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Short communication

Temporal and spatial estimation of soil moisture using RISAT-1 in semi-arid tropics of India

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Soil moisture is an essential climate variable of major importance for land–atmosphere interactions and global hydrology in rainfed areas. The spatial and temporal variability of soil moisture at scales from small catchments to large river basins is important in the understanding of subsurface - land surface - atmospheric interactions as well as, drought analysis, crop yield forecasting, irrigation planning etc. Microwave bands have proven particularly interesting for this purpose because the soil dielectric constant at these frequencies exhibits a noticeable dependence on the moisture content of the observed bodies (Ulaby *et al.,* 1981, 1982 and Srivastava, 2006). Information on soil moisture before sowing and up to establishing of crop cover is very essential thus serves as a surrogate indicator of general plant health. Vegetation cover is the most important factor that influences the retrieval of soil moisture from MW RS. Previous studies (Neusch and Sties 1999; Sikdar and Cumming 2004) revealed that radar signals of C-band are not significantly affected if vegetation has < 0.4 NDVI value. RISAT-1 is India's first microwave remote sensing satellite carrying aSAR payload operating in the C-band (5.35 GHz). FRS image (spatial resolution of 3 m) and MRS image (spatial resolution of 25m) acquired at circular and Dual polarization have been used for the retrieval of soil moisture in and around Hayatnagar Research Farm of CRIDA situated in Hayatnagar village, Rangareddy district of Telangana. RISAT-1 works well in all weather conditions. The overall aim of the study is to retrieve soil moisture both spatially and temporally based on RISAT-1 SAR data to improve understanding of the hydrological behavior of soil and to derive a correction factor for it.

The experiment was carried out at Hayatnagar Research Farm (17°19'52.549''-17° 21'42.986'' N and 78°35'03.295''-78°36'46.990'' E). The mean annual rainfall is 764 mm and during the time of field data collection the humidity of that area was very low with no rainfall and vegetation. For ground truthing, the samples were collected from agriculture field with no crop stand. There was almost no rainfall during the data collection period. Minimum Sampling Unit Size (in m^2) for RISAT-1 SAR (For an error of 5% on the signal amplitude at 90% confidence interval) for FRS-1 mode of RISAT-1 as suggested by Patel and Srivastava (2013). 134 Soil samples (excluding few samples which were showing extreme values) were analyzed for soil moisture and basic physico-chemical properties. Thematic base maps for the Study area were also prepared for the study area in ArcGis 10.0. Gravimetric soil moisture (SM_G) value was obtained from laboratory analysis, which was converted to volumetric soil moisture (SM_V) by multiplying bulk density (BD).

$$SM_V = SM_G * BD$$

Data procured and processing

RISAT-1 microwave data has been procured from NRSC (National Remote Sensing Centre), Hyderabad for the dates 21st and 23rd March 2014 (FRS under - Circular Polarization), dates - 10th and 12th May 2014 (MRS under - Circular Polarization), dates -3rd November and 21st December 2014 (FRS under - Dual Polarization) and dates - 12th September 2014 (MRS under - Dual Polarization). For the study, software including SARC-View, ENVI 4.3, and ERDAS Imagine were used to process the acquired data. Surface Roughness, Backscatter co-efficient and Dielectric constant (ε was used for estimating SM using Topp model Rawat *et al.,* 2018) were calculated (Thanabalan, 2018; Srinivasa, 2013, Tahnabalan, 2018; Hallikainen, 1985) and the soil moisture determination using RISAT-1 Microwave data was done using a methodology developed given in the flowchart given below (Fig.1). The surface texture indicates that sandy loam and sandy (sand 70-85 %) clay (clay 10-15 %) loam soils are occurring in 33% and 32 % area respectively followed by loamy sand (28%). The subsurface soils are somewhat heavier than the surface layers.

