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Estimation of soil moisture from sentinel-1a synthetic aperture radar (SAR) in Perambalur district of Tamil Nadu

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Abstract
An attempt was made to estimate and map soil moisture in Perambalur district of Tamil Nadu using sentinel – 1A Synthetic Aperture Radar (SAR) Data. Sentinel -1A C band data with VV and VH polarization were acquired for the study area during September 2018 to January 2019 at monthly interval. Ground truth collections were performed to estimate in-situ soil moisture both by gravimetric method and using TDR probe at the time of satellite pass. Images were processed using SNAP toolbox and backscattering co-efficient (σ^0) were generated for each pixel. The backscattering co-efficient value for VV polarization for different dates varied from -14.28 to -2.47 and for VH polarization it was -21.84 to -9.04 since the backscattering co-efficient has a direct relationship with volumetric soil moisture, the same was correlated with in-situ soil moisture. The correlation value is maximum, minimum in the study period dates of (0.62 to -0.49) and (0.69 to -0.72) represented for VH and VV polarization. The negative correlation occurring dates are dense vegetation occurring the field.

Keywords: Soil moisture, SAR data, VV, VH, backscattering, polarization

Introduction
Soil moisture is majorly contributing the agricultural crop planning (the time of sowing, flowering, and maturity stages). Fresh water is mostly used in (75%) the agriculture crop production. As there is an increase in the fresh water demand, it is important to make optimal use of water resources with improved agricultural productivity through accurate information provided by remote sensing (Lakhankar *et al*., 2009) [5]. Knowledge about the spatial distribution and temporal variation of soil moisture in a region is a pre-requisite for effective crop planning, in-season drought assessment, irrigation management and soil conservation programme. The conventional method of measuring soil moisture using neutron probe, TDR probe and gravimetric methods are not appropriate for understanding of the spatial and temporal dynamics of soil moisture due to variation in topography, soil type and land use pattern. The advances in microwave remote sensing both passive and active have demonstrated the potential to map the spatial extent of soil moisture at different scales (Khedikar *et al*., 2014) [4]. Recent advances in microwave remote sensing have demonstrated the potential toquantitatively measure the soil moisture on bare and short-vegetated surfaces (Engman and Chauhan *et al*., 1995) [1]. Despite the importance of soil moisture information, widespread and continuous measurement of soil moisture is also possible. The remote sensing challenges are top few centimetres of surface soil. Soil penetration depth mainly depends on the wave frequency of the radiation and the condition of the target. At all weather conditions (cloud, rain, storms) microwave penetrates into the soil for 5cm orup to 15cm root zone level of volumetric analysis. Polarimetric radar systems having both soil moisture and surface roughness have been successfully retrieved from a quad-polarimetric radar data set. Oh *et al*., (1992) [6] developed an empirical polarimetric scattering model using a database of scatter meter measurements, which was used to simultaneously retrieve surface root-mean-square (RMS) height and soil moisture contents. It was using C-band ENVISAT ASAR data that is sensitive to soil moisture studies in C-HH polarization data. C-band data is horizontally polarized data channel in conjunction with ancillary data on vegetation. The objective of this study is to map soil moisture distribution of Perambalur District of Tamil Nadu using the data

value of new generation satellite of Sentinel-1ASynthetic Aperture Radar (SAR) data.

Materials and Methods

Study area

Perambalur district boundary on the north by Cuddalore and Salem districts, south by Tiruchirappalli, east by Ariyalur district, west by Tiruchirappalli and Salem districts. The district has an area of 1,756 sq. km. Perambalur District lies in the geographical co-ordinates of longitude 78° 52' 47.9892" E and latitude11° 13' 48.0000" N showed on the (fig. 1) .The period of 1901 – 1970 rainfall ranges from 843.5 to 1123.3 mm. The highest average temperature is 31.7ºC in the month of May, 24.9ºC in the month of lowest average temperature. During the year, the average temperatures vary by 6.8 °C. The precipitation variation between driest and wettest months is the 185 mm. the Perambalur district having a semi-arid climate and contains high humidity. Various land forms occurring in the area such as structural hills, erosional plains, residual hills rolling uplands and pediments of different facies belonging to the denotational and structural land forms. These district major areas occupy the black soil, and minimum areas only occupy red loam and alluvial soils.

