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Studies on agroclimatic elements and soil wetness estimation using MSMR data

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ABSTRACT

Daily actual evapotranspiration, soil wetness and soil moisture adequacy are computed for the selected stations in Andhra Pradesh state for the monsoon period of 1999 to 2002 using the revised water balance model (Thronthwaite and Mather (1955)) from rainfall and potential evapotranspiration and are analysed in space and time.

The daily brightness temperature data (BTD) is retrieved from the 6.6 GHz channel Multifrequency Scanning Microwave Radiometer (MSMR) of IRS-P4 satellite for the monsoon periods (June to August) of 1999 to 2001 and are compared with the soil wetness data. Correlation and regression analysis are made for the soil wetness and BTD for the footprints over Andhra Pradesh to point out the inverse relation between them.

Keywords : Water balance model, soil wetness, brightness temperature dat

Soil moisture influences the infiltration and runoff processes as the hydraulic conductivity and water intake capacity of soil during a rainfall event can be determined by the soil moisture content (Haider *et al.*, 2004). The study of variations in soil wetness (S_{WT}) over a region is of practical importance for the crop and irrigation schedules. The water balance method developed by Thornthwaite (1948) and subsequently modified by Thornthwaite and Mather (1955) is used to obtain moisture gains and losses in storage and actual evapotranspiration (AET) from the inputs of rainfall and potential evapotranspiration (PET) at the surface of the earth. The model helps in deriving the agroclimatic indices such as aridity, humidity and soil moisture adequacy (S_{AD}) to understand the agroclimatic potentialities of the region. The stations that are selected from Andhra Pradesh for the present study are fairly widespread in dry subhumid (Visakhapatnam, Hyderabad and Machilipatnam), moist subhumid (Ramagundam and Nizamabad) and semi arid (Ongole, Ananthapur and Nellore) regions based on season climate concept and is of importance to understand the agroclimatic regime of Andhra Pradesh.

Remotely sensed data in terms of

brightness temperature is very much useful in the study of spatiotemporal variability and in verifying land surface processes (Rao *et al* 2001). Soil moisture can be retrieved by making use of remote sensing observations (Thapliyal *et al*, 2005). Wetzel *et al* (1984) investigated the possibility of estimating soil moisture from the land surface temperature calculated through the infrared data of geosynchronous satellite. Pathak *et al* (1993) reported the estimation of soil moisture using land surface temperature retrieved from the INSAT - VHRR data. Microwave sensors provide a great opportunity to measure soil moisture because these microwave radiations can penetrate the clouds and vegetation over the land surface (Dadhwal and Bhattacharya, 2004). Microwave brightness temperature can be used to measure soil wetness under different surface roughness and vegetation cover conditions (Ahmed, 1995). Thapliyal *et al* (2003) reported soil moisture over India using microwave brightness temperature of IRS-P4. The data retrieved from the MSMR carried by IRS - P4 satellite is useful in providing estimates of soil moisture over large areas.

In the present paper, the authors attempted to study the anomalies in spatiotemporal variability of agroclimatic elements such as rainfall (RR), PET, AET, soil wetness (S_{WT}) and S_{AD} over Andhra Pradesh for the study period. The present study also deals with BTD of 6.6GHz frequency channel of MSMR, taken at 1830hrs IST for the horizontal polarization for the estimation of soil wetness. The evening hour observations are preferred because of fewer thermals, less cloud cover and a more uniform atmospheric layer, which is more conductive to microwave propagation. The sensitivity of brightness temperature to moisture is more at the horizontal polarization than for vertical polarization (Ahmed, 1995).

METHODOLOGY

Since 80 to 85% of the rainfall over Andhra Pradesh occurs during the summer monsoon period (Lakshmnaswamy and Jindal, 1990), the study confines to monsoon season only. Taking daily temperature and rainfall, the water balance model (1955) is forced for the study period in obtaining daily agroclimatic elements.

From the study, the years 2000 and 2002 are categorized as the wet and the dry years respectively based on the percentage departures of these elements from the respective mean of the study period.

Using S_T and AET, PET, the soil wetness and soil moisture adequacy in percentages are calculated with the following formulae for each station respectively.

$$S_{WT} = (S_T/F_C)*100$$

$$S_{AD} = (AET/PET)*100$$

F_C is the field capacity of the station under consideration.

