Estimation of Soil Moisture Contents of Paddy Fields in Vavuniya District using Remote Sensing Technology

K. Arjunan*[1], S. Suthakar[2] and P. Loganthan[1]
[1]Faculty of Applied Science, Vavuniya Campus of the University of Jaffna, Vavuniya, Sri Lanka
[2]Regional Agricultural Research and Development Centre, Kilinochchi, Sri Lanka

Abstract

Soil moisture is an important bio-physical parameter that is used as an interface for the land surface and for the atmosphere, particularly in agricultural perspective. Cultivation of paddy is a major livelihood activity associated with seasonal rainfall and the supplementary irrigation in Vavuniya District. This study aimed towards the estimation of soil moisture content using remote sensing technology (SEBAL- Surface Energy Balance Algorithm for Land) for paddy fields in Vavuniya District after the *Maha* season during the period of March to July 2012 associated with MODIS products and meteorological data from Vavuniya meteorological station. It was clearly identified except in July, estimated soil moisture content at the top layer (0 - 15 cm) showed both under-estimation and over-estimation. Other estimation of soil moisture correlated perfectly with measured soil moisture content. The obtained root mean square error (RMSE) for each month during the study period lies in the range of 5-10 % except in July (12.58%). Therefore, this estimation could be used to estimate the soil moisture content up to 15 cm from surface to this region. From the estimation of soil moisture content using SEBAL algorithm, estimated moisture content lies in between 30-40 % during March & April. Then, there was a sudden drop of moisture content in May (10-20%) and increased to about 26% in June. Hence, there is a possibility of using residual soil moisture with the supplementary irrigation for the cultivation of crops such as vegetable, chili, oil crops and onion.

Key words: Paddy fields, Remote sensing, SEBAL methodology, Soil moisture content, Validation

Introduction

Soil moisture content is an essential data for hydrological works and for the cultivation practices in which, crops utilize the water or the available moisture that present in the soil. The utilization pattern of moisture varies with cultivation seasons. In rainy seasons (*Maha*) crops dependent upon the utilization of seasonal rain fall while in *Yala* season, crops utilize the small extent of rain water with the supplementary irrigation. The main objective of this study was to estimate the temporal and spatial variations of soil moisture of paddy lands in the study area using remote sensing technology after Maha season. This is required for improving utilization of soil moisture, crop diversification in paddy lands and predictions particularly for supplementary irrigation.

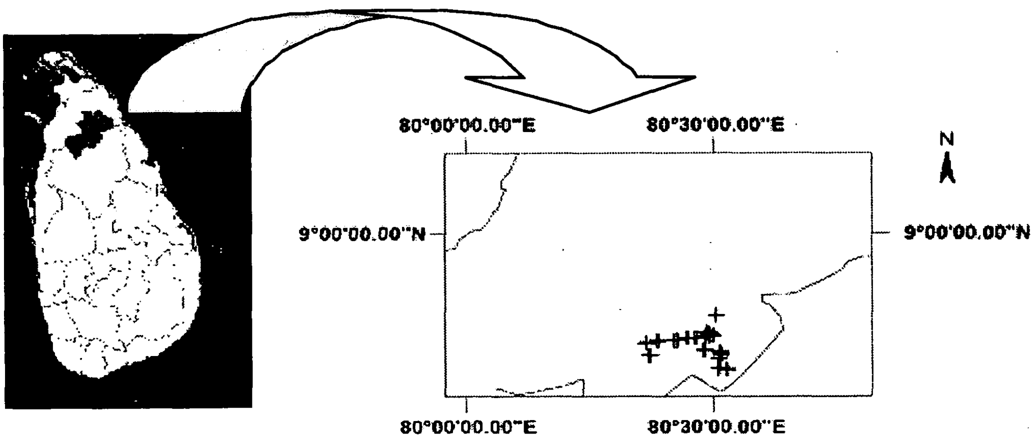

Figure 1. Map of Vavuniya District and study area

***Corresponding author:** arjunan17@hotmail.com

Study area is situated from Komarasankulam to Poovarasankulam (29 X 20 km) in Vavunia District (Figure 1). Study area covers 20 sampling points maintaining minimum distance of 500 m. The general landscape of study area with 3% to 4% of slopes contains minor and medium water sheds and catchment basins. Reddish brown earth, Low humic glay and Alluvial soils which occupy the concave valleys and bottom lands are the main soil groups. The cultivation of subsidiary food crops obtain water mostly from seasonal rain fall and from shallow dug wells which have been constructed at the size of 4 m to 6 m diameter and about 9 m depth.