Though, the cropping intensity is very high in irrigated systems there is an uncertainty of judicious supply of water in canal i.e., turn system is in practice. Poor distribution of rainfall is a matter of concern to plan for a better cropping programme in rainfed areas. Thus, the monitoring and mapping of moisture zones will certainly help to identify the potential cropping zones in this region and manage irrigation source effectively.

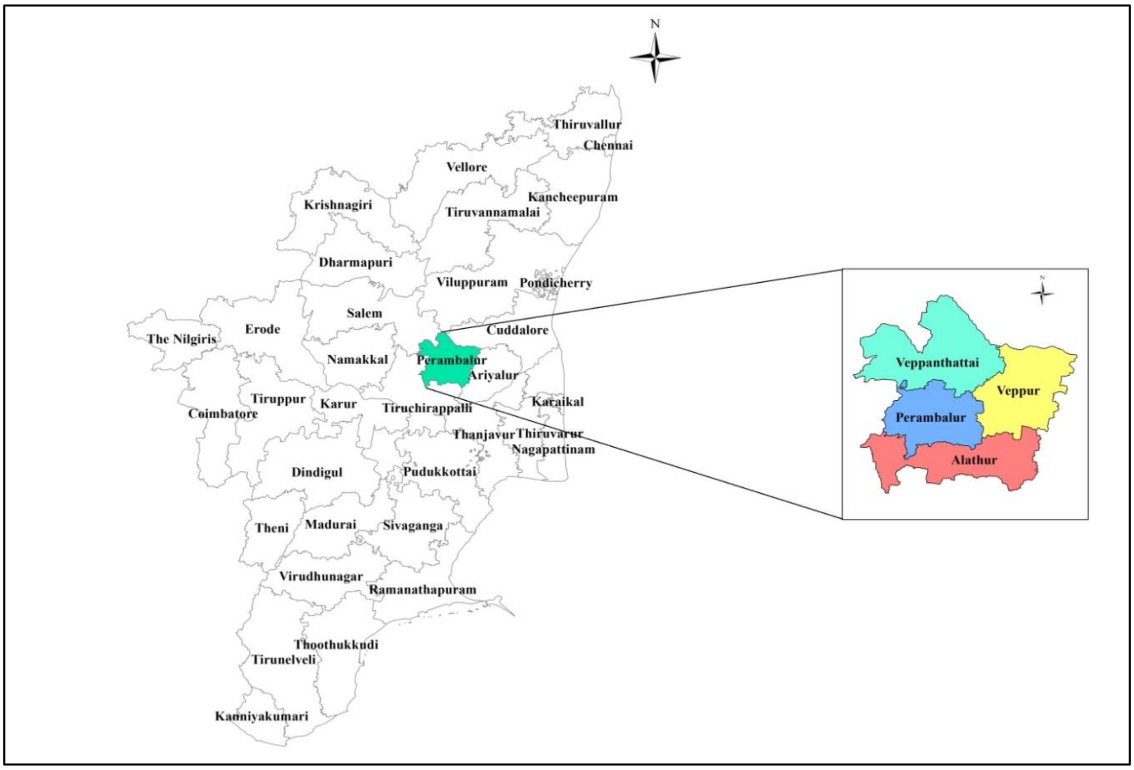

Fig 1: Map showing the study area

Satellite data

The Sentinel-1A SAR data with a spatial resolution of(20*5m) with 12days temporal resolution Interferometric Wide swath (IW) mode was downloaded from the European space agency website and utilized for the study. The characteristics of the sensor are presented in Table 1. (Annonymous, 2019) (https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-1-sar/sar-instrument/acquisition-modes) [3].

Table 1: IW Data Characteristics

Characteristic	Value
Swath width	250 km
Incidence angle range	29.1° - 46.0°
Sub-swaths	3
Azimuth steering angle	± 0.6°
Polarisation options	Dual HH+HV, VV+VH, Single HH, VV
Maximum Noise Equivalent Sigma Zero (NESZ)	-22 dB

Ground truth data

Ground truth verification was carried out in the study area to estimate the *in-situ* soil moisture during different dates which coincides with date of pass of the satellite (between September, 2018 and January, 2019). Soil sampling was done to represent various types of lands (irrigated, rainfed and crop lands).