Sarma (1983) reported the spatial

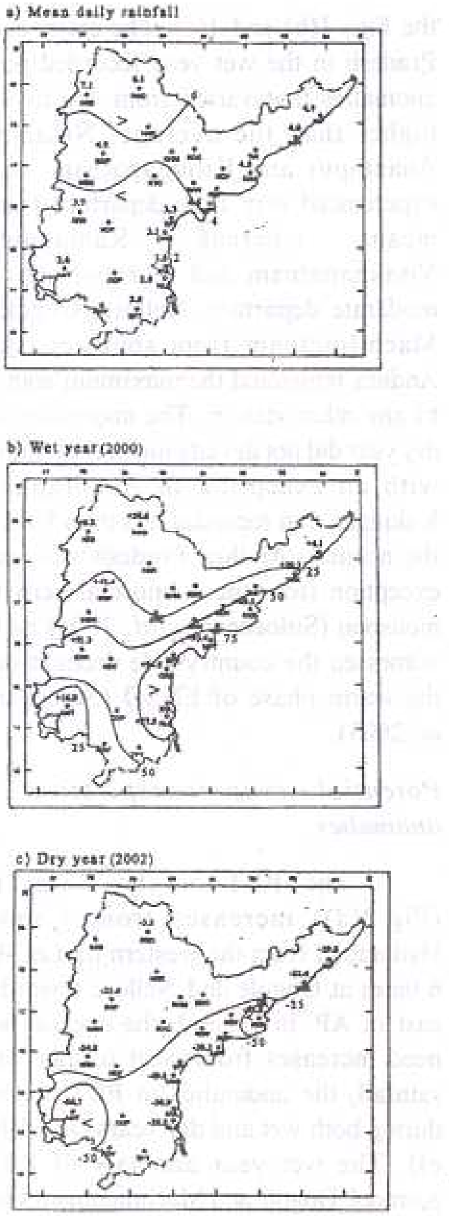

Fig. 1: Mean daily rainfall and anomalies for June to September

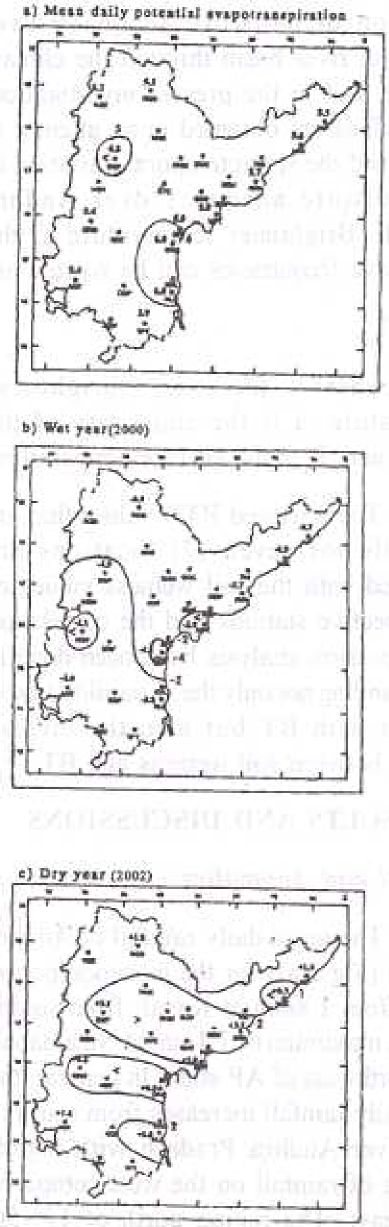

Fig. 2: Mean daily potential evapotranspiration and anomalies for June to September.

variation of moisture adequacy over Mahanadi river basin through the climate concept. But in the present investigation, daily values are obtained in an attempt to understand the spatiotemporal variation of soil moisture adequacy over Andhra Pradesh. Brightness temperature at the microwave frequencies can be written as

$$BT = \mathring{a}T_s$$

where BT is brightness temperature, å is the emissivity of the surface and T_s is the surface temperature

The retrieved BTD values that are available for seven (7) locations are compared with the soil wetness values of the respective stations and the correlation and regression analysis have been done in understanding not only the variability in soil wetness with BT but also the inverse relation between soil wetness and BT.