RISAT-1 data analysis

Selection of polarization and resolution which is best suited for soil moisture estimation in the study area after radiometric calibration, backscatter values were compared for different images. FRS 21st March MW data with angle 23

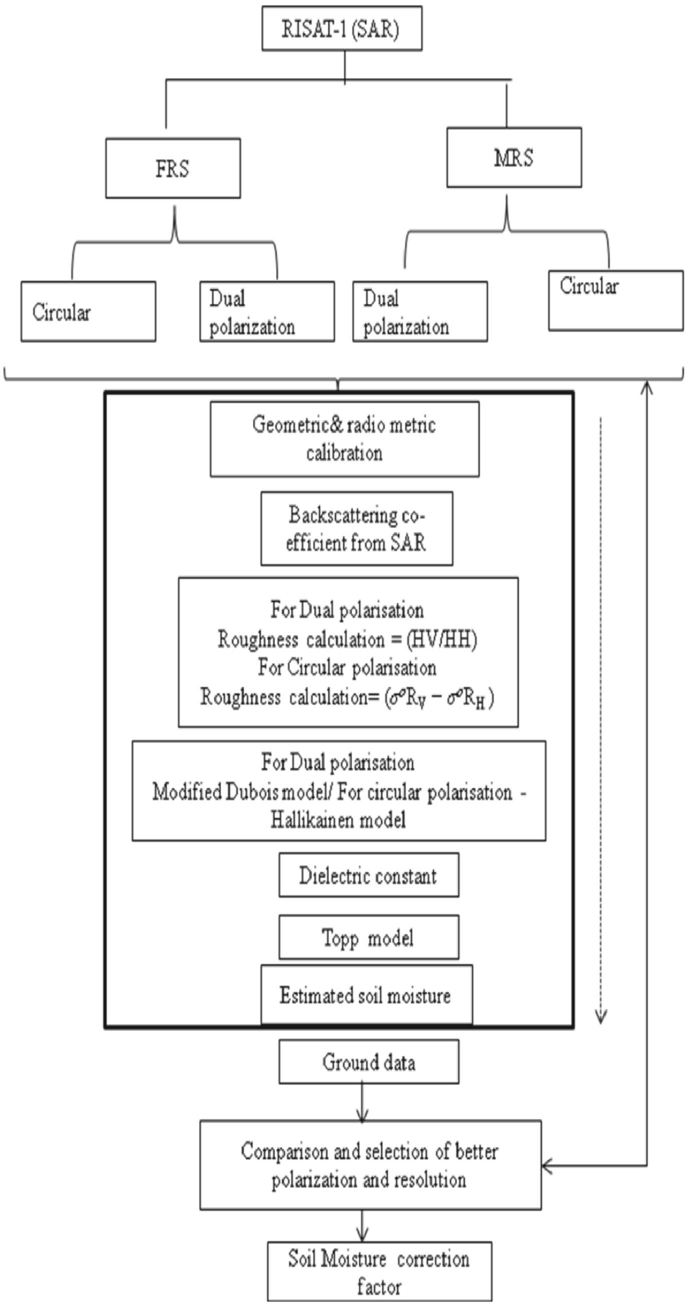


Fig. 1: Methodology chart

degree and MRS 10th May MW data with angle 23 degree (same angle) is compared to choose the resolution which is best suited for soil moisture estimation .FRS data are best suited for the soil moisture estimation of soil moisture in the study area. FRS 23rd march MW data with circular and FRS 3rd Nov MW data with dual polarization with same angle (17 degree) is compared to choose the resolution which is best suited for soil moisture estimation. Dual polarization compare to circular polarization is best suited for the soil moisture estimation of soil moisture in the study area. Soil moisture estimation for dual polarization at particular location as compared to ground truth.

Soil moisture

Topp's model is being used to derive soil moisture. The soil moisture can be secondarily derived from the dielectric constant using (Topp *et al.,* 1980) model. This model has been used by many researchers effectively for retrieving soil moisture (Song *et al.*, 2010) shows good correspondence.

$$\theta_v = -5.3\times10^{-2} + 2.92\times10^{-2}\varepsilon - 5.5\times10^{-4}\varepsilon^2 + 4.3\times10^{-6}\varepsilon^3 \qquad (4)$$

Where: ε is di-electric constant and θ_v is volumetric moisture content.

