IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 4, Issue 6 Ver. II (Nov-Dec. 2016), PP 48-54
www.iosrjournals.org

Detection of Soil Surface Warming in Madurai District, South India Using Geospatial Techniques

Suhatha Rahima S, Gurugnanam B
Centre for Applied Geology, Gandhigram Rural Institute – Deemed University
Gandhigram, TN, India
geosuha@gmail.com

Abstract: *The study aimed to analyze the historical changes of soil moisture Index of Madurai District, South India using remote sensing techniques.Soil moisture index retrieved from Landsat data for 1991, 2001, 2003, 2010 and 2016. The NDVI and Land Surface Temperature were calibrated and then the relative soil moisture data were calculated using remote sensing techniques. The soil moisture were classified in to five groups and the changes were monitored since 1991. The black soil possessed high soil moisture and alluvial soil possessed low moisture. The high and very high soil moisture zones were present in 1991image and these zones were absent in other images. The spatial distribution of soil moisture was poor except 1991 image. Low and very low soil moisture zones were common in recent years.The area of soil moisture were correlated with mean air temperature of the study area. The air temperature warming was detected after 1981 and the soil surface warming also detected after 2001.*

Keywords: *Soil Moisture Index, Global warming, Soil Surface Warming, Remote Sensing.*

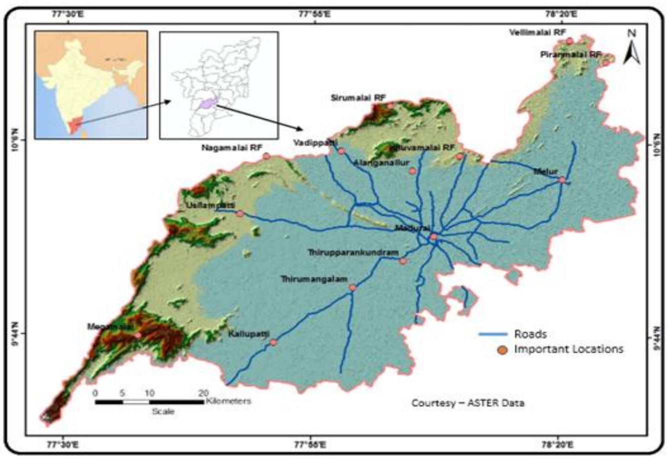
I. Introduction

The historical wetness and dryness of the soil decipher the environmental condition of a region. The climate and water resources have been influenced the soil moisture conditions. The drought and flood events can be predicted through the soil moisture data. The above said technique of retrieving soil moisture index includes the vegetation health and surface climate hence it may serve the details of desertification and land degradation.

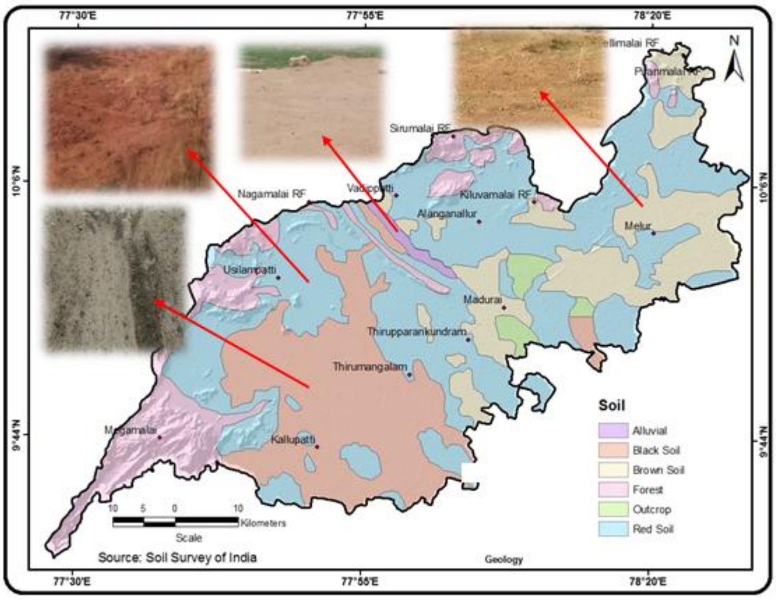
Jian *et al*. (2009) stated that the soil moisture is one of the key proxies of hydrological component which controlling run off, evaporation and infiltration. And they mentioned that soil has a crucial participation in link between biosphere and hydrosphere of the earth. Moran *et al*. (2004), Wagner *et al*. (1999) and De Ridder (2000) retrieve the soil moisture from visible, NIR, SWIR reflectance and thermal emittance. Verstraeten *et al*. (2006) also used visible, Infra-red and thermal bands to retrieve the soil moisture and mentioned that soil moisture is an early warning indicator for the flood and drought study. Maxwell and Atchley (2011) denoted the direct link between energy fluxes, ground surface temperature and total evapotransporation and also linked with the soil-moisture patterns soil and hydraulic-conductivity of the soil. Soil moisture is having an important role in both vegetation dynamics and local atmospheric conditions (D'Odorico *et al*. 2007; Maxwell and Kollet 2008; Ferguson and Maxwell 2010). Surface soil moisture controls on hydrological, meteorological, and organic processes (Nash *et al*. 1991; Berndtsson *et al*. 1996; Famiglietti *et al*. 1998; RodriguezIturbe *et al*. 1999; Baldocchi and Xu, 2007; Maxwell *et al*. 2007; Williams *et al*. 2008; Pan and Wang 2009). Tromp-van Meerveld and McDonnell (2006) explored the relationship between soil moisture, transpiration rates, and species distribution on an established forested hillslope.

