ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

ASSIMILATION AND TEMPORAL EVALUATION OF SURFACE SOIL MOISTURE IN PAKISTAN

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Abstract- Remote Sensing is a powerful tool for calculating surface soil moisture even on a large scale. Evaluating surface soil moisture is an essential activity for the determination of plant and crop growth in agriculture. Setting soil moisture for water resource management and land-surface atmosphere interaction is extensively useful by using Geographic Information Science (GISc) and Remote Sensing (RS). Assimilation and evaluation of surface soil moisture in Pakistan is the main aim of this research for year the 2016, 2017 and 2018. In association with soil moisture Normalized Difference Vegetation Index (NDVI) index was also calculated for year 2018. This research study also shows the climatic impact on vegetation and soil moisture temporally. For the analysis radiometric data was captured of Soil Moisture Active Passive (SMAP) Ease Grid for surface soil moisture. From analysis it has been observed that soil moisture change has shown distinctive results. 2016 has decreased moisture in surface soil, 2017 analysis shows increase in soil moisture while 2018 has again decrease in soil surface moisture in Pakistan. Analysis shows that there was decrease in moisture of surface soil in the year 2016, on the other hand, there was significant increase in soil moisture followed by once again decrease in soil moisture in the year 2018.
Keywords: Soil Moisture, SMAP, Soil Stress, NDVI, Radiometric data, GIS and RS.

1. INTRODUCTION

Due to increase in land surface temperature surface soil moisture has decreased its value, globally. For calculation of increasing and decreasing trend of soil moisture it is very important to monitor climatic trends of area. It is very important to monitor climatic trends of an area for calculation of increasing and decreasing trend of soil moisture. An increase in temperature has ultimate decrease in soil moisture that leads to arid conditions [1]. Due to the globalization environmental changes are taking place and temperature of the earth is increasing day by day. Therefore, many green policies and strategies are defined. For controlling temperature and protecting environment many scientific researchers have been done and Satellite remote Sensing (SRS) tools and techniques are quite helpful in terms of mapping analysis and generating results. For controlling temperature and protecting environment many scientific researchers have been done. In such researches, Satellite remote Sensing (SRS) tools and techniques are quite helpful in terms of mapping analysis and generating results.

Human activities has have become more harmful for environment than pervious previously and behaviorism is also changing [2]. The soil moisture is considered as key factor in production of precipitation, water-cycle, agricultural activities and land with atmosphere interactions. Presence of moisture in root level is always useful for crops or plant growth therefore, moisture availability is principal element. Soil moisture has gained its value in the world of agricultural activities on both small and high scale as it manifest the knowledge of wetness and helps crops to grew well. Capacity of soil to perpetuate water depends upon structure and texture of soil. There are certain ways to calculate soil moisture content information which includes indirect methods for measuring soil water capacity, volumetric soil determination for density measurement and by mapping surface soil moisture after using RADAR or radiometric data [3]. The Soil Moisture Active Passive (SMAP) used in this study was collaborated with radar data of instantaneous 9 km range with 5 cm of soil column. In order to interpret the vigorous occurrence of changing surface soil moisture patterns in Pakistan temporally data was acquired. Analysis was applied for the verification soil moisture content and then it was related with vegetation of recent year which is 2018. For estimation of vegetation, Normalized Difference Vegetation Index (NDVI) was calculated.

Pakistan is located in the North-Western part of great Indo-Pak sub-continent. It is beautiful country with stretched Himalaya Mountains in the north, plains in Punjab and Sindh and great coastal boundaries in south of Sindh and Baluchistan. Its geographical coordinates are 30.3753° N and 69.3451° E. Pakistan is surrounded by countries of Iran, Afghanistan, China and India with a coast on Arabian Sea. The total area of Pakistan is 803,936 Km^2. It is a land of varied landscapes ranging from perpetually snowcapped peaks of Himalayan Range like the Karakoram, K-2 elevation 28,265 ft. (8,615 m) to lush green canal irrigated areas. Pakistan is located in temperate zone therefore monsoons keeps the temperature cold, moderate and rainy in December, extremely hot and dry in April, hot and very humid in September and cool to dry in November. Due to the presence of monsoonal activity in Pakistan the overall climate of Pakistan remains arid and semi-arid [4]. The study area map of Pakistan is shown in Fig. 1.1.

