Comparative Study of Different Vegetation Indices for Savitri Basin using Remote Sensing Data

T. V. Bhambure, K. D. Gharde*, D. M. Mahale, S. B. Nandgude, M. S. Mane, T. Bhattacharyya
College of Agricultural Engineering and Technology, Dapoli
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli - 415712 Maharashtra (India)

Abstract

Soil moisture is spatially and temporally highly variable, and it influences range of environmental processes in a nonlinear manner. The characterization of temporal and spatial variability of soil moisture is highly relevant for understanding the many hydrological processes, to model the processes better and to apply them to conservation planning. The vegetation indices (VI) adopted for qualitatively and quantitatively evaluating vegetative covers using spectral measurements. The spectral response of vegetated areas presents a complex mixture of vegetation, soil brightness, environmental effects, shadow, soil colour and moisture. This study investigates comparative applicability of NDVI, SAVI and MSAVI to estimate the soil moisture using NDWI for Savitri basin for the period 1999-2003. The highest value of NDVI and SAVI was obtained in year of 1999 while the highest value of MSAVI was obtained in year of 2000.The moisture variation level by NDWI method was high in Savitri basin in the year of 1999 with threshold of 137-255. The moisture variation in the watershed estimated by NDWI using Landsat dataset is very useful for proper crop planning management, estimate moisture stress period, decide cropping system and density, estimate crop productivity.

Keywords: Normalised Difference Vegetation Indices, Soil Adjusted Vegetation Indices, Normalised Difference Water Indices, Soil moisture

***Corresponding author :** ghardek@rediffmail.com

Introduction

The usefulness of vegetation indices lies as an aid to remote sensing image interpretation, the detection of land use changes, and the evaluation of vegetative cover density, forestry, crop discrimination and crop prediction. Land surface temperature (LST) is a key parameter for many environmental studies such as global environmental change, climate models, and human-environment interactions. Land surface temperature (LST) is an important factor in vegetation growth, and glacier [Bannari *et al.* 1995]. Knowledge of surface soil moisture at the watershed scale would be useful for such critical applications as regional resource management during times of drought or flooding. Knowledge of soil moisture is useful for proper crop planning management, estimate moisture stress period, decide cropping system, density and estimate crop productivity. It will also help in deciding drought status in the basin in different seasons in the academic year. Also the estimation of soil moisture is adopted for crop planning and their management.

Vegetation Indices (VIs) are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation. They are derived using the reflectance properties of vegetation. Each of the VIs is designed to accentuate a particular vegetation property (Singh *et. al.*, 2010). The vegetation indices are influence by external and internal factors (Yoshioka *et al.* 2000, Basso *et. al.* 2004) such as sensor calibration, sun and view angle, and atmospheric condition, variation in canopy, leaf optical properties and canopy background. The vegetation indices are useful for assessing vegetation condition, foliage, cover, phenology, and processes such as evapotranspiration (ET) and primary productivity, related to the fraction

of photosynthetically active radiation absorbed by a canopy (Glene and Huete 2008). Spectral vegetation indices (VIs) have been used for monitoring of Earth's vegetative cover as a precise radiometric measure of green vegetation. The analysis of vegetation and the detection of change in vegetative patterns are keys to natural resource assessment and monitoring. One of the major applications for remote sensing data is the detection and quantification of green vegetation (Ahmad 2012). Normalised Difference Vegetation Index (NDVI) [Rouse *et al.* 1974] is most economical dynamic indices compared to Soil Adjusted Vegetation Index (SAVI) [Huete *et al.* 1988] and Modified Soil Adjusted Vegetation Index (MSAVI) [Qi *et al.* 1994] but NDVI does not count the brightness from soil surface leads to NDVI have different value at different brightness (Huete *et al.* 1985, Linlin *et al.* 2015). Reflective Bands are used to determine NDVI, Modified Soil Adjustment Vegetative Index (MSAUI) and Normalised Differential Water Index (NDWI). The three different vegetative moisture estimation methods namely MSAUI - LST (land surface temperature), feature space identification, NDWI and Vegetation Dryness Index (VDI) is applied to determine vegetation moisture level (Singh *et al.* 2010, Klemas and Pieterse 2015). Therefore there is need to compare the performance of NDVI with other indices such as SAVI and MSAVI with different changing time period in different seasons (Singh *et al.* 2010).