1.1. Study Area

The study area is situated in the southern part of Tamil Nadu state, India and it covers 3,741 sq km. Vaigai, is the major seasonal river is flowing across the district. The district covers part of Vaigai, Gundar, Vaipar and Thirumanimuthar basins and also covers parts of Sirumalai, Vellimalai, Megamalai, Kiluvamalai reserved forests. The north and northwestern boundary of the district are hilly regions other parts are showing plain topography. The climate of the region is tropical, which is hot in many months and wet during monsoons.



Madurai District is the 9th highest district in terms of population size among the districts in Tamil Nadu. The district urban population share is 60.8%. The population density of the district is 819 persons per square kilometer. The total population of the district is 30,38,252 by 2001 census report. The district is not endowed with good forest resources. Madurai district is the second important region in Tamil Nadu, which have the noteworthy potential for the future development of Tamil Nadu. Madurai district has extensive rural vicinity and serves as an important trade and commercial center of the state. It is also having heritage symbols and growing population. The city Madurai receives, 2,10,000 visitors every day. The study area is covered by four different soil types. The soil classification is based on the soil colour. The Alluvial soil has reported in the flood plains of vaigai and south western parts of the district, parts of sedappatti, kalluppatti and kallugudi blocks are covered by Black Soil (Fig. 1.5). The north eastern parts of the district is shielded by brown soil. Red soil is seen in usilampatti, vadipatti, melur and madurai south blocks.



1.2.

1.3.

1.4. Dataset and Methodology

The historical Landsat data were collected for March month of 1991, 2001, 2003, 2010 and 2016. The soil moisture retrieval possesses three steps and they are NDVI calibration, surface temperature calibration and soil moisture retrieval. Surface temperature (T, Kelvin) and Normalized Difference vegetation Index were calibrated for all images. Wet and dry ends of linear equations were calculated to calculate the relative soil moisture data. The dry and wetedge linear equations are calculated as follows (Jian et al. 2009):

Dry edge:

$$Tmax = -18.356343 * NDVI + 307.57766$$

Wet edge:

$$Tmin = 0.68168266 * NDVI + 288.26377$$

The relative soil moisture data was calibrated for data sets using the following formula.

$$SMI = 100 - \frac{T - Tmin}{Tmax - Tmin} \times 59.29378862$$

Where SMI is the Soil Moisture Index and T is the Surface temperature of the pixels. The wetness of the soil was classified into five groups. The soil moisture index ranges in positive and negative values. The negative values indicate the dryness and positive values indicate the wetness of the soil. This has been classified as very low, low, moderate, high and very high soil moisture indices. The clear water, water plants and ever green vegetation have very high SMI. The built-up and outcrops have very low SMI.

