Soil Moisture determination from Passive Microwave Remote Sensed data using ANN

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Abstract: ***Soil moisture is a derived product of passive microwave remote sensors. But the soil moisture data from passive microwave sensors is often not correct for the places having large open water bodies. The present paper describes a technique of soil moisture determination from passive microwave brightness temperature values, by using ANN. Two ANNs are trained using either brightness temperature values or Polarization Index (PI) values as input with measured actual soil moisture values as target. The trained ANNs are then capable of estimating the soil moisture values with fair accuracy. The technique using PI and two brightness temperature values as input is found to be a better technique, due to less data requirement for both training and estimation.***

Keywords: Soil moisture, passive microwave remote sensing, brightness temperature, AMSR-2, gravimetric method.

1. Introduction

The Microwave Remote Sensing (MRS) has tremendous potential because of its unique capabilities. It offers specific advantages in applications like soil moisture detection, geological survey for petroleum and mineral prospecting, crop and vegetation monitoring, water resource management, agriculture, oceanography, and atmospheric sciences [1]. The Advanced Microwave Scanning Radiometer 2 (AMSR2) on board the GCOM-W1 satellite is a remote sensing instrument for measuring weak microwave emission from the surface and the atmosphere of the earth and is a multi-frequency, total-power microwave radiometer system with dual polarization channels for all frequency bands.

The brightness temperature is a measurement of the radiance of the microwave radiation traveling upward from the top of the atmosphere to the satellite, expressed in units of the temperature of an equivalent black body. The brightness temperature (or Tb) is the fundamental parameter measured by passive microwave radiometers. Satellite passive microwave radiometers measure raw antenna counts from which we determine the antenna temperature and then calculate the brightness temperature of the Earth [2].

Soil moisture is the water that is held in the spaces between soil particles. Surface soil moisture is the water that is in the upper 10 cm of soil. Soil moisture information can be used for reservoir management, early warning of droughts, irrigation scheduling, and crop yield forecasting. It also helps to understand the initiation of convective events, and to forecast the risk of flash floods, or the Occurrence of fog. Quantitative measurements of soil moisture in the surface layer of soil have been most successful using passive remote sensing in the microwave region [3].

Soil moisture is highly variable in both space and time, rendering it difficult to measure on a continental or global scale that is needed by researchers. Space-based remote sensing of soil moisture accommodates these needs by providing surface soil moisture observations on a global scale every one to two days under a variety of conditions [4]. Although remote sensing has proven to be a valuable tool to measure soil moisture on a global scale, in situ soil moisture measurements are imperative for the calibration and validation of satellite-based soil moisture retrievals. In addition, many studies have focused on error characterization of the different soil moisture products. These studies show that most soil moisture products from remote sensing are capable of depicting seasonal and short term soil moisture changes quite well. However, biases in the absolute value and dynamic range may be large when compared to in situ and modeled soil moisture data [5].

In [6], the relationship between satellite microwave remote sensing polarization index and SM was used to estimate the land surface SM from AMSR-E (Advanced Microwave Scanning Radiometer – Earth Observing System) brightness temperature data. With consideration of land surface soil texture, surface roughness, vegetation optical thickness, and the AMSR-E monthly SM products, the regional daily land surface SM was estimated over the eastern part of the Qinghai-Tibet Plateau. In [7], it is stressed that the Advanced Microwave Scanning Radiometer 2 (AMSR2) on-board the GCOM-W1 satellite has additional features in comparison to its predecessor AMSR-E, as two channels working in C-band are included there. However, soil moisture data obtained from AMSR2 is found to be not accurate for places having large open water bodies [8].

It is also to be noted that the brightness temperatures measured at single frequency do not represent the changes in soil moisture [9]. Therefore a work is done to derive a methodology of finding soil moisture from passive microwave sensed brightness temperature values at different frequencies as obtained from AMSR2, based on Artificial Neural Network (ANN). Also the paper presents a work done to determine the suitable microwave frequencies of the passive microwave sensors which will be suitable for measuring soil moisture.

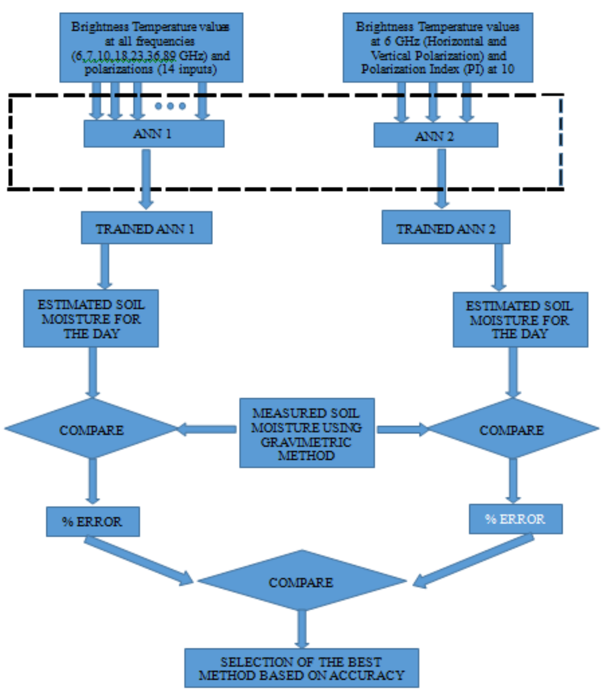

Figure 1. Methodology for selection of the best method for Soil Moisture determination from Passive Microwave Remote Sensed Brightness Temperature data

2. Methodology

Two Methodologies for deriving Soil Moisture from Passive Microwave Remote sensors have been experimented, where ANN are used for both the cases, namely, ANN 1 and ANN 2.

