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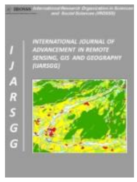

ASSESSING AGRICULTURAL VULNERABILITY USING GEOMATIC TECHNOLOGY: A CASE STUDY OF SRIVILLIPUTHUR TALUK OF VIRUDHUNAGAR DISTRICT, TAMIL NADU

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ABSTRACT*:* Agriculture is an economic activity that is highly dependent upon weather and climate in order to produce the food and fiber necessary to sustain human life. The climate variations have direct and indirect effects on agricultural productivity. If these variations continue on a long term period, an issue of agricultural drought and food scarcity occur making agricultural productivity vulnerable. Especially, the effects of climate variation on agriculture are recurrent meteorological phenomenon affecting several parts of the world, in India too. The main objective of the present study is to make an attempt to understand the biophysical aspects of agricultural vulnerability using the modern methods of remote sensing and GIS. Agricultural vulnerability is determined based on Standardized Precipitation Index (SPI), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Water Index (NDWI). SPI values of rain gauge stations are interpolated to determine the spatial pattern and threshold value of drought for agricultural vulnerability. Anomaly of the NDVI and NDWI were classified to determine the agricultural drought vulnerability. SPI, NDVI and NDWI were integrated to classify the agricultural vulnerability of the present study area namely Srivilliputhur Taluk of Virudhunagar district. From the study, it is found out that the north east part is highly vulnerable and the western part of the study area is less vulnerable to agricultural drought. The resultant map shows the spatial distribution of the areas facing agricultural drought conditions. The agricultural vulnerability map will help in the preparation of the area for mitigation measures that will in turn reduce the impacts of climate variation on agriculture.

KEYWORDS*:* Agricultural vulnerability, NDWI, NDVI, SPI, Mitigation.

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1. INTRODUCTION: Agriculture the climate-sensitive sector is one of the most important determinant factors for Indian economy. The combined and interacting influences of climate change and its variations in rainfall and temperature conditions directly affects Indian agriculture mainly plant and animal production. It indirectly affects the agricultural production through changes in soil, water, pests, and diseases making agriculture more vulnerable. The main factor for agricultural vulnerability is drought. Drought always starts with the lack of precipitation, but may (or may not, depending on how long and severe it is) affect soil moisture, streams, groundwater, ecosystems and human beings. This leads to the identification of different types of drought (meteorological, agricultural, hydrological, socio-economic, ecological), which reflect the perspectives of different sectors on water shortages. Drought affects virtually all climatic regions and more than one half of the earth is susceptible to drought each year. Drought causes changes in the external appearance of vegetation, which can clearly be identified (by their changed spectral response) using satellite sensors through the use of vegetation indices.

NDVI is a powerful indicator to monitor the vegetation cover of wide areas, and to detect the frequent occurrence and persistence of droughts (1). It provides a measure of the amount and vigor of vegetation at the land surface. These indices are functions of rate of growth of the plants and are sensitive to the changes of moisture stress in vegetation (2). Wilhelmi, V.O (3) in his study of the assessment of vulnerability to agricultural drought in Nebraska hypothesized that the biophysical and social factors, that define agricultural drought vulnerability were climate, soil, land use and access to irrigation. The result of the study indicates that the most vulnerable areas to agricultural drought were non irrigated cropland and rangeland on sandy soil with a very high probability of seasonal crop deficiency. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of vegetation. Tucker first suggested NDVI in 1979 as an index of vegetation health and density and it has been considered as the most important index for mapping of agricultural drought (4). In the year 2011, Kaushalya Ramachandran had assessed the agricultural vulnerability to climate change using NDVI data products and the results were discussed spatio-temporally at district level for the country. Likewise, Sumanta Das (5) had assessed the severity of drought using long term mean values of maximum NDVI in Bankura District, West Bengal