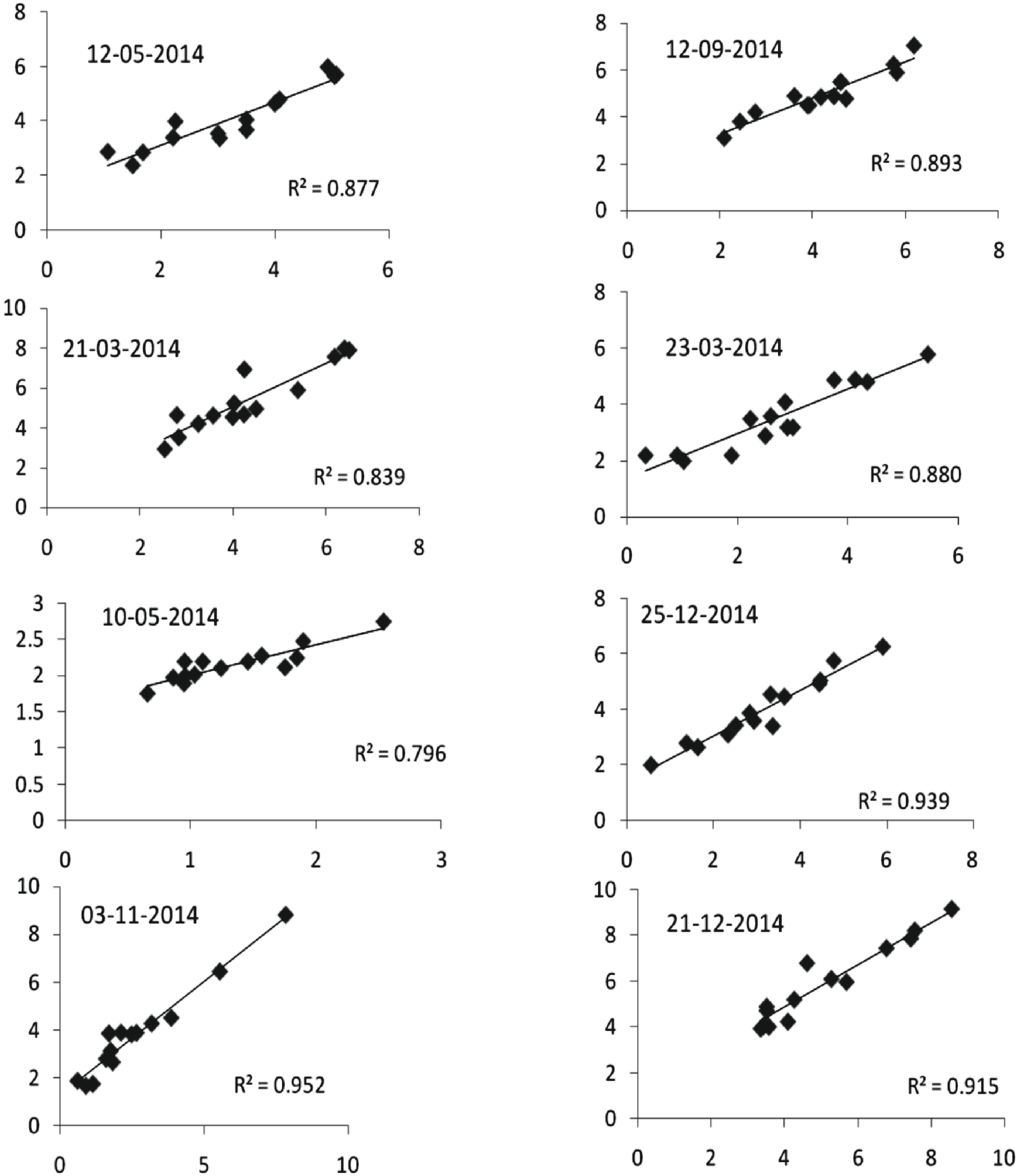
The soil moisture retrieved through RISAT-1 data showed a good comparison with the field measured soil moisture (Fig. 3 and 4). By studying their relationship it was found that FRS dual polarization with less than 20 degree incidence angle shows better (R^2= 0.952) result for soil moisture estimation. Validation sample size was 17-25 as suggested by Patel *et al*., 2013, for the models where R^2_m is 0.85 with 95% of user defined upper limit.