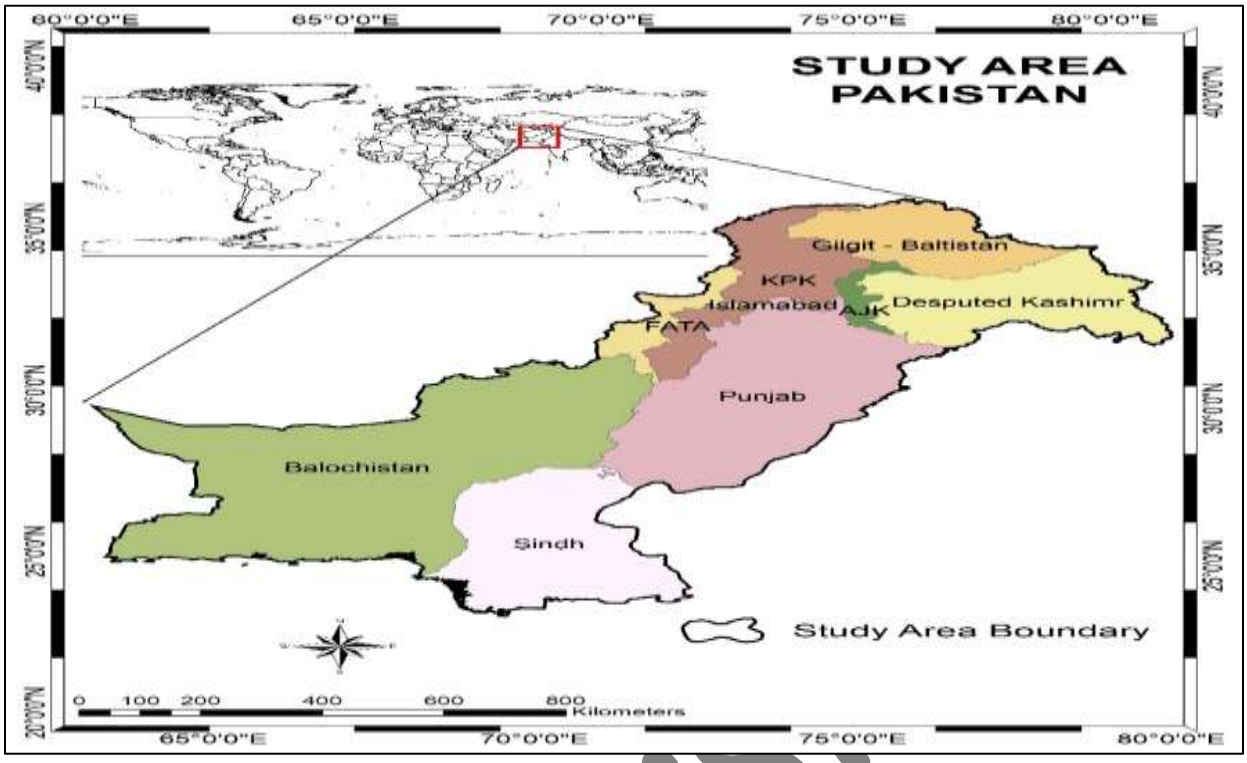

Fig. 1.1 Map Showing Study Area Pakistan

2. RESEARCH ELABORATIONS

Adequate rapid urbanization and industrialization has progressively worse the condition of soil and eventually it is decaying therefore the record or supervision of soil moisture content is required [5]. Satellite Remote Sensing (SRS) is known as the data acquisition of those remote areas where analyst is unable to reach. Data captured for the analysis of surface soil moisture is of Soil Moisture Active Passive (SMAP) L4- Band with 9 Km EASE- Grid surface. The EASE grid is Equal Area Scalable Earth Grid (EASE) it is very essential in mapping techniques as it is a versatile format for global scale grid data. This assimilation of data is for root zone and surface moisture found in Pakistan. This SMAP L- Band brightness data captures brightness temperature data from ascending and descending satellite passes of 12 hours a day. This radiometric data is very fine and useful for at least 5cm depth analysis of soil moisture content [6].