For the first methodology (Methodology-1), ANN 1 is trained using brightness temperature values at all frequencies as inputs (14 inputs) and measured soil moisture as the target. Here the soil moisture is measured using Gravimetric method. Similarly for the second methodology (Methodology-2), ANN 2 is trained using brightness temperature at 6 GHz for both Horizontal and Vertical polarization as well as Polarization Index (PI) at 10 GHz as inputs (3 inputs) and Soil Moisture measured using Gravimetric method as the target.

PI is defined as the ratio of the difference between the brightness temperatures in both horizontal and vertical polarizations to the sum of the brightness temperatures in both polarizations.Comparison between the two Methodologies is done in terms of their accuracy. Fig. 1 shows the two methodologies used for determining soil moisture from passive microwave data.

3. Area of study and data used

Soil Samples are collected from four different places of Meghalaya on different dates ranging from October 2015 to April 2016. The places include Mawlai having latitude and longitude of 25.5º N and 91.8º E, Mawlynrei (25.5º N, 91.9º E), Raliang (25.4º N, 92.3º E) and Jowai (25.4º N, 92.2º E). Since the soil samples for soil moisture measurement are collected during the morning time for all the dates, therefore the AMSR-2 brightness temperature data are also collected only for the ascending (morning) passes of the GCOM satellite for the same days. The brightness temperature data collected are at 6, 7, 10, 18, 22, 36 and 89 GHz frequencies and at both Horizontal and Vertical Polarizations. The soil samples collected from the sites on a particular day are shown in Fig. 2.

Figure. 2. Soil Samples collected

I. TABLE I. ANN CONFIGURATION COMBINATIONS HAVING HIGHER ACCURACY

ANN configuration	Network Training function	Transfer function	Remarks
trainlm_tansig	Levenberg-Marquardt optimization	Hyperbolic tangent sigmoid	Shows high accuracy in estimating soil moisture with methodology-1
traingda_eloitsig	Gradient descent with adaptive learning rate backpropagation	Elliot symmetric sigmoid	Shows high accuracy in estimating soil moisture with both methodology-1 & 2
trainlm_purelin	Levenberg-Marquardt optimization	Linear	Shows high accuracy in estimating soil moisture with methodology-2

II. TABLE II. PERCENTAGE ERRORS IN ESTIMATED SOIL MOISTURE USING METHODOLOGY-1 AND METHODOLOGY-2

Methodology	ANN Configuration	Percentage error values in estimating soil moisture for the places			
		Mawlynrei	Mawlai	Jowai	Raliang
1	traingda_eloitsig	-12.1	7.7	-12	6.7
	trainlm_tansig	-9.5	5.4	-6.9	5.3
2	traingda_eloitsig	-9.3	9.1	-12.5	-7.3
	trainlm_purelin	-4.7	5.5	9.2	-10.7

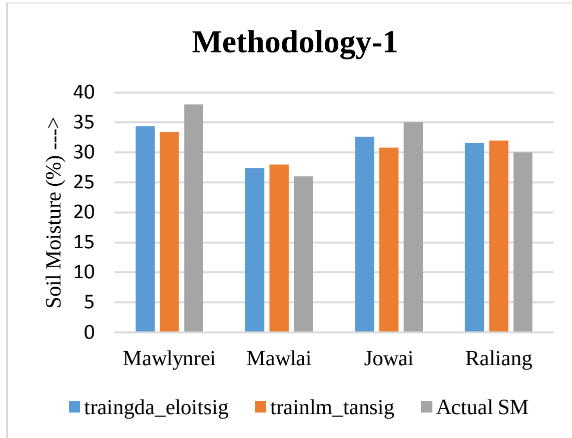

Figure 3: Bar-graph between Actual and Estimated Soil Moisture values for Methodology-1

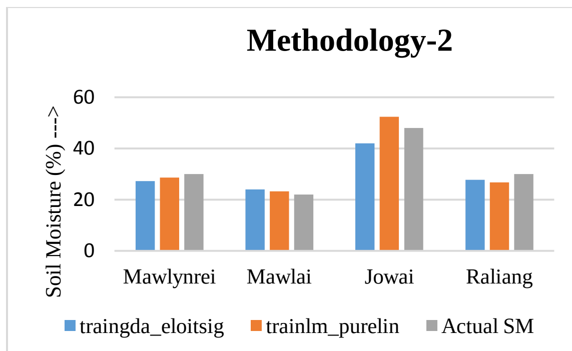

Figure 4: Bar-graph between Actual and Estimated Soil Moisture values for Methodology-2

4. Conclusion

The soil moisture products of passive microwave sensors are often not accurate in regions having large open water bodies. Hence a methodology is derived to estimate soil moisture from brightness temperature values. The brightness temperature values are applied to Artificial Neural Networks for training, with measured soil moisture values as target. The training of the ANNs involve one with 14 inputs of brightness temperature values of the days in different frequencies and polarizations; and the other with brightness temperatures in 6 GHz at vertical and horizontal polarizations as well as Polarization Index value calculated in 10 GHz. Accuracies obtained in soil moisture estimation are found to be similar in both cases and hence the second method requiring less inputs for both training and estimation is considered to the most optimized one for soil moisture estimation. The accuracy level obtained by comparing the ANN estimated soil moisture with the measured soil moisture using Gravimetric method is within ±12.5%. Testing of the methodology can be done for other places on earth to establish it as a valid method of soil moisture measurement globally.

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