By considering the above fact, NDVI, SAVI, and MSAVI indices were determined for Savitri Basin of different years i.e 1999, 2000, 2002 and 2003 using remote sensing image to study the variation in indices and compute the moisture variation. The comparative performance of the adopted indices is present in this study.

Materials and Methods

Study area

The Savitri river basin comes under the Western part of Sahyadri Ghat part of Konkan region. Study area belongs to Mahad and Poladpur Tahshils of Raigarh district in Konkan region of Maharashtra state. The latitude and longitude of the study area is $18^0$20'N to $17^0$51'N and $73^0$22' E to $73^0$41'E respectively and elevation ranges from 6.50 m to 1366.23 m MASL. The location of Savitri Basin is given in Figure 1. The main stream of the study is Savitri river basin has average length of 57.57 km.Average annual rainfall in the area is 3560 mm in the form of intense storms and its distribution is

Table:1 Details of Satellite Data Collected of Landsat 7 (Enhanced Thematic Mapper Plus ETM)

Sr. no.	Image details	Satellite/ Sensor	Reference system	Path/Row
1.	November 1999	Landsat 7/ ETM+	World Wild Reference System –II (WRS-II)	147/47 and 147/48
2.	October 2000	USGS Earth Explorer	WRS-II	147/47 and 147/48
3.	September 2002	USGS Earth Explorer	WRS-II	147/47 and 147/48
4.	March 2003	USGS Earth Explorer	WRS-II	147/47 and 147/48

Source: www.earthexplorer.gov.in)

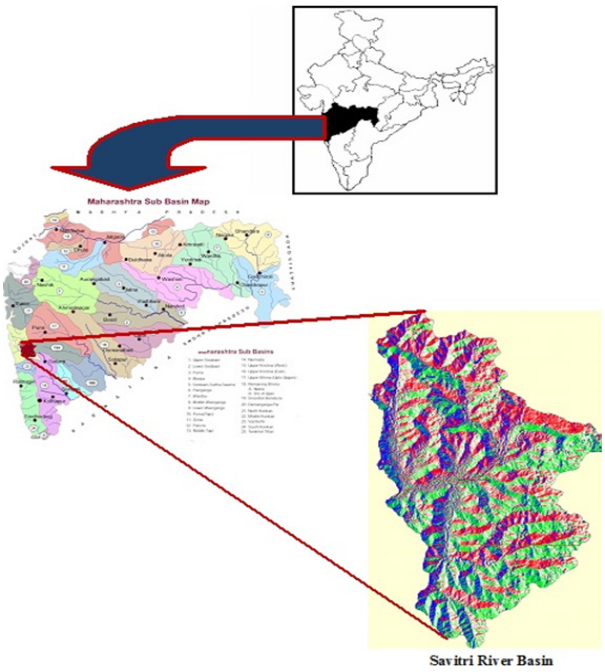

Figure 1. Location Map of Savitri Basin

highly erratic as more than 90 percent occurred during the monsoon months (June to October). Topography of the watershed is undulating with the land slope varying from more than 30 percent.

Data Used

Cloud Free Landsat satellite data of 1999, 2000, 2002 and 2003 for the study area has been downloaded from Landsat data and official website of USGS (www.earthexplorer.gov.in). All the data were pre-processed and projected to the Universal Transverse Mercator (UTM) projection system. The details of the satellite data collected and Band designation are given in the Table 1.

