Prediction of Surface Soil Moisture Content using Multispectral Remote Sensing and Machine Learning

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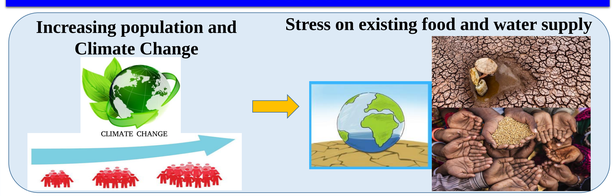
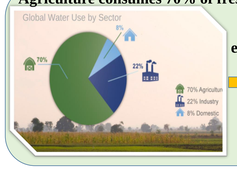
Introduction

Increasing population and Climate Change → **Stress on existing food and water supply**



Agriculture consumes 70% of freshwater



Need to improve water use efficiency i.e. Precise Irrigation

- Soil moisture content (SMC)
- ↓ spatial heterogeneity
- ↓ Varies with soil properties

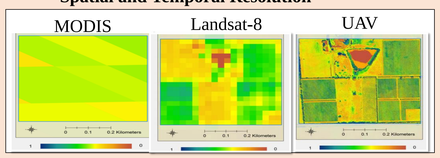
- Traditional methods are to laborious and time consuming
- ↓ Need to find easy method

✓ Remote sensing data gaining importance; covers large-scale area in a short amount of time; non-destructive approach;

✓ It can be easily accessed and analyzed using various software tools.

Sensing platforms

Spatial and Temporal Resolution



Satellite Imagery not suitable for crop and soil monitoring at small farm level

NDVI maps from different platforms (*Wang et al., 2015*)

Existing Satellite based Soil Moisture Products

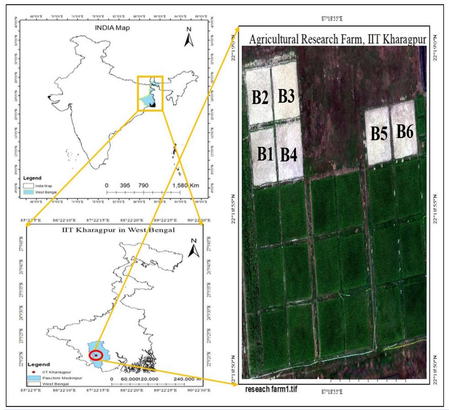
Sr No	Sensor	Short Form	Spatial Resolution	Temporal Resolution	Start
1	Soil Moisture Active Passive	SMAP	36 Km	2–3 days	2015
2	Advanced Microwave Scanning Radiometer for EOS	AMSR-E	25 km	1 day	2012
3	Soil Moisture and Ocean Salinity	SMOS	50 km	2–3 days	2009
4	Advanced Scatterometer	ASCAT	25 km	1, 5 days	2007

Objectives

✓To determine the relationship between moisture content at different soil depths and UAV-based multispectral image data

✓To develop machine learning models for prediction of surface soil moisture content using UAV-based multispectral image data.

Study Area

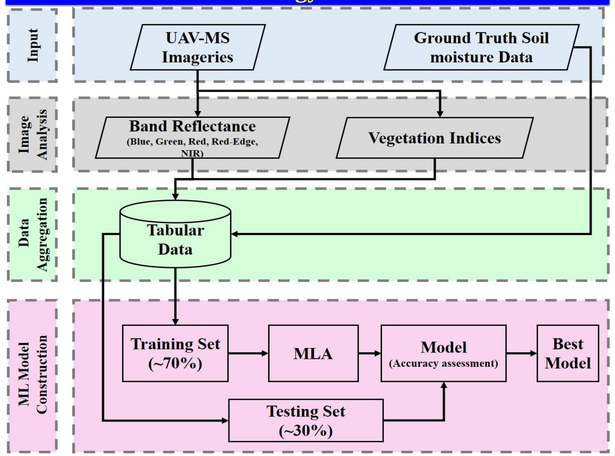


- ✓**Study area :** Research farm, AgFE Department, IIT Kharagpur, India
- ✓**Soil type :** Sandy loam type
- ✓**Climate :** Sub-humid and subtropical
- ✓**Plot size :** 10 m×10 m (100 m^2)
- ✓**Bare Land Plots:** B1, B2, B3, B4, B5, B6

Data Collection Plan

Parameter		Instruments used	Collection Interval
Soil moisture data	Gravimetric Soil Moisture Content (Surface, 5cm, 10cm, 20cm, 30cm and 50cm)	Hot Air Oven	2 Days (10.30 – 11.30 AM)
Aerial data	UAV based multispectral images (40 m Height)	Quadcopter UAV	2 Days (11.30 AM)

Methodology Flowchart



ML Algorithms

1.Linear Regression
2.K-Nearest Neighbors
3.Support Vector Regression
4.Random Forest Regression
5.Decision Tree Regression