Correction factor: Based on observation and estimated value of soil moisture through microwave data a correction factor was developed for the study area. The soil moisture estimated was more than the observed value as also observed by Palanisamy, 2018 at all the places so a correction factor of -0.90 may be applied to RISAT-1 microwave data to get more

Table 1: Statistical analysis for observed, estimated and estimated value using CF

Particulars	df	Mean ± SE	t-value	95% Confidence interval of the difference	
				Lower	Upper
Observed	111	3.38±.168[A]	20.050	3.04	3.71
Estimated	111	4.19±.163[B]	25.739	3.87	4.51
Estimated value using CF	111	3.31±.161[A]	20.581	2.99	3.63

[AB] Significant at p<0.01



X- axis: Observed soil moisture Y-axis: Estimated Soil moisture

Fig. 2: Relation between observed and estimated soil moisture

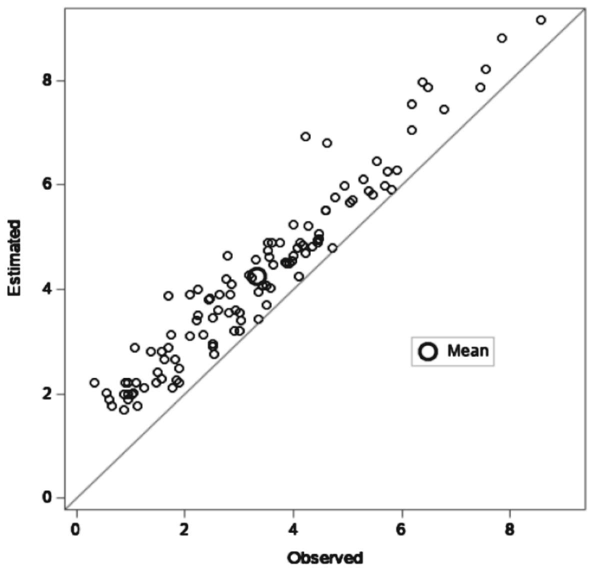


Fig. 3: Agreement of observed and estimated soil moisture

Correlation studies

FRS (Fine Resolution Sensor) data are best suited for the soil moisture estimation of the study area with dual polarization compare to circular polarization is best suited for the soil moisture estimation of the study area. Incidence angle best suited for soil moisture estimation should be between 17° to 20°. Topps model has estimated slightly high soil moisture percentage as compared to the ground truth data collected using a correction factor of -0.90.

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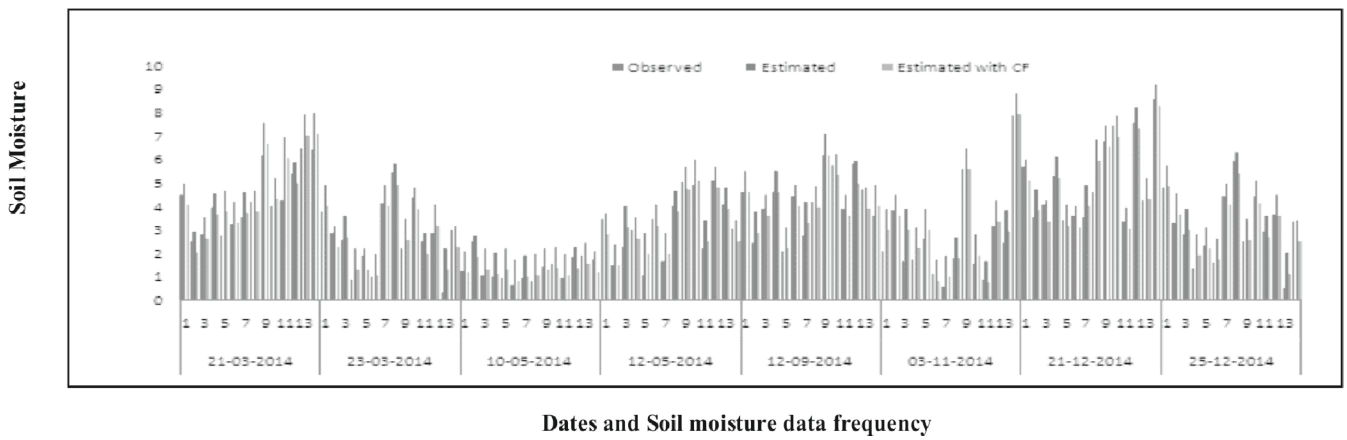

Fig. 4: Average of observed, estimated and corrected soil moisture in different periods of year over different locations

realistic soil moisture value for this region (Fig. 2).

The correction factor was estimated using the following formula:

$$\epsilon = \frac{1}{n}\sum_{i=1}^{n} x_i - y_i,$$

$$y = x + \epsilon.$$

X = Estimated Soil Moisture value

Y= observed Soil Moisture Value

ε = Correction factor

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