In this paper, a conceptual approach for assessing agricultural vulnerability using geomatic technology is adopted and is presented by selecting Srivilliputhur Taluk of Virudhunagar District, Tamil Nadu as the study area. The main objective of the present study is to make an attempt to understand the spatial aspects of agricultural vulnerability using remote sensing and GIS techniques. Agricultural vulnerability is determined based on Standardized Precipitation Index (SPI), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Water Index (NDWI). Thus a contribution is made directly to enhance the efforts for the sustainability of agricultural sector. In order to understand the variation in weather and its impact on agriculture, a study of Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) was undertaken using Landsat ETM+. Time series Landsat datasets were downloaded from their respective websites and is used for assessing agricultural vulnerablity in the study area. Standardized Precipitation Index (SPI) instead of actual rainfall data was used to corroborate extreme weather events with the resultant of NDVI and NDWI variations.

2. STUDY AREA: The study area namely Srivilliputhur Taluk is situated between 9° 52' and 9° 18' north latitude and 77° 24' and 77° 48' east longitude (See Figure I). It has an area of 686 square kilometers. It is bounded on the north and north-east is by Madurai district, south-east by Sivakasi Taluk, on the south by Rajapalayam Taluk and on the west by Theni district and Kerala State. The Taluk is located at the foot hills of the Western Ghats at about 77 km (48 mi) south west of Madurai. It has an average elevation of 137.2 meters (450 ft) above mean sea level. Srivilliputhur receives scanty rainfall with an annual average of 811 mm (31.9 in), which is lesser than the state average of 1,008 mm (39.7 in). The south west monsoon, which onset in June and lasting up to August, brings scanty rainfall. Most of the rainfall is received during the North East monsoon in the months of October, November and December.

According to the 2011 census, Srivilliputhur Taluk had a population of 2,92,895 persons with 1,45,763 males and 1,47,132 females. There were 1009 women for every 1000 men. The Taluk had a literacy rate of 70%. The population in the age group below 6 was 13,150 males and 12,615 female children. There were a total of 1,61,239 workers of which 7,360 are cultivators, 47,791 persons are engaged as agricultural laborers and 7,949 are engaged in house hold industries. The decadal growth of population during the years 2001 to 2011 shows a fall due to migration towards industrial centers and other family welfare schemes.

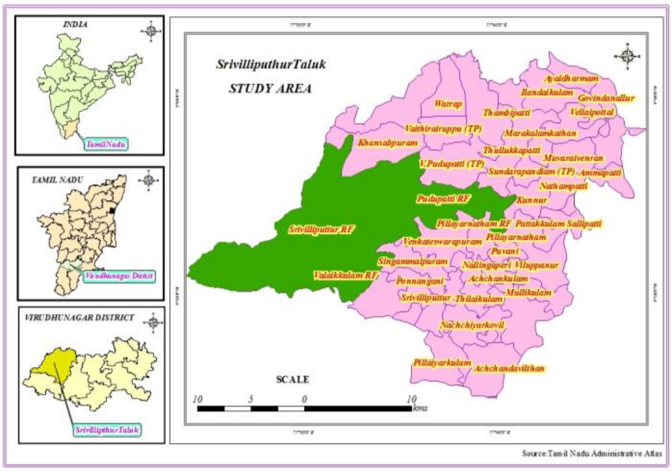

Fig.: I Map Showing Study area (Location Map)

Many rare and endemic varieties of flora and fauna are found along the mountain slopes. A wildlife sanctuary, spread over 480 km^2 (190 sq mi) was established in 1989 at Shenbaga Thoppu. The sanctuary is contiguous with the Periyar tiger reserve on the south-western side and the Megamalai reserve forest on the north-western side.