Along with the estimation of surface soil moisture in Pakistan, vegetation impacts and growth is equally important for analyst for example in case of germination of seed, knowledge of wetness of surface needs to be known [7]. So with the help of Geographic Information System (GIS) and Remote Sensing (RS) applications evaluation of Normalized Difference Vegetation Index (NDVI) was performed for recent year 2018. Research tools, software and methods described were used to find and analyze results. NDVI was correlated with surface soil moisture that temporally analyze changes for year 2016, 2017 and 2018. NDVI index was correlated with SAVI for the determination of vegetation in Kalat for comparative study from 2000 to 2017.

The main ambition of this article is to define the mapping technique of Surface Soil Moisture for years 2016, 2017, 2018 and its relationship with vegetation in the form of NDVI for year 2018. The spatial map and NDVI was generated followed by integrated analysis and results were reckoned in GIS. These tools are very helpful in evaluation, assessment and monitoring of soil moisture and temporally condition of soil and vegetation can be easily mapped.

3. RESULTS AND DISCUSSIONS

3.1 Surface Soil Moisture

According to NASA, T. Schmugge (1978) has presented the Remote Sensing of Surface Soil Moisture by explaining the different relationship of thermal energy with dielectric properties of water. The moisture of soil has its unique heat capacity and water has its thermal conductivity that makes the connectivity and measurement easy by remote sensing. The wavelength of dry soil at microwave level is of (5 cm) and brightness temperature is also sensitive for its analysis [8].

Decrease in Surface Soil Moisture is top climacteric issue faced globally it is driving faster due to urbanization and temperature increasing factors. For the estimation of soil moisture in Pakistan, algorithm L4- Soil Moisture (SM) was used that has different classes of water catchment areas where water concentration is calculated from root zones to surface excess. In SMAP L- band first calculate the 9 km grid cell for selected area or areas of interest as shown in the equation below as (Eq. 3.1).

$$X_{(n)} = [x_1, x_2, x_3 \ldots\ldots x_{N9}] \quad 3.1$$

In above equation (Eq. 3.1) x represents the area or areas of interest, N9 represents number of 9 km grid cells in study area. After the assimilation of number of grid cells the brightness temperature value was calculated with SMAP- EASE grid cell. However, radiometric data is of high resolution and explains the differences of yearly surface soil moisture clearly as shown in Fig. 3.1 (a) for year 2016, (b) for year 2017 and (c) for year 2018.