RESULTS AND DISCUSSIONS

Rainfall and Anomalies

The mean daily rainfall of Andhra Pradesh (Fig.1(a)) for the monsoon period varied from 1.8mm at Kavali from south-east to a maximum of 7.1mm at Nizamabad from northwest of AP state. In general, the mean daily rainfall increases from south to north over Andhra Pradesh with higher amounts of rainfall on the west compared to the east. The region north of 17^0 50^l showed a maximum amount of rainfall of 6mm while south of this recorded less than 4mm. The anomalies of rainfall for the wet (2000) and dry years (2002) are shown in the Figs 1(b) and 1(c). The entire Andhra Pradesh in the wet year recorded positive anomalies that varied from 4% to 97.5% higher than the average. Nizamabad, Anantapur and Kilingapatnam stations experienced very little departure from the mean whereas Ramagundam, Visakhapatnam and Kurnool showed a moderate departure. Nellore, Ongole and Machilipatnam from south coastal of Andhra registered the maximum compared to any other station. The anomalies in the dry year did not deviate much from the mean with an exception to Anantapur and Kakinada that recorded less than 50% from the normal. Andhra Pradesh was not an exception from the subnormal activity of monsoon (Sulochana *et al*, 2005) as India witnessed the countrywide drought due to the warm phase of ENSO (Sulochana *et al*, 2003).

Potential evapotranspiration and anomalies

The PET or the water need (Fig.2(a)) increases from 4.8mm at Hyderabad from the western part of AP to 6.0mm at Ongole and Nellore towards the east of AP. In general, the over all water need increases from west to east unlike rainfall, the anomalies in PET are small during both wet and dry years (Fig.2(b and c)). The wet year anomaly of PET at Kurnool, Ongole and Machilipatnam showed a maximum of -4% from the normal while for the rest of all stations varied from -3.9% to -0.3%. Even in dry year, the anomalies did not deviate much and varied from 0.5 to

Fig. 3: Mean daily soil wetness and anomalies for June to September

Fig. 4: Mean daily soil moisture adequacy and anomalies for June to September

3.1%. Kurnool and Visakhapatnam reported the least deviation of 0.5% whereas Hyderabad showed a maximum departure of 3.1%.

Soil wetness and anomalies

The mean daily values of soil wetness (Fig.3(a)) for the study period varied from 16.4% at Nellore to a maximum of 64.2% at Nizamabad. As in the case of rainfall, the soil wetness also witnessed an increase from south to north of Andhra Pradesh. From the study, it is noticed that, no single station showed the mean soil wetness of more than 75%. The present study highlights that the rainfall of the monsoon period is just sufficient to match the water need of the place. The wet year anomalies (Fig.3(b)) for the soil wetness varied from +5.6% to a high value that is more than 100% from the mean. The southern stations of Andhra Pradesh witnessed a marked deviation from the mean values whereas the northern stations of Andhra Pradesh experienced very little variation from the mean. In the dry year (Fig.3(c)), the departures varied negatively with respect to the mean and Anantapur showed a larger deviation (about 64.6% less than the mean). Kalingapatnam recorded a positive departure of about +4.8%.

Moisture adequacy and Anomalies

The mean moisture adequacy showed a steep increase in its value from 26.2% at Kavali to 75% for Ramagundam (Fig.4(a)). The southern stations such as Anantapur, Nellore, Ongole registered less than 50% of adequacy whereas the northern stations Ramagundam, Hyderabad experienced higher than 50% of moisture adequacy. The low moisture adequacy in the southern part of Andhra Pradesh suggests need for irrigation for a better production from crops. The moisture adequacy during wet year (Fig.4(b)) varied from +4.2% at Kalingapatnam to +88.3% for Nellore. Nellore is the only station that recorded more than 75% departure from the mean while the rest is at less than 50% departure. During the dry year (Fig.4(c)), alomost all the stations indicate a decreasing trend in adequacy that varied from -47.3% at Anantapur to -4.4% for Ramagundam. Kalingapatnam is the lone station from north coastal with a positive departure of 4.7% over the normal adequacy.