Materials and Methods

Location identification and soil sampling

The study area was demarcated to identify the soil sampling locations during field visits generally considering paddy growing area using GPS. The soil core samples were collected at 0-15 cm depth as ground truth for all analysis synchronizing with satellite overpass. The meteorological data were collected from Vavuniya meteorological station. Soil moisture content was measured using gravimetric soil moisture content method. Soil texture was found using hydrometer method. Soil pH and EC were measured using pH/EC meter. The soil bulk density was measured using core method.

Satellite image acquisition and processing

From the USGS website, MOD 09 A1 (Solar Zenith Angle), MOD 11 A1 (Land Surface Temperature), MOD 13 A1 (Normalized Different Vegetation Index) and MOD 43 B3 (Surface Albedo) geo-referenced and preprocessed images were downloaded. ILWIS and ENVI image processing software were used for the image processing of MODIS products. Geometric corrections were made for each image. Instantaneous net radiation was developed for each month from solar zenith angle, corrected albedo, land surface temperature, incoming long wave radiation and outgoing long wave radiation image of respective month. The meteorological data affixed with the image processing. Instantaneous soil heat flux was estimated from instantaneous net radiation, albedo, NDVI and LST images. Instantaneous sensible heat flux was calculated by iteration procedure until reach stable aerodynamic resistance and stable sensible heat flux. Instantaneous latent heat flux was calculated from instantaneous net radiation, Instantaneous soil heat flux and Instantaneous sensible heat flux. Evaporative fraction (Van der Tol and Parodi, 2012) was estimated from instantaneous latent heat flux, Instantaneous net radiation and instantaneous sensible heat flux (Parodi, 2002). There were numerous identified patches identified from both LST (Land Surface Temperature) and albedo images after the downloading preprocessed images. Appropriate image correction techniques were applied for particular images.

Estimation of soil moisture from SEBAL algorithm

SEBAL algorithm was used for soil moisture estimation. This algorithm was used on the basis of energy balance of soil surface. All kind of heat energy fluxes is utilized for the estimation. Evaporative fraction is the final output of this algorithm and this fraction was matched with volumetric soil moisture fraction to estimate the soil moisture for larger scale.

Results and Discussion:

Soil analysis

All soils were belongs to sandy clay loam texture. Therefore, these soils are very suitable for crop production activity. The Soil pH was ranged between 7 and 7.5 and electrical conductivity was varied from 1 to 1.5 ds/m . It is confirmed that the above soils are in suitable ranges for crop cultivation (Sirisena *et al.,* 2010).

Estimation of volumetric soil moisture content

The actual volumetric soil moisture content was calculated using porosity values of particular soils. Volumetric soil moisture was estimated using saturated moisture content of soil and actual soil moisture content (Equation 1).

VMC = AVMC/SVMC .... (Equation 1) (Gupta, 2000)

Where;

AVMC - Actual volumetric soil moisture

SVMC - Saturated volumetric soil moisture

VMC - Fraction of volumetric soil moisture

Then, the relationship was made between evaporative fraction which was developed from SEBAL algorithm and volumetric soil moisture content fraction (Equation 2). The area specific coefficients (a = 0.869 and b = 0.625) (Suthakar, 2012) were exercised.

VMC = EXP ((EF - a)/b)   Equation 2 (Gupta, 2000)

Where;

EF - Evaporative fraction

a and b - Area specific coefficients

The above coefficients were incorporated to find out the estimated moisture content of unknown pixels of study area using evaporative fraction values of images.

Validation of moisture content

Validation was made against actual soil moisture content versus estimated soil moisture content developed from satellite images. For this purpose RMSE value calculated as follows for each month during the study period.

$$RMSE = \sqrt{\Sigma_i^n = 0 (X_{ob} - Xexp)^2/n}$$

Where; X_{ob} is measured as value of volumetric soil moisture content and X_{exp} is the estimated value of volumetric soil moisture content. Obtained RMSE of all months except July (12.58 %), were in between acceptable range of 5-10%.