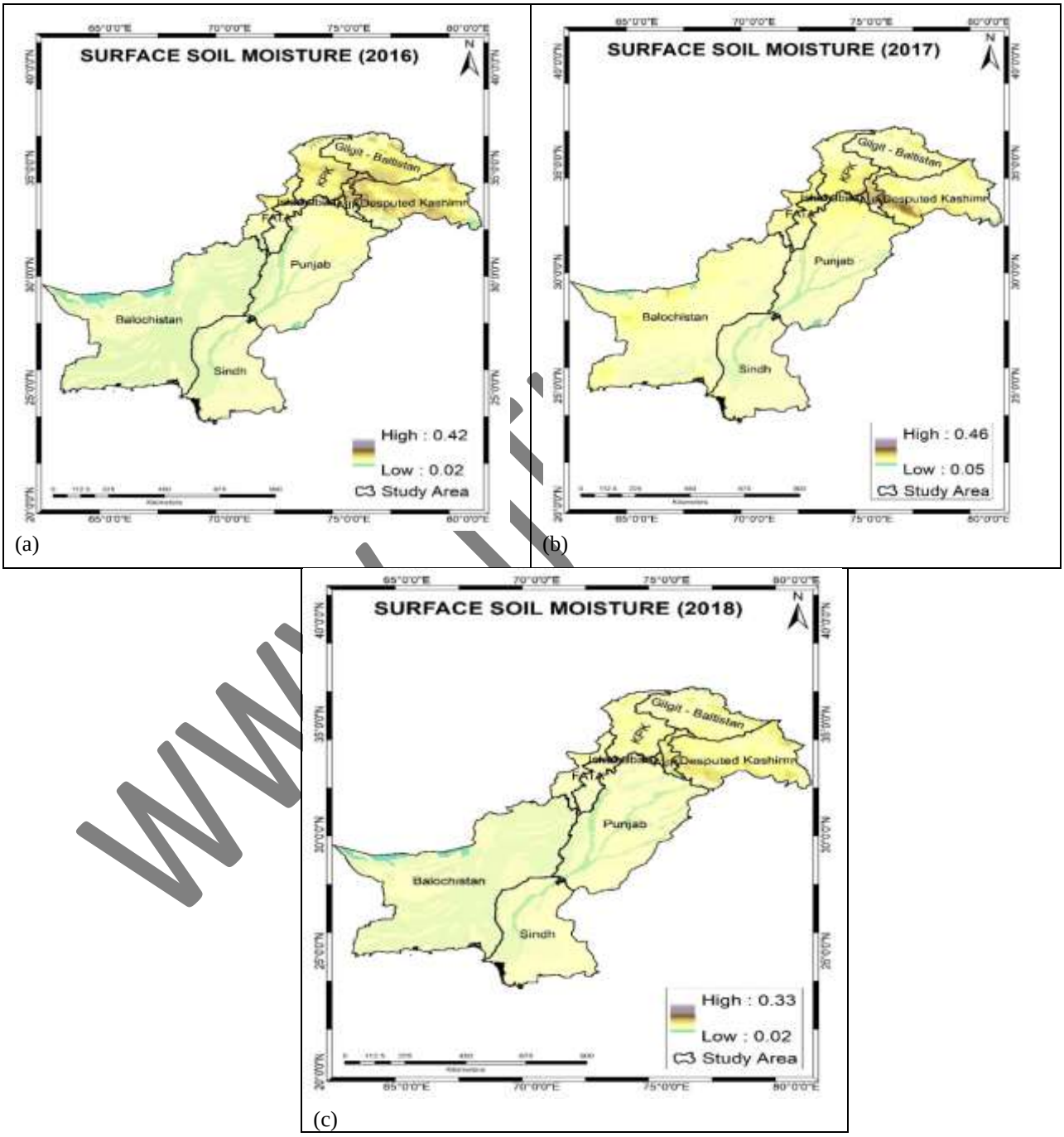

Fig. 3.1 Map Showing Surface Soil Moisture Difference (m^2/m^2) Pakistan Based on L- Band SMAP- EASE Grid (a) Year 2016, (b) Year 2017 and (c) Year 2018

Firstly, catchment areas or area of interest was measured and radiometrically all data was analyzed and captured through SMAP. After the number of 9 km for 5 cm depth of soil surface determination the water catchment was converted into thermal heat conductivity of soil as L-Band brightness temperature.

In Fig. 3.1 maps showing comparative soil moisture for all three years that indicates that soil moisture is varying. In year 2016, from Fig. 3.1 (a) the green areas found in south western province (Baluchistan) shows the decrease in soil moisture which means soil moisture stress is increased in those particular areas where green values are shown as clearly visible from legend of maps in Fig.2. In year 2017, Fig. 3.1 (b) explains that soil moisture has increased its value which means that moisture in environment has remained proper and rainfall activity is also producing its effect. As the map (b) of Fig. 3.1 explains that there is no moisture stress in 2017 of choose date. While, in year 2018 Fig. 3.1 (c) it shows again the moisture stress and decrease in soil surface moisture repeatedly in the same areas of year 2016 Fig. 3.1 (a) of Baluchistan, Pakistan. All these analysis also shows that Northern parts of Pakistan remained enriched with moisture with high and medium values as shown in Fig. 3.1.