Normalized Difference Vegetation Index (NDVI)

The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyse remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not. The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which allows us to generate an image showing the relative biomass. The chlorophyll absorption in Red band and have relatively high reflectance of vegetation in Near Infrared band (NIR) were used for calculating NDVI. Values close to zero represent rock and bare soil where negative values represent water, snow and clouds. By taking a ratio of two bands drop the values between -1 to +1. Water has an NDVI value less than 0, bare soils between 0 and 0.1, and vegetation over 0.1. Increase in the positive NDVI value means greener the vegetation.

The NDVI is calculated from reflectance measurements in the red and near infrared (NIR) portion of the spectrum with the help of Equation 1. NDVI estimated from RS Images in GIS environment using standard procedure.

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}} \quad \ldots\ldots (1)$$

Where,

NDVI = Normalized Difference Vegetation Index,

NIR = Near Infrared band value for a cell,

RED = Red band value for the cell.

Soil Adjusted Vegetation Index (SAVI)

Soil Adjusted Vegetation Index shows background soil conditions. SAVI is a hybrid between NDVI and PVI (Perpendicular Vegetation Index). The SAVI is calculated using Equation 2. SAVI estimated from RS Images in GIS environment using standard procedure.

$$\mathrm{SAVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED} + \mathrm{L}} \times (1 + \mathrm{L}) \quad \ldots\ldots (2)$$

Where,

SAVI = Soil Adjusted Vegetation Index,

NIR = Near Infrared band value for a cell,

RED = Red band value for the cell,

L = constant to minimize soil brightness influences and to produce vegetation iso-lines independent of the soil background equal to 0.5.

Modified Soil Adjusted Vegetation Index (MSAVI)

A Modified Soil Adjusted Vegetation Index (MSAVI), proposed by Qi *et al.* (1994) was created using VNIR and RED band. The MSAVI is calculated using Equation 3. MSAVI estimated from RS Images in GIS environment using standard procedure.

$$\mathrm{MSAVI} = \rho_n + 0.5 - \sqrt{(\rho_n + 0.5)^2 - 2(\rho_n - \rho_r)} \ldots\ldots (3)$$

Where,

MSAVI = Modified Soil Adjusted Vegetation Index,

ρn = Reflectance at Near Infra-Red (NIR) band,

ρr = Reflectance at Red (R) band.

Normalized Difference Water Index

The Normalized Difference Water Index was calculated using the NIR and SWIR Landsat imagery. The NDWI

is calculated using Eq. 4.

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR} \quad \ldots\ldots(4)$$

Where,

NDWI = Normalized Difference Water Index,

NIR = Near Infrared band value for a cell,

SWIR = Short Wave Infra-Red value for a cell

Results and Discussion

Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) has been used widely to examine the relation between spectral vegetation variability and the changes in vegetation growth rate. In the present study, NDVI's were determined in ArcGIS environment (Figure 2). It is observed that, the NDVI value of study area varied from -0.71 to 0.83, -0.35 to 0.63, -0.50 to 0.74 and -0.16 to 0.76 for the year 1999, 2000, 2002 and 2003 respectively. The highest value of NDVI i.e. 0.83 was obtained in year 1999. For year 2002 and 2003 the values of NDVI was almost same. The lowest value (-0.16) of NDVI was obtained in year 2003. The average NDVI for study period ranges between -0.43 to 0.74 for the study period 1999-2003. Hence, for study period i.e.1999 to 2003 (four years period) lowest NDVI is -0.43 and highest NDVI is 0.74. It indicates that, Savitri river basin has good vegetation cover throughout the year's period. There may be more moisture stress found even in the month of March.