Performance Indicator

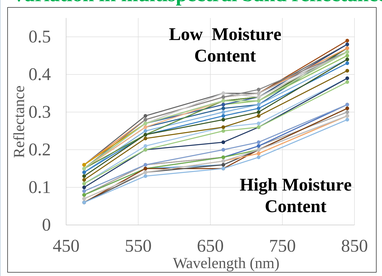
✓Coefficient of Determination (R^2)
✓MAE
✓RMSE
✓MSE

Formulas for different vegetation indices used in this study

Sr. No.	Vegetation indices	Formula
1	Normalized difference vegetation index (NDVI)	$\frac{NIR-R}{NIR+R}$
2	Normalized difference water index (NDWI)	$\frac{G-NIR}{G+NIR}$
3	Transformed Normalized difference vegetation index (TNDVI)	$\sqrt{NDVI+0.5}$
4	Simple Ratio (SR) or Ratio Vegetation Index (RVI)	$\frac{NIR}{R}$
5	Soil-Adjusted Vegetation Index (SAVI)	$\left[\frac{NIR-R}{NIR+R+L}\right]\times[1+L]$

Results and Discussion

Variation in multispectral band reflectance with respect to SMC



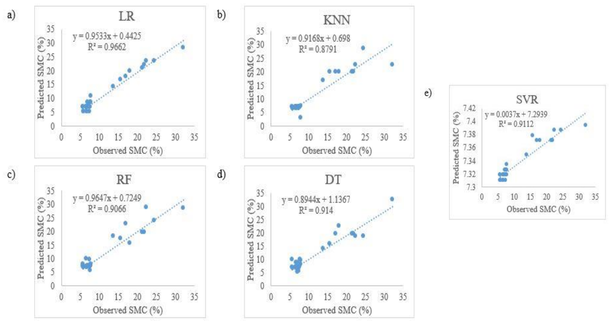
- ✓**High moisture content:** low spectral reflectance;
- ✓**Low moisture content:** high spectral reflectance.
- ✓Kaleita et al., (2008) and Tian et al., (2015) also observed that **spectral band reflectance decreases with increasing water content**

Relationship between SMC using reflectance of multispectral bands

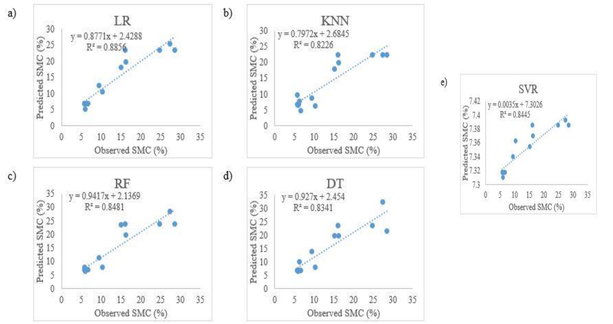
(Coefficient of Determination (R^2))

Soil depth	Blue	Green	Red	NIR	Red-edge
Surface	0.8996	0.8379	0.8049	0.8380	0.8309
5 cm	0.5148	0.4489	0.4464	0.4311	0.4264
10 cm	0.2293	0.2051	0.1925	0.1925	0.1968
20 cm	0.0125	0.0071	0.0075	0.0061	0.0038
30 cm	0.046	0.0400	0.0651	0.0525	0.0676
50 cm	0.2812	0.2661	0.2946	0.3032	0.2762

Training of ML Algorithms for prediction of Surface SMC



Testing of Machine Learning Model



Conclusions

- ✓ Soil moisture content (SMC) has great influence on multispectral bands reflectance. At high SMC, multispectral band reflectance is low and vice versa.
- ✓ The surface SMC shows good correlation (R^2 > 0.80) with the reflectance of multispectral spectral bands as compared to SMC at deeper depth.
- ✓ For prediction of surface SMC, linear regression algorithm performed well with R^2 as 0.89 and RMSE as 2.80%, than the other four ML algorithms.
- ✓ For prediction of surface SMC, blue band reflectance correlated well as compared to other multispectral band reflectance's and vegetation indices.
- ✓ This approach of prediction of SMC may be helpful to irrigation planners to schedule irrigation accordingly.

References

✓Kaleita, Amy L., Lei F. Tian, and Michael C. Hirschi. "Relationship between soil moisture content and soil surface reflectance." Transactions of the ASAE 48, no. 5 (2005): 1979-1986.

✓Tian, J., & Philpot, W. D. (2015). Relationship between surface soil water content, evaporation rate, and water absorption band depths in SWIR reflectance spectra. Remote Sensing of Environment, 169, 280-289.

✓Wang, Y., Ryu, D., Park, S., Fuentes, S., & O'Connell, M. (2017, December). Upscaling UAV-borne high-resolution vegetation index to satellite resolutions over a vineyard. In 2nd International Congress on Modelling and Simulation, Hobart, Tasmania, Australia (Vol. 3).

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