3.2 Normalized Difference Vegetation Index (NDVI)

NDVI in satellite remote sensing plays very important role in the estimation of vegetation in an area of interest. The amalgamation of spectral bands that reflects, absorbs and transmit UV- radiations and spatial distribution locate the presence of vegetation with classes as densely vegetated, moderately vegetated, light vegetation and areas with no vegetation [1]. NDVI implies red (R) and infrared (NIR) wavelengths and its value ranges from -1 to +1 [5].

$$\textbf{NDVI= (NIR-R) / (NIR+R)} \qquad 3.2$$

In above equation (Eq. 3.2) it shows the calculative measure of vegetation index by NDVI, Near Infra-Red (NIR) is first subtracted with Red (R) wavelength than divided by Near Infra-Red (NIR) with the addition of Red (R) wavelength. In Fig.3. Map is showing the spread of vegetation cover over the Pakistan for year 2018.

Table-3.1 Showing Normalized Difference Vegetation Index (NDVI) for Provinces of Pakistan year 2018

Provinces	Area in percentage (%)
High Vegetation	25
Moderate Vegetation	14
Dead/ No Vegetation	39

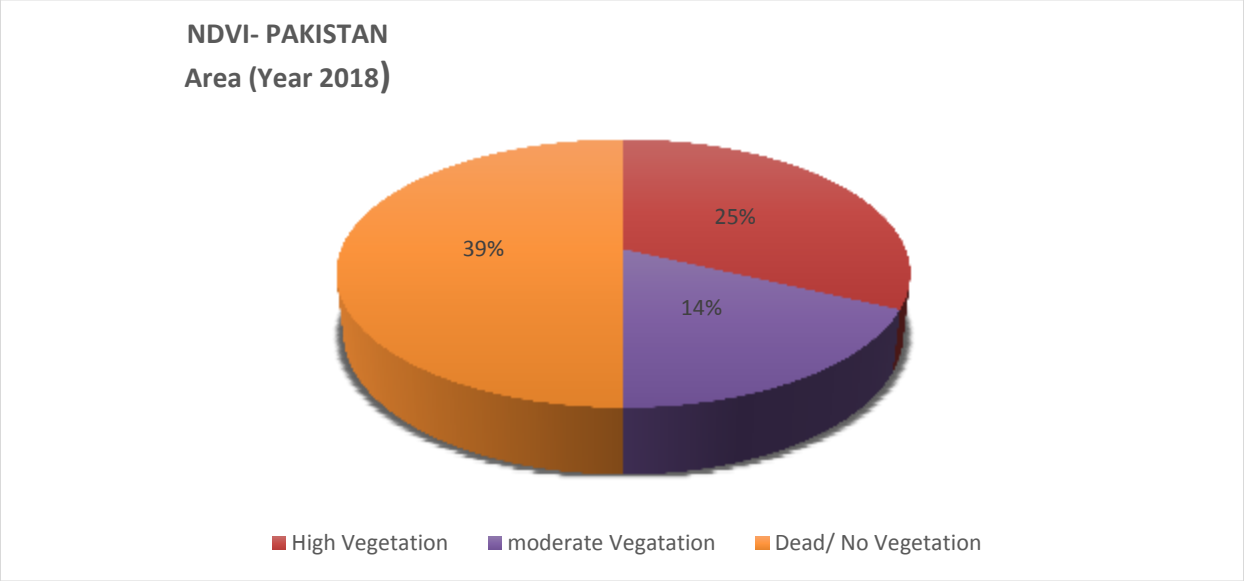

Fig. 3.2 Showing Normalized Difference Vegetation Index (NDVI) for Provinces of Pakistan Year 2018