II. Results and Discussion

1.4.1. NDVI Maps

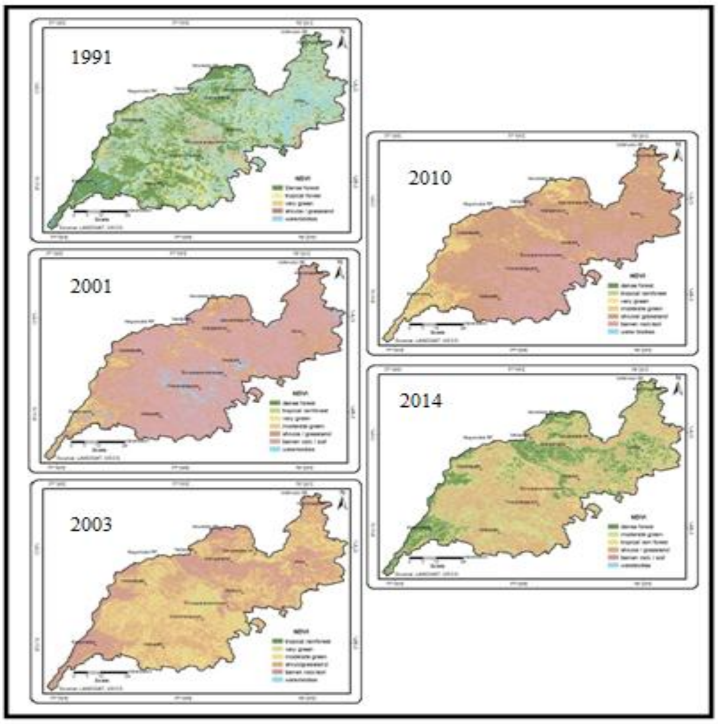


Fig. 3. NDVI Maps

1.4.2. Land Surface Temperature Maps

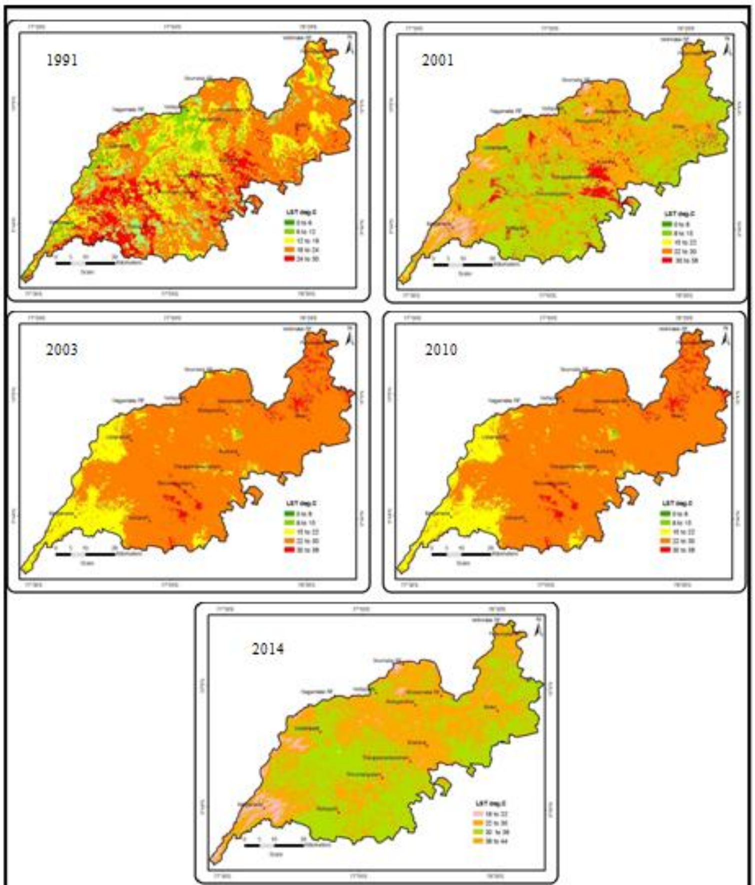


Fig. 4. Land Surface Temperature Maps

1.4.3. Soil Moisture Index (SMI)

The spatial distribution of different SMI zones were also calculated in GIS environment. The soil moisture zones were distributed differently in each image (Table 1). In 1991 image (Fig.5), the soil moisture ranges from very low to very high. 17.04 km^2 of area retained very low SMI, 0.12 km^2 had retained very high SMI. The low and moderate SMI areas were 1264.94 km^2 and 2253.06 km^2 respectively. 208.8 km^2 were retained high SMI. The 2001 image (Fig. 6) revealed that 1370.90 km^2 and 2372.95 km^2 had classified under low and moderate SMI respectively. There were no other classes in 2001 image.The 2003 image (Fig.7) did not exhibit the very high SMI. The 1.39 km^2 area had very low SMI. 757.08 km^2 and 2985.35 km^2 areas were classified as low and moderate SMI zones. Only 0.098 km^2 area had retained the high SMI. 2010 image (Fig. 8) shown very low SMI in 2.77 km^2, low SMI in 99.84 km^2, moderate SMI in 3598.21 km^2 and high SMI in 43.09 km^2. 2016 image (Fig. 9) shown moderate and low SMI zones and their spatial extent were 2347.15 km^2 and 1396.77 km^2.

Table 1. Spatial Extent of Soil Moisture Index Zone

Soil Moisture	1991	2001	2003	2010	2016
Area in km^2					
Very low	17.04	-	1.39	2.77	-
Low	1264.94	1370.98	757.08	99.84	1396.77
Moderate	2253.06	2372.95	2985.35	3598.21	2347.15
High	208.8	-	0.098	43.09	-
Very high	0.12	-	-	-	-