Soil Adjusted Vegetation Index

The Soil Adjusted Vegetation Index (SAVI) is a hybrid index between NDVI and PVI (Perpendicular Vegetation Index). The variable soil brightness constant (L) function improves vegetation sensitivity, particularly in high vegetation densities. In the present study, NDVI's were determined in ArcGIS environment (Figure 3). It is observed that, the SAVI value of study area varied from -0.10 to 0.60, -0.12 to 0.36, -0.15 to 0.50 and -0.34 to 0.40 for the year 1999, 2000, 2002 and 2003, respectively. The highest value of SAVI i.e. 0.60 was obtained in year 1999. The high value of SAVI indicates good and healthier vegetation and low value indicates vegetation is scare. The results of the years 2002 and 2003 were almost same. The value near or equal to 1 is good vegetation and SAVI value near or equal to -1 is vegetation is not there i.e. it is barren land. The average SAVI for study period iranges between -0.17 to 0.46 for the study period 1999-2003. Hence, for study period i.e 1999 to 2003 (four years period) lowest SAVI is -0.17 and highest SAVI is 0.46. It indicates that, Savitri river basin has good vegetation cover throughout the year's period. There may be more moisture stress found even

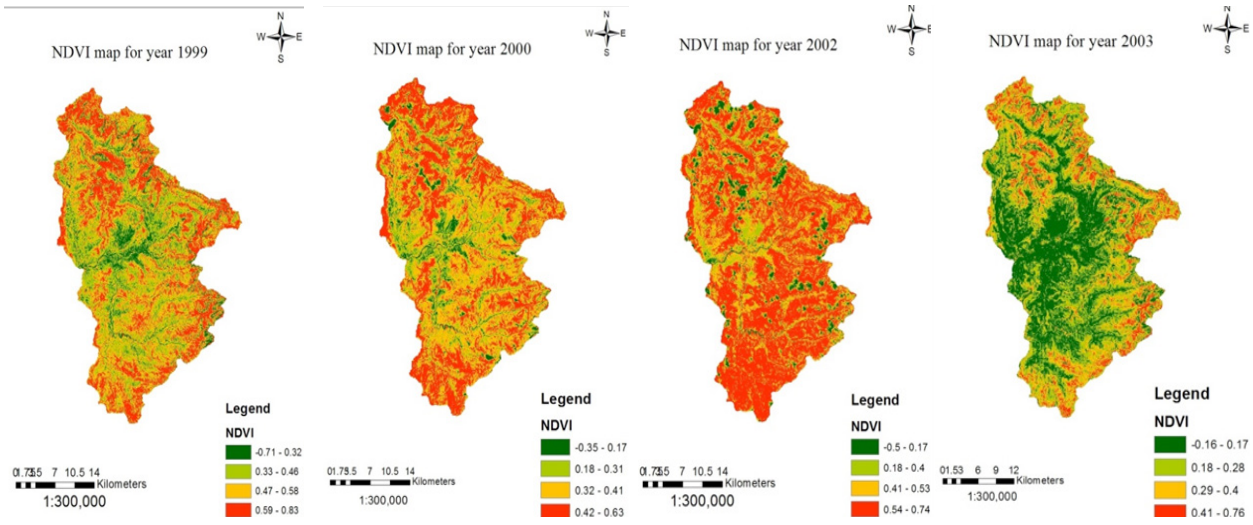

Figure 2. Computed NDVI for different years. 1999 (November), 2000 (October), 2002 (September), 2003 (March)

in the month of March.

Modified Soil Adjusted Vegetation Index

The Modified Soil Adjusted Vegetation Index (MSAVI) calculated using reflectance values of band 3 (RED) and 4 (NIR). The MSAVI and their transformations and derivatives are extremely useful tools in monitoring processes related to PAR absorbed by vegetation. In the present study, NDVI's were determined in ArcGIS environment (Figure 4). It is observed that, the MSAVI value of study area varied from 0.36 to 0.64, 0.47 to 0.76, 0.54 to 0.95 and 0.14 to 0.49 for the year 1999, 2000, 2002 and 2003 respectively. The highest value of MSAVI i.e. 0.95 was obtained in year 2000. The high value of MSAVI indicates good and healthier vegetation. The value near or equal to -1 indicates there is no vegetation i.e. it is barren land. The lowest value of MSAVI (0.14) was obtained in year 2003.The average MSAVI for study period is ranges between 0.63 to 0.71 for the study period 1999-2003. Hence, for study period i.e 1999 to 2003 (four years period) lowest MSAI is 0.63 and highest MSAVI is 0.71. It indicates that, Savitri river

