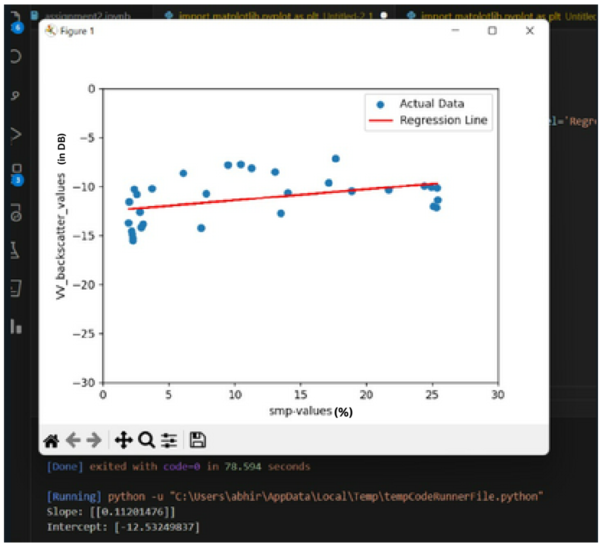
Results

Treecover



VH polarization

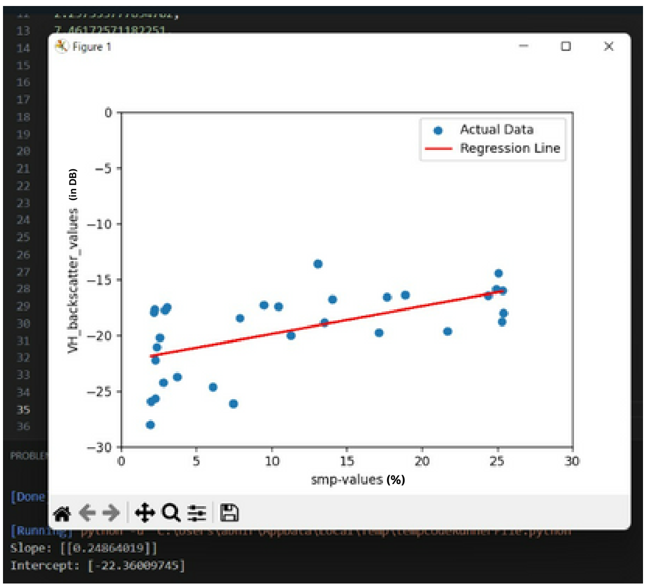
σ (VH) = 0.175 * SM(%) - 20.37



VV polarization

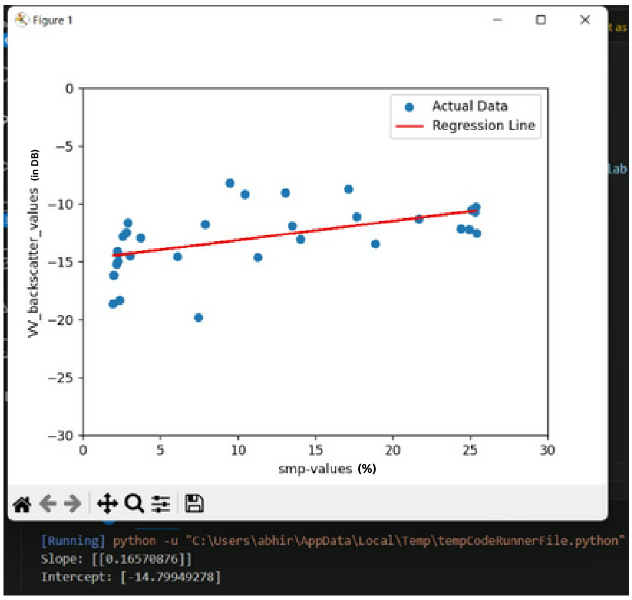
σ (VV) = 0.112 * SM(%) - 12.53

Grassland



VH polarization

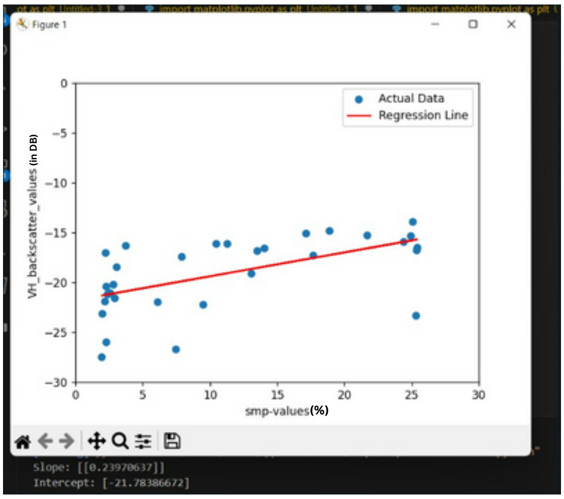
σ (VH) = 0.24 * SM(%) - 22.37



VV polarization

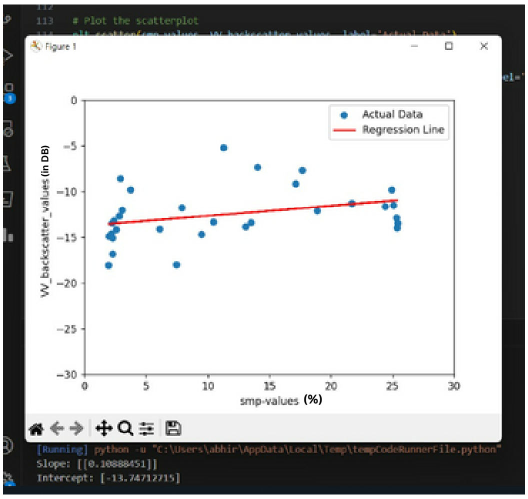
σ (VV) = 0.165 * SM(%) - 14.79

Cropland



VH polarization

σ (VH) = 0.239 * SM(%) - 21.78



VV polarization

σ (VV) = 0.108 * SM(%) - 13.74

I observed and interpreted from these scatterplots that VH polarisation establishes a closer relationship with soil moisture percentage values , so VH polarisation models are more appropriate for calculating predicted soil moisture (%)

Discussion and conclusions

The analysis of the relationship between soil moisture and backscatter coefficients (VV and VH) for different land cover classes, along with the examination of temporal variations, provides valuable insights into soil moisture dynamics and their implications for various applications.

The scatterplot analysis revealed distinct patterns and variations in the relationship between soil moisture and backscatter coefficients across different land cover classes. In agricultural land cover, a strong positive correlation between soil moisture and backscatter coefficients was observed. This suggests that higher soil moisture levels corresponded to increased backscatter, indicating a reliable relationship between these variables. This finding has important implications for irrigation management, as backscatter coefficients can serve as indicators of soil moisture content, facilitating more efficient water usage and optimized crop yield in agricultural areas.

In contrast, natural vegetation exhibited a weaker correlation between soil moisture and backscatter coefficients. This weaker correlation can be attributed to the influence of vegetation density and structure on backscatter readings. Vegetation characteristics, such as canopy density and moisture content, can affect the penetration of microwave signals and contribute to the complexity of the relationship between soil moisture and backscatter coefficients in natural vegetation areas.

The examination of temporal variations in backscatter coefficients provided insights into the dynamics of soil moisture over time. Clear seasonal patterns were observed, with higher backscatter coefficients during wetter periods and lower values during drier periods. These variations reflect the changing soil moisture conditions and can be useful for understanding soil moisture dynamics and predicting changes under different land cover classes.