3. DATASET: The dataset used in the present study and their basic characteristic relevant to the aim of the study is briefly described as follows:

3.1. RAINFALL DATA: Daily rainfall datasets were acquired from the grid data for the period of 1990, 2000, and 2011. The Indian Meteorological Department (IMD) and Statistical department have setup a rainfall monitoring station for the Taluk. Thus, there are three meteorological stations (Srivilliputhur, Watrap, and Pillavakkal) within the study area and are selected for the present study.

3.2. SATELLITE DATA: The two ETM+ datasets acquired by Landsat on 29th November 1990 and 20th November 2000 and one LISS III data acquired by IRS P6 on 9th November 2011 are used in the present study.

The methods used in the present study to assess the agricultural vulnerability of Srivilliputhur taluk is given below.

4. METHODS:

4.1. STANDARDIZED PRECIPITATION INDEX (SPI): The SPI formulated by Tom Mckee, Nolan Doesken and John Kleist of the Colorado Climate Center in 1993 was used in the present study for the estimation of SPI value for the three meteorological stations viz. Srivilliputhur, Watrap, and Pillavakkal. The purpose of calculating SPI is to assign a single numeric value to precipitation, which can be compared across regions with markedly different climates. Technically, SPI is the number of standard deviations that the observed value would deviate from the long-term mean, for a normally distributed random variable. Mathematically, SPI is based on the cumulative probability of a given rainfall event occurring at a station (6).

In order to analyse the impact of rainfall deficiency and the development of drought in this study area, SPI has been used to quantify the precipitation deficit in the three different periods i.e. 1990, 2000 and 2011. The SPI is calculated using the following equation,

$$\mathbf{SPI = (Xij - Xim)/\sigma}$$

Where, Xij is the monthly precipitation at the i^{th} rain-gauge station and j^{th} observation, Xim is its long-term precipitation mean and σ is its standard deviation. Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation (5). Drought periods are represented by relatively high negative deviations. Normally, the "drought" part of the SPI range is arbitrarily split into moderately dry ($-1.0 > SPI > -1.49$), severely dry ($-1.5 > SPI > -1.99$) and extremely dry conditions ($SPI < -2.0$). A drought event starts when SPI value reaches −1.0 and ends when SPI becomes positive again. Instead of averaging anomalies for the entire terrain, SPI has been computed separately for each of the 3 rain-gauge stations falling within the study area. Since drought is a regional phenomenon, SPI values of the rain gauge stations have been interpolated using Spline interpolation technique in Arc GIS to demarcate its spatial extent.

The result of SPI shows that the study area falls in the category of moderately dry, severely dry and wet condition. The index shows less vulnerable areas in southern part and high vulnerable areas in north eastern part. But the area under severely dry conditions increase towards south in comparing the three time points viz. 1990, 2000 and 2011. The figure IIa, IIb, and IIc shows the spatial extent of SPI value for the years 1990, 2000 and 2011 respectively.