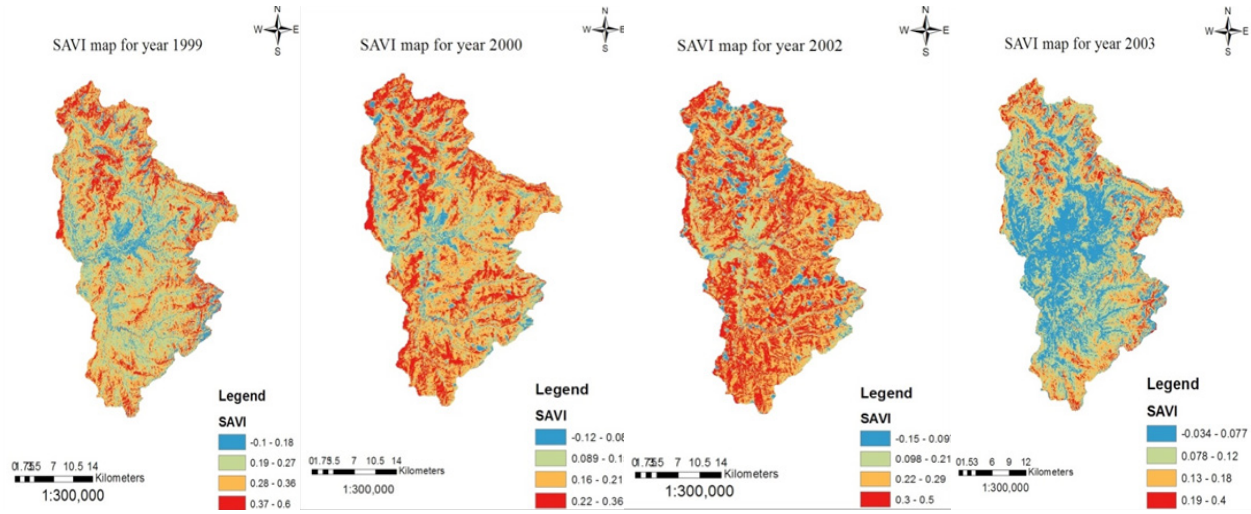

Figure 3. Computed SAVI for different years. 1999 (November), 2000 (October), 2002 (September), 2003 (March)