Data analysis

Image preprocessing of Sentinel-1A IW GRDH dataset was carried out in order to reduce orbital errors, radiometric distortion, geometric distortion and speckle noise. Orbital correction was done using precise orbit files that are available in https://qc.sentienl1.eo.esa.int/ [2] which could be directly downloaded to SNAP toolbox for the orbital correction of the data. Radiometric Correction is a progressive reduction in brightness over images from near to far range (Rosich *et al*., 2004) [7]. Geo-coding converts an image from Ground Range or Slant Range geometry into a map coordinate system. In SNAP toolbox, the terrain correction will be carried out using

SRTM 3sec DEM which is automatically downloaded from the servers.

Post – processing of the satellite data

Speckle filter exploits the space varying temporal correlation of speckle between images to significantly reduce the noise. Refined Lee Sigma filter averages the image while preserving the edges was used to reduce the noise in the data. The intensity values are converted to dB values using the linear to dB conversion tool in SNAP and stored for further processing. Derive sigma naught is a fraction which describes the amount of reflectivity of an object is normalized with respect to a unit area on the horizontal ground plane in the field (Khedikar *et al*., 2014) [4]. This function is also involves the physical and electrical properties of the incident material.

Result and Discussion

The soil moisture retrieved for the study area from the C – band Sentinel - 1A SAR data with the help of ground truth points for various dates of image acquisition. To derive the backscattering values for at the time of ground truth point locations to collect the satellite data collected. The backscattering co-efficient (dB) during the study period of September 2018 to January 2019. The dB value for ground truth point (D1) varied from -22.40 to -14.32, -15.10 -5.88and similar for all the dates VH, VV polarization. Where in satellite pass date wise minimum, maximum, radar backscattering values (dB) presented. The minimum value during the period (D1 to D5) ranged from -22.40 to -18.46 and maximum ranged from -14.32 dB to -9.03 dB, respectively (Table.2). The dB value comparatively good for D1 and D2 date of both VH and VV polarizations. The date wise dB values indicate the low moisture during the non-rainy date of SAR data collection and increases in moisture for during the rainy dates. The correlation vales range -0.49 to 0.62 in VH and -0.72 to 0.69 in VV polarizations occurred. The correlation value is high in D1, D2 and D5for correlation of VV polarization comparatively high in VH polarizations, respectively (Table. 3). D3 and D4 dates are mostly interpreted on high vegetation so can't be correlated on the soil moisture and satellite dB value. Veppenthatai and alathur region is the highly moisture represented on the satellite passing dates, respectively. In this study carried on feature study used to extract backscattering co-efficient and ground points to validate the soil moisture estimation.

Table 2: Minimum and Maximum backscattering (dB) value derived from the VH and VV polarization

VH Polarization		
Sensing date	***Minimum***	***Maximum***
D1	-22.40452	-14.325363
D2	-20.53855	-12.574832
D3	-18.46949	-12.076166
D4	-18.76068	-9.0388775
D5	-19.982494	-9.97371

VV Polarization		
Sensing date	***Minimum***	***Maximum***
D1	-15.106349	-5.881948
D2	-14.228681	-5.259611
D3	-11.299759	-3.300343
D4	-12.454727	-2.472215
D5	-14.275249	-2.764092

Table 3: The correlation between soil moisture and dB value (σ^0) obtained from VH and VV polarization in the study area

VH Polarization	
Sensing date	***Correlation value***
D1	0.42
D2	0.55
D3	-0.49
D4	-0.35
D5	0.62

VV Polarization	
Sensing date	***Correlation value***
D1	0.69
D2	0.51
D3	-0.67
D4	-0.72
D5	0.68

Conclusion

In the study area during the September 2018 to January 2019 the radar backscattering value of soil moisture in different stages of planting and non-planting field are observed in the polarization type (VV and VH). The unique backscattering values derived from ground truth points in the entire locations shows similar trend on soil moisture extraction using Sentinel-1A SAR data.

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