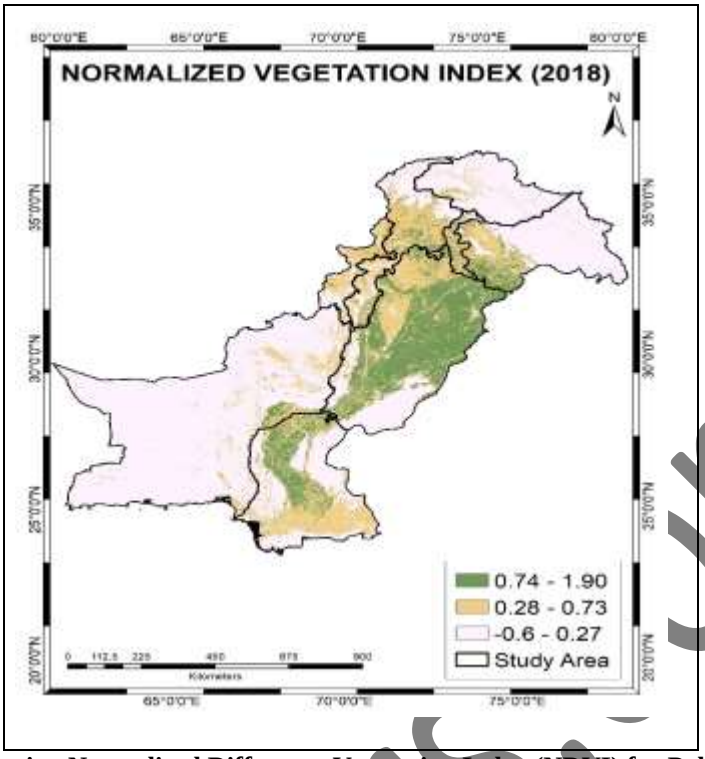

Fig. 3.3 Map showing Normalized Difference Vegetation Index (NDVI) for Pakistan year 2018

The vegetation cover assessment based on NDVI, it explains that high vegetation is found in the provinces of Punjab and Sindh with the values of **0.74 – 1.90** as shown in Fig. 3.3 it covers the area of 25% of vegetation as shown in Table. 3.1.. The moderate values of NDVI as per analysis are shown in Northern Punjab, Province of KPK and Southern Parts of Sindh which covers the value of **0.28 – 0.73** it covers the area of 14% of vegetation as shown in the Table. 3.1. Whereas, the parts of Baluchistan and northern Pakistan covers no vegetation or dead vegetation with values of **-0.6 to 0.27** this part of Pakistan covers the area of 39% as shown in Fig. 3.2, Table. 3.1 shows that area of No/Dead vegetation is 39% that needs to reduce moisture stress and vegetation growth.

CONCLUSION

This research study is a useful, comprehensive and appropriate approach for monitoring and mapping surface soil moisture and moisture stress in any area of the world. All analysis are completely understandable and can be easy applied since SMAP is acquiring instantaneous data for required year. The relationship between NDVI and surface soil moisture has explained that wherever vegetation is found zero or dead or with lowest value the content of soil moisture is also found decreased as in Baluchistan, Pakistan. Because of increasing stress in moisture vegetation loses its originality and tends to detoriation. In this factor not only climatic change or environment is involved it may also include the extra intrusions of anthropogenic activities, which leads to urbanization, over agricultural activities, deforestation and extra cutting of vegetative land into open barren land for new housing societies. This study will help the research community to correlate and understand NDVI with surface soil moisture by using SMAP data and applications of GIS and RS.

Another factor Land Surface Temperature (LST) is also associated with surface soil moisture thus climatic variations were followed in this research study. This research study also reveals the areas for better vegetation growth in future, which include the areas of Baluchistan need to control LST and vegetation needed to grow for the reduction of moisture stress. This article concludes that Pakistan is a region with multiple climatic ranges, it is considered as cool in winters and reaches to maximum temperature in summers. The soil moisture content has been constant relation with moisture stress that is varying in Pakistan. NDVI relationship with moisture stress and surface soil moisture need to be mapped temporally so that areas of stress can be identified and vegetation cover should be placed.

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