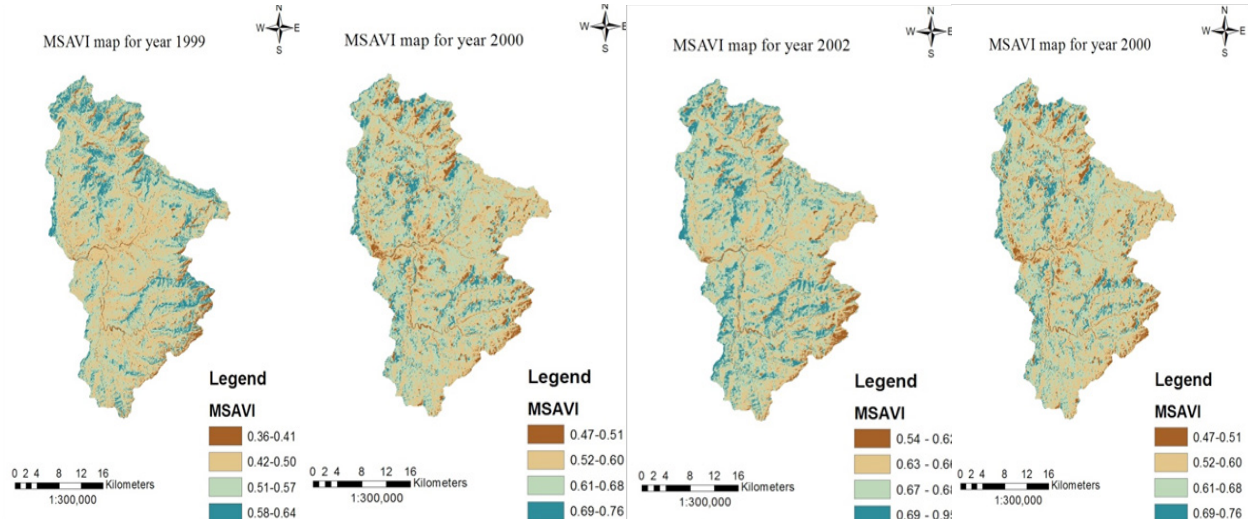

Figure 4. Computed MSAVI for different years. 1999 (November), 2000 (October), 2002 (September), 2003 (March)

basin has good vegetation cover throughout the year's period. There may be more moisture stress found even in the month of March.

Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index (NDWI) has been widely used to flood and drought monitoring. The NDWI method was best approach for determining moisture content in the top layer of the soil. In the present study, NDWI's were determined in ArcGIS environment. The computed NDWI for study area is given in Figure 5 for the year 1999, 2000, 2002 and 2003, respectively. The index image was normalized to 8-bit and classified into the three classes of crop moisture variation as very low moisture, low moisture and moderate moisture. Thresholds DN values were determined by feature physical inspection of the VNIR image. The thresholds DN values for the respective classes are given in Table 2.

For threshold DN value 0-122, the moisture variation is 16 to 34 percent. For threshold DN value 123-136, the moisture variation is 35 to 59 percent. For threshold DN value 137-255, the moisture variation is 60 to 72 per cent. It is inferred that, the high moisture percentage was obtained in the year 1999, the threshold DN value for this year was 137-255.

The area under very low moisture, low moisture and moderate moisture were 99.4 km^2, 298.2 km^2 and 596.4 km^2, respectively for year 1999. The area under very low moisture, low moisture and moderate moisture were 198.8 km^2, 298.2 km^2 and 497 km^2, respectively for year 2000. The area under very low moisture, low moisture and moderate moisture were 248.5 km^2, 298.2 km^2 and 447.3 km^2, respectively for year 2002. The area under very low moisture, low moisture and moderate moisture were 397.6 km^2, 248.5 km^2 and 347.9 km^2, respectively for year 2003. The average area (472.16 km^2) under moderate moisture availability in the basin is moderate, which is 47.5 percent of total area of basin, area under low moisture availability was 285.77 km^2 (28.75 per cent) and 236.07 km^2 (23.75 percent) found in very low moisture availability of the basis during 1999 to

Table: 2 Thresholds DN values for NDWI image classification

Class	Threshold DN value
Moderate Moisture	137-255 (60 to 70 per cent)
Low Moisture	123-136 (35 to 59 per cent)
Very Low Moisture	0-122 (16 to 34 per cent)