Brightness temperature in relation to soil wetness

As BT is a function of surface emissivity and surface temperature, the lands having less emissivity (wet lands) show low BT signatures and is a good indicator of soil wetness status. Similarly, the lands having high emissivity (dry lands) give high BT signatures resulting poor soil wetness values. Nellore showed a maximum BT of 255K for a soil wetness of 1% in the year 1999 and registered a minimum at 197K for the corresponding soil wetness of 80% in the year 2000. Ongole experienced maximum BT of 265K for a soil wetness of 19% in 2001and a minimum BT of 195K for 100% soil wetness in the year 2000. The BT of Anantapur showed

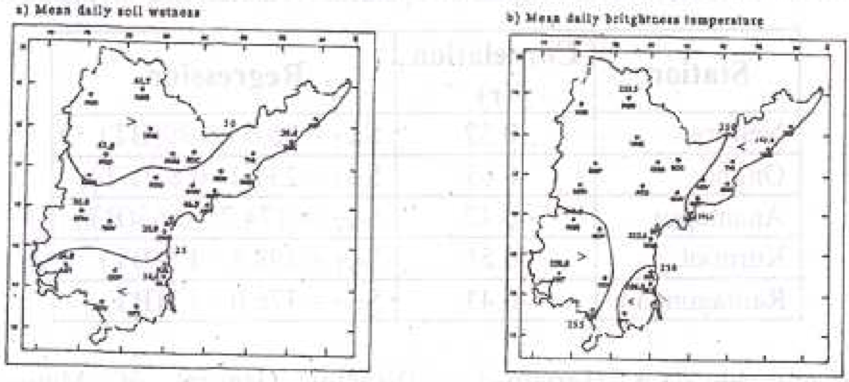

Fig. 5 : Mean daily soil wetness and brightness temperature for the period June to August

the maximum at 278K for a S_{WT} of 5% in the year 2001 and decreased to 216K for the S_{WT} of 89% in 1999. Kurnool and Ramagundam showed the maximum BT of 257K for the 1% soil wetness in the year 2001 and recorded minimum of 212K and 192K for the soil wetness of 100% in 2000 and 1999 respectively. From the study, the authors observed that the BT is mostly varying from 190K to 225K for more than 75% soil wetness and from 250K to 278K for the poor soil wetness(1to 20%). So, it is understandable that the BT of the wet lands having high soil wetness signals can vary from 192K to 225K and for dry lands, it changes from 250K to nearly 280K.

The correlation coefficients between soil wetness and brightness temperature for the respective stations from 1999 to 2001 are presented in Table 1. The correlation between S_{WT} and BT indicate an inverse relation i.e. as the soil wetness increases, the BT decreases and *vice-versa*. Ongole recorded the maximum correlation of -0.63 compared to any other station. The southern stations registered a very low soil wetness of 25% (Fig.5a) whereas the northern part maintained more than 50% of soil wetness. In the case of brightness temperature, the southern part maintained more than 235K (Fig.5b) while in the northern part, it decreased to less than 235K. Anantapur and Ramagundam showed less correlation and might be due to more vegetal cover that reduces the sensitivity of soil wetness to BT. For the coastal stations, the brightness temperature did not respond that much to soil wetness because of high humidity values at these stations that enhance the soil reflectance and is also coupled with mild temperatures that can alter BT inspite of the prevalence of less than 50% soil wetness at Visakhapatnam and Machilipatnam. It is very important to note here that the grid of MSMR used for the retrieval of BT is 150kmX150km which includes ocean contamination (Thapliyal *et al*, 2003) i.e the influence of water vapour and strong winds

Table 1: Correlation coefficients and regression equations for the test sites in Andhra Pradesh.

Station	Correlation (r)	Regression
Nellore	-0.52	S_{WT} = 96.0 - 0.39(BT)
Ongole	-0.63	S_{WT} = 231.1 -0.87(BT)
Anantapur	-0.42	S_{WT} = 174.7 - 0.63(BT)
Kurnool	-0.55	S_{WT} = 398.8 - 1.5(BT)
Ramagundam	-0.43	S_{WT} = 376.0 - 1.3(BT)

from the ocean is more on BT (Ferraro *et al*, 1998) and this might me another causal factor for the perturbed BT values that can mask the soil wetness variations at coastal stations. Regressions obtained between BT and soil wetness taking BT as independent variable for the selected stations yielded to linear fit approximation (Table 1).

CONCLUSION

The daily water balance analysis for the monsoon period helps in understanding the interdaily variability in agroclimatic elements. The study highlights the inverse relation of BT and soil wetness which helps to understand the moisture availability over the study region and illustrate utility of estimating areal soil wetness by using remote sensing data.

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