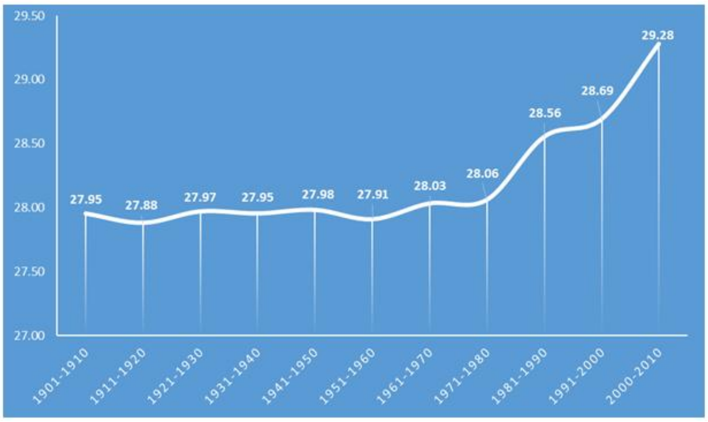


Fig. 5. Soil MoistureMap of 1991

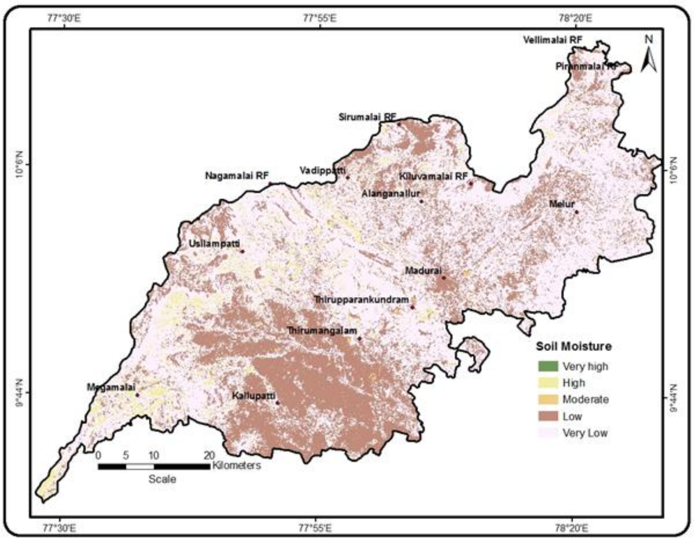


Fig. 6. Soil MoistureMap of 2001

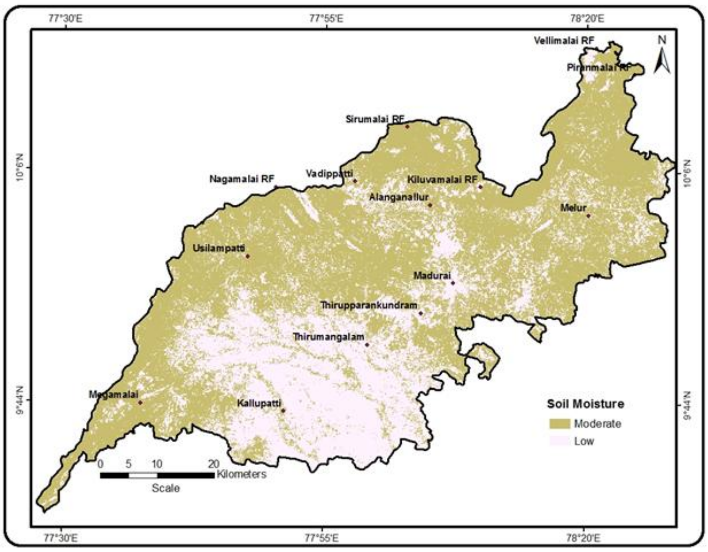


Fig. 7. Soil MoistureMap of 2003

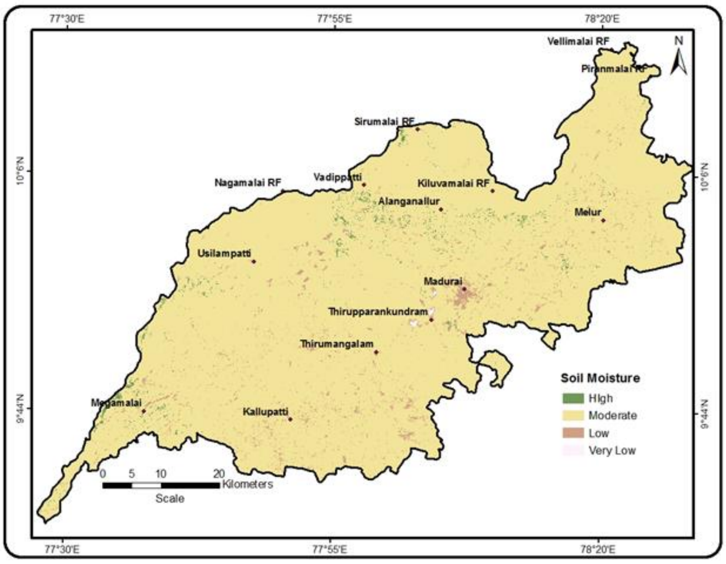


Fig. 8. Soil MoistureMap of 2010

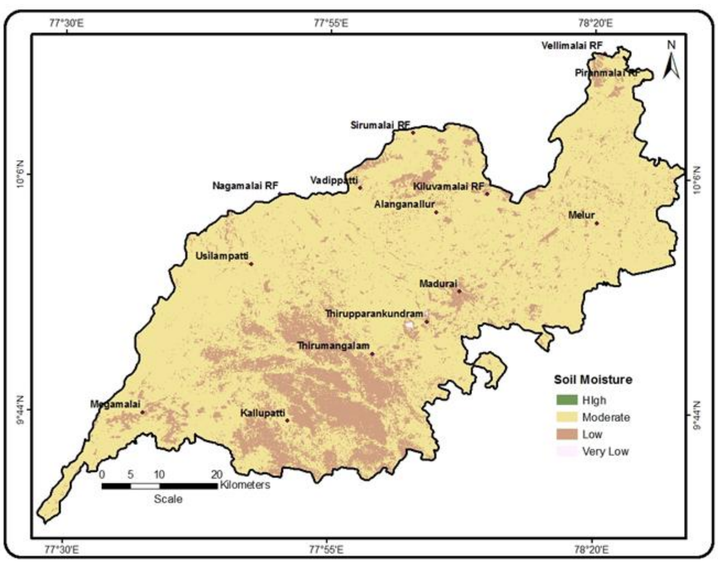


Fig. 9. Soil MoistureMap of 2016

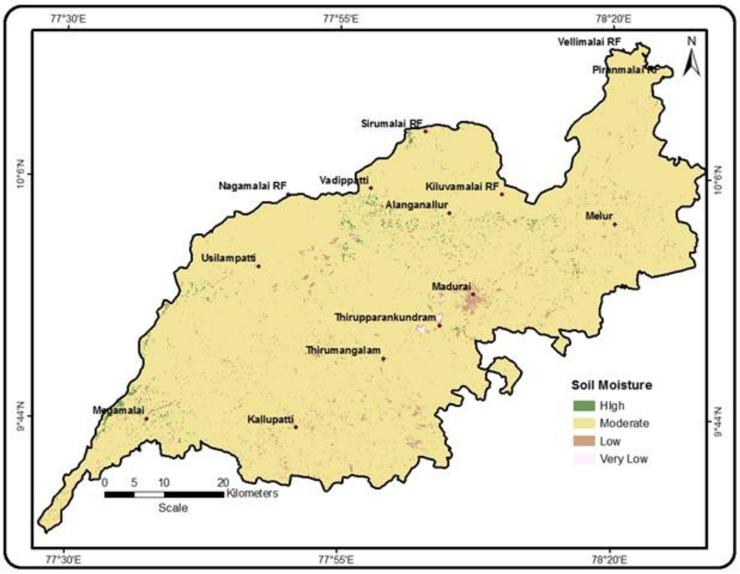


Fig. 10. Mean Temperature of Decades from 1901 to 2010

The black soil region showed the relatively high moisture and alluvial and brown soil possessed low soil moisture. The red soil possessed moderate soil moisture and the forest region were always having high and moderate soil moisture even during summer. The outcrops were covered by very thin soil cover and showed dry condition in the satellite images. The air temperature removes the moisture from soil and vegetation. Global warming and rising temperature are the major causes for the dynamics of soil moisture in the study area. The annual mean air temperature of the study area were analyzed for 1901- 2010 period.The decadal average mean