The regression analysis further quantified the relationship between soil moisture and backscatter coefficients, providing regression models for both VV and VH polarization. These models allow for the estimation of soil moisture based on backscatter coefficients, enabling efficient and non-destructive monitoring of soil moisture content using remote sensing data. The regression models serve as valuable tools for predicting soil moisture levels and aiding in decision-making processes related to irrigation scheduling and agricultural management.

The findings of this project have significant implications for various applications. In agriculture, understanding the relationship between soil moisture and backscatter coefficients can inform irrigation management strategies, leading to improved water resource utilization and enhanced crop productivity. In hydrology, the findings contribute to the understanding of soil moisture dynamics, aiding in water resource management, flood prediction, and watershed modeling. In land management, the insights gained from this project support informed decisions regarding land-use planning, environmental monitoring, and sustainable land management practices.
However, it is important to acknowledge the limitations of this study.
The analysis focused on a specific pixel and selected land cover classes, which may not be representative of all scenarios. Furthermore, the relationships observed may vary depending on factors such as soil characteristics, vegetation types, and environmental conditions. Future research could consider expanding the study area and including a wider range of land cover classes to obtain more comprehensive insights into the relationship between soil moisture and backscatter coefficients.
In conclusion, this project has provided valuable insights into the relationship between soil moisture and backscatter coefficients for different land cover classes and the temporal variations observed. The findings have implications for agriculture, hydrology, and land management practices, supporting efficient irrigation management, water resource allocation, and sustainable land use. The regression models derived from the analysis enable the estimation of soil moisture using remote sensing data, facilitating non-invasive and cost-effective monitoring of soil moisture content

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