When the estimated volumetric moisture content plotted against the measured volumetric moisture content, most of the values of estimated soil moisture content at the top layer (0 - 15 cm) shows both under-estimation and over-estimation while the other estimation of soil moisture is correlated perfectly with the measured soil moisture content.

Temporal and spatial variation of estimated moisture content

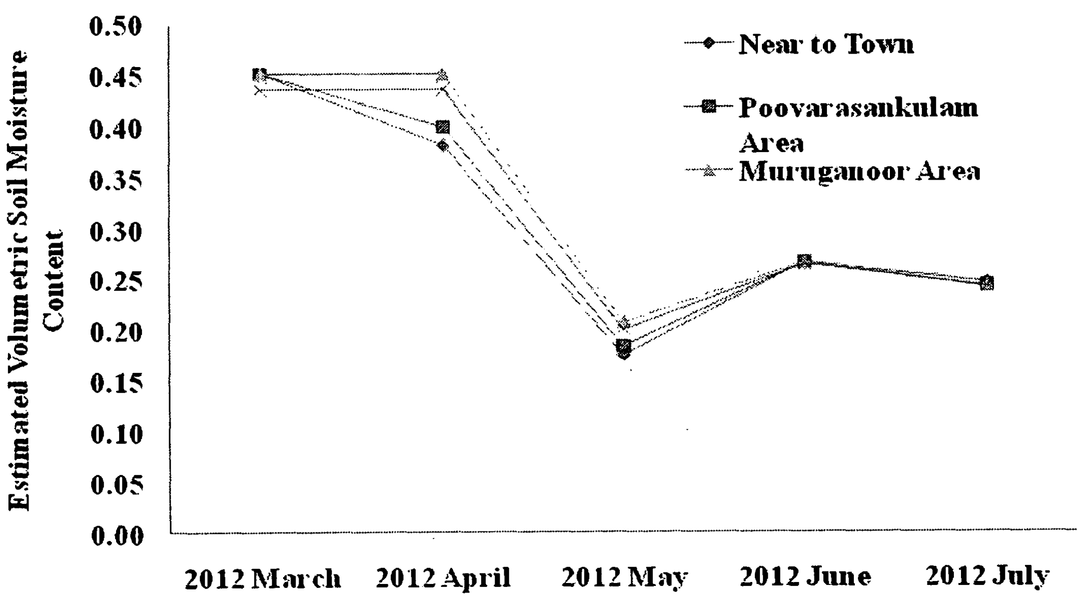

Figure 2. Temporal and spatial variation of estimated volumetric moisture content.

As far as temporal variation of estimated volumetric soil moisture content was concerned, estimated moisture content lied between 30% and 40 % during March & April. Then, there was a sudden drop in May (10-20%) and again reached to about 26 % in June and finally it reached to nearly 15-20 % in July.

As far as the spatial variation was concerned study area distinguished into 4 regions and the pattern of change in the estimated volumetric soil moisture approximately was same throughout the study area.

Estimation of Soil moisture content using remote sensing technology by SEBAL algorithm method, in this study revealed that most of the estimated and measured moisture content values resemble one another while some of the estimated soil moisture content and measured soil moisture contents were slightly deviated from each another. The obtained root mMean square error (RMSE) for each month lied in the range of 5-10 % except in July (12.58%). RMSE values confirmed the accuracy of the estimation in this region. Therefore, this estimation could be used to estimate the soil moisture content up to 15 cm from the surface in this region. This study also concluded that taking of instantaneous and unique meteorological reading is more advisable for the estimation of soil moisture content using SEBAL methodology. Apart from images, soil analysis indicates that these soils are very suitable for field crops because of soil texture, soil pH and soil salinity condition. Therefore, farmers can cultivate any three month-crops such as vegetable, chili, oil crops, onion in this area with the residual moisture for crop diversification with supplementary irrigation. Meanwhile, an attention is required against the soil moisture depletion. As an alternative, implementing water saving techniques or adaptation of other supplementary irrigation practices will be recommended for successful crop diversification and food security of the region.

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