temperature were plotted (Fig. 10). The graph showed the mean temperature has raised 2^0C in the last 110 years. The mean temperature was below 28^0C till 1960. The mean temperature was raised above 29^0C during 2001-2010. During the industrial era mean temperature rise was rapidly raised to 1.22^0C. Before 1980, the temperature raise was only 0.11^0C during 1901-1980. During 1981-1991 the air temperature started increasing and the soil moisture data was moderately distributed. The 1991 soil moisture data showed the high and very high classes which revealed low warming in the study area. After 1991, the district did not showed high soil moisture zones and the distribution was poor. In 2010 image the high soil moisture zones was 43.09 km^2 and this year was meteorologically wet year. Other images were showed poor distribution and low soil moisture and the warming effect were noticed in the study area. Results from many numerical models have suggested that climatic warming will accelerate the release of carbon dioxide from soils, leading to additional warming (Cox *et al*. 2000; Dufresne *et al*. 2002; Friedlingstein *et al*. 2003). Results of this study proved that, when air temperature is increasing, the soil also getting warm. This could lead more loss of moisture and lead an inconvenient environment. Madurai district is getting warmer and losing its soil wetness which cause great biodiversity loss in future.

III. Conclusion

This study was tried to analyse the spatial dynamics of the soil moisture index and related with soil type. From the above results, soil surface warming is detected in the study area. The loss of soil moisture is the warning for soil infertility anddegradation. Soil moisture is also the key finder for ground water level. The soil surface warming in the study area indicates the decreasing ground water reserves.The author plan to work for the entire state and identify the vulnerable zones and also plan to relate with climate, topography, soil, vegetation, water level and geology.

Acknowledgments

The authors would like to thank the INSPIRE Division, Department of Science and Technology, Government of India, for financially supporting this research.The author thank reviewers for their suggestions and reviews.