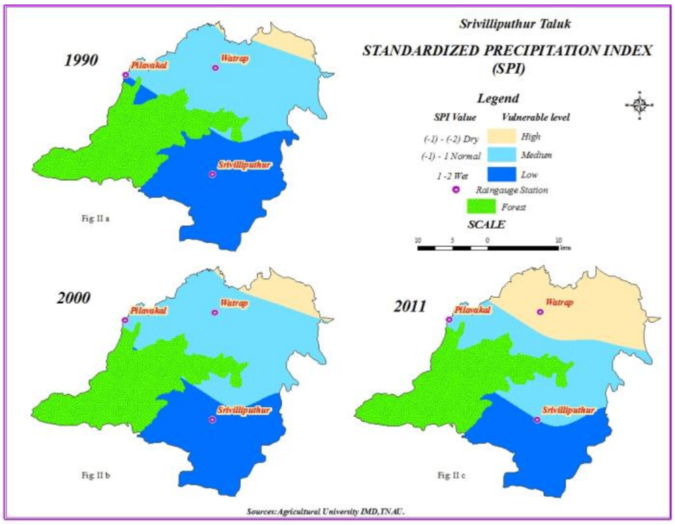

Fig: IIa, IIb, IIc Map Showing SPI in the year 1990, 2000 & 2011

4.2. NORMALISED DIFFERENCE VEGETATION INDEX (NDVI): The Normalised Difference Vegetation Index (NDVI) gives a measure of the vegetative cover and is sensitive to the chlorophyll content of plants. Dense vegetation shows high value in the NDVI imagery, and the areas with little or no vegetation shows negative value and is also clearly identified. The water surface is also delineated from NDVI images. Vegetation differs from other land surfaces because it tends to absorb strongly the red wavelengths of sunlight and reflect in the near-infrared wavelengths.

The NDVI images are generated using the imageries of LANDSAT ETM+ acquired in 1990 and 2000 and

IRS P6 LISS III in 2011. The LANDSAT ETM+ measures the intensity of the reflection from the Earth's surface in both these wavelength ranges. IRS P6 LISS III is well suited for agricultural and forestry monitoring tasks. The Normalised Difference Vegetation Index (NDVI) is a measure of the difference in reflectance between these wavelength ranges. NDVI takes values between -1 and 1, with values 0.5 indicating dense vegetation and values less than 0 indicating no vegetation.

The NDVI is given by the following equation:

NDVI= (NIR-RED/NIR+RED)

Where RED and NIR correspond to band 3 and 4 respectively. By normalising the difference in this way, the values can be scaled between values of -1 to +1. This also reduces the influence of atmospheric absorption. Water has an NDVI value less than 0, bare soils between 0 and 0.1 and vegetation above 0.1. The NDVI values are calculated for three years namely 1990, 2000 and 2011 and represented in the figure IIIa, IIIb and IIIc respectively.

The result of NDVI shows the areas is less vulnerable in southern part and high vulnerable in north eastern part. The areal extent under negative values of NDVI increases from 1990 to 2011.

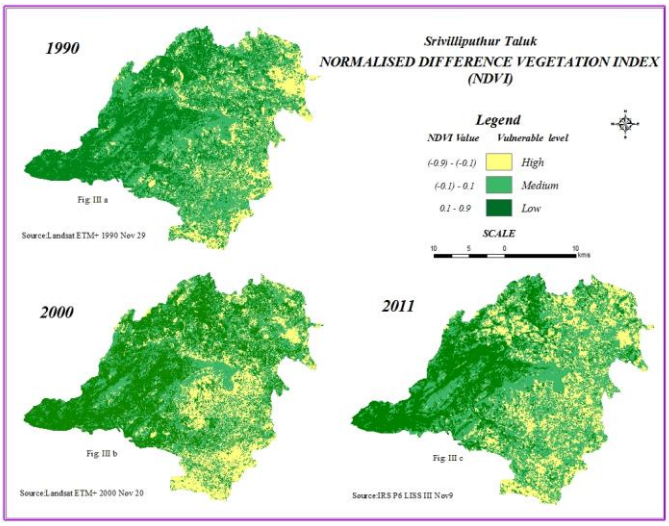

Fig: IIIa, IIIb, IIIc Map Showing NDVI in the year 1990, 2000 & 2011

4.3. NORMALISED DIFFERENCE WATER INDEX (NDWI): The Normalised Difference Water Index is a very important factor in estimation of water contents which is needed for soil moisture estimation using microwave methods (7). The NDWI images are also generated using the LANDSAT ETM+ in 1990, 2000 and IRS P6 LISS III 2011 satellite images. The LANDSAT ETM+ Shortwave Infrared (SWIR) i.e. band5 is sensitive to moisture available in soil surface and crop canopy. In the beginning of the season, soil of 1-2 cm is a dominant factor determining the spectral reflectance and hence SWIR is sensitive to soil moisture. When the crop is grown-up, SWIR response is from the canopy. NDWI using SWIR can complement NDVI for drought assessment particularly in the beginning of the season.