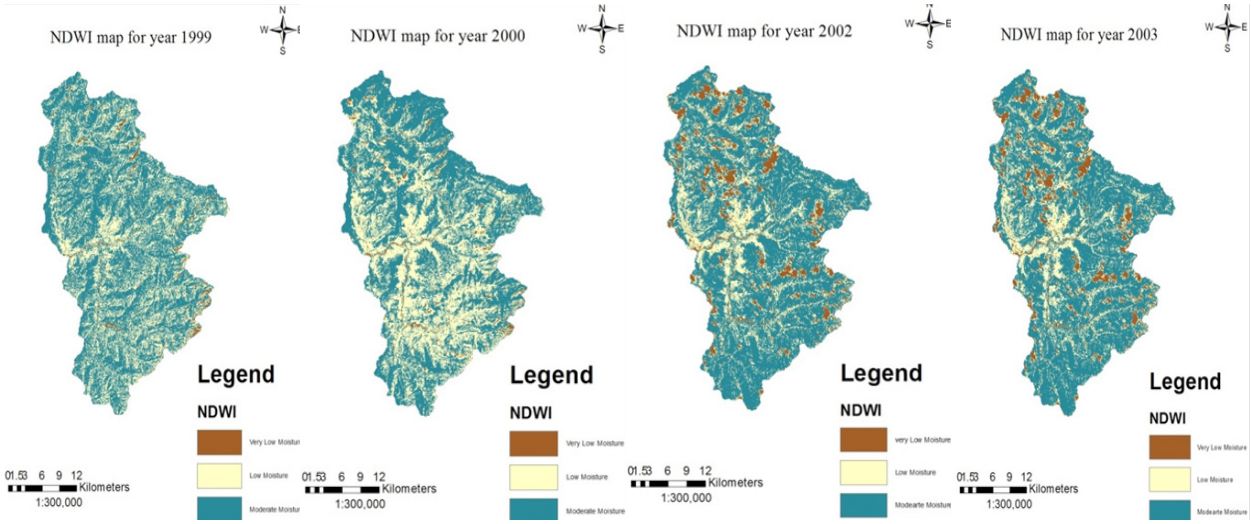

Figure 5. Computed NDWI for different years. 1999 (November), 2000 (October), 2002 (September), 2003 (March)

2003. Hence, Moisture variation found in the basin but availability is good with different season for supporting vegetation.

Conclusions

The computed NDVI, SAVI and MSAVI were compared to compute moisture in the soil of Savitri Basin. The NDVI values are found to be higher compared to the SAVI and MSAVI values and it gives more negative values. Therefore, NDVI values cannot be used for computing the moisture in the soil. The IDWI of the Savitri Basin found to be moderate in nature.

References

Ahmad F. 2012. Spectral vegetation indices performance evaluated for Cholistan Desert, J. Geogr. Reg. Plann. 5: 165-172.

Basso B., Cammarano D., and DeVita P. 2004.Remotely sensed vegetation indices: theory and applications for crop management, RivistaItaliana di Agrometeorologia,1: 36-53.

Bannari A., Morin D. and Bonn F. 1995.A Review of vegetation indices, J. Remote Sens., 13: 95-120.,

Glene E. P. and Huete A. R. 2008.Relationship between remotely-sensed vegetation indices, canopy attributes and plant physiological processes: what vegetation indices can and cannot tell us about the landscape Sensos. 8: 2136-2160.

Huete H R., Jackson R D. and Post D F. 1985. Spectral response of a plant canopy with different soil backgrounds. Remote Sens. Env. 17: 37-53, doi:http//dx.doi.org/10.1016/0034-4257 (85)90111-7.

Huete A. R. 1988. Soil adjusted vegetation index (SAVI). Remote Sens. Env. 25: 296-309.

Klemas V. and A. Pieterse. 2015. Using remote sensing to map and monitor water resources in arid and semiarid regions. IN The Handbook of Environmental Chemistry, pp: 33-60.

Linlin Lu, Claudia Luenzer, Cuizhen Wang, Huadong Huo and Qingting li. 2015. Evaluation of three MODIS – derived vegetation index time series for dry land vegetation dynamics monitoring. Remote Sens. 7: 7597-7616. Doi:10.3390/rs 70607597.

Qi. J., Chetbouni A., Huete A. R., Kerr Y H., Sorooshia S. 1994. A modified soil adjusted vegetation indicx. Remote Sens. Env. 48: 119-126. doi:http/dx/doi.org/10/1016/0034-4247 (94) 90131-1

Rouse J. W., Haas R. H., Schell J. A. and Deering, D. W., 1974. Monitoring vegetation system in the Great Plains with ERTS symposium. NSSA SP -351, 1: 309-351.

Singh V. K., Satpathy A. and Parveen R. 2010. Spatial variation of vegetation moisture mapping using advanced spaceborne thermal emission and reflection radiometer (ASTER) data, J. Environ. Prot., 1: 448-455.