References

[1] Baldocchi, D.D. and Xu, L. (2007) What limits evaporation from Mediterranean oak woodlands: the supp. ly of moisture in the soil, physiological control by plants or the demand by the atmosphere? Adv. Water Resour. V. 30, pp. 2113–2122.
[2] Berndtsson, R., Nodomi, K., Yasuda, H., Persson, T., Chen, H. and Jinno, K. (1996) Soil water and temperature patterns in an arid desert dune sand. J Hydrol., v. 185, pp. 221–240, doi:101016/jadvwatres.2006.06.013.
[3] D'odorico, P., Caylor, K., Okin, G.S. and Scanlon, T.M. (2007) On soil moisture–vegetation feedbacks and their possible effects on the dynamics of dryland ecosystems. J. Geophys. Res. v. 112, G04010. doi:1029/2006JG000379.
[4] De Ridder, K. (2000). Quantitative estimation of skin soil moisture with the Special Sensor Microwave/Imager. Boundary-Layer Meteorology, v. 96, pp. 421−432
[5] Famiglietti, J.S., Rudnicki, J.W. and Rodell, M. (1998) Variability in surface moisture content along a hillslope transect: Ratlesnake Hill, Texas. J Hydrol., v. 210, pp. 259–281. doi:10.1016/S0022-1694(98) 00187-5.
[6] Ferguson, I.M. and Maxwell, R.M. (2010) The role of groundwater in watershed response and land surface feedbacks under climate change. Water Resour Res., v. 46:W00F02. doi:10.1029/ 2009WR008616.
[7] Ji Jian, Peifen Pan, Yuanyuan Chen and Wunian Yang, (2009) Soil Moisture Retrieval Quantitatively with Remotely Sensed Data and Its Crucial Factors Analysis, J. Water Resource and Protection, v. 1, pp. 439-447.

[8] Maxwell, R.M. and Adam L. Atchley (2011) Influences of subsurface heterogeneity and vegetation cover on soil moisture, surface temperature and evapotranspiration at hillslope scales, Hydrogeology Journal, v.19: 289–305
[9] Maxwell, R.M., Kollet, S.J. (2008) Capturing the influence of groundwater dynamics on land surface processes using an integrated, distributed watershed model. Water Resour Res v. 44:W02402. doi:1029/2007WR006004
[10] Moran, M.S., Peters-Lidard, C.D., Watts, J.M., and Mcelroy, S. (2004) Estimating soil moisture at the watershed scale with satellite-based radar and land surface models. Canadian Journal of Remote Sensing, v. 30(5), pp. 805-826.
[11] Nash, M.S., Wierenga, P.J. and Gutjahr, A. (1991) Time series analysis of soil moisture and rainfall along a line transect in arid rangeland. Soil Sci, v. 152, pp. 189–198.
[12] Pan, Y.X. and Wang, X.P. (2009) Factors controlling the spatial variability if surface soil moisture within revegetated-stabilized desert ecosystems of the Tengger Desert, northern China. Hydrol Process v. 23, pp. 1591–1601. doi:10.1002/hyp.7287.
[13] Rodriguez-Iturbe, I., D'odorico, P., Porporato, A., Ridolf, L. (1999) On the spatial and temporal links between vegetation, climate, and soil moisture. Water Resour Res., v35(12), pp. 3709–3722. doi:10.1029/1999WR900255
[14] Tromp-Van, Meerveld, H.J. and Mcdonnell, J.J. (2006) On the interrelations between topography, soil depth, soil moister, transpiration rates and species distribution at the hillslope scale. Adv Water Resour., v. 29, pp. 293–310. doi:10.1016/j.advwaters.2005.02.016.
[15] Verstraeten W., William, Frank Veroustraete, Corné J. Van Der Sande, IEF Grootaers and Jan Feyen, (2006) Soil moisture retrieval using thermal inertia, determined with visible and thermal spaceborne data, validated for European forests, Remote Sensing of Environment, v. 101, pp. 299–314.
[16] Wagner, W., Lemoine, G., and Rott, H. (1999) A method for estimating soil moisture from ERS Scatterometer and soil data. Remote Sensing of Environment, v. 70, 191-207.
[17] Williams, C.J., Mcnamara, J.P. and chandler, D.G. (2008) Controls on the temporal and spatial variability of soil moisture in a mountainous landscape: the signature of snow and complex terrain. Hydrol Earth Syst Sci., v. 13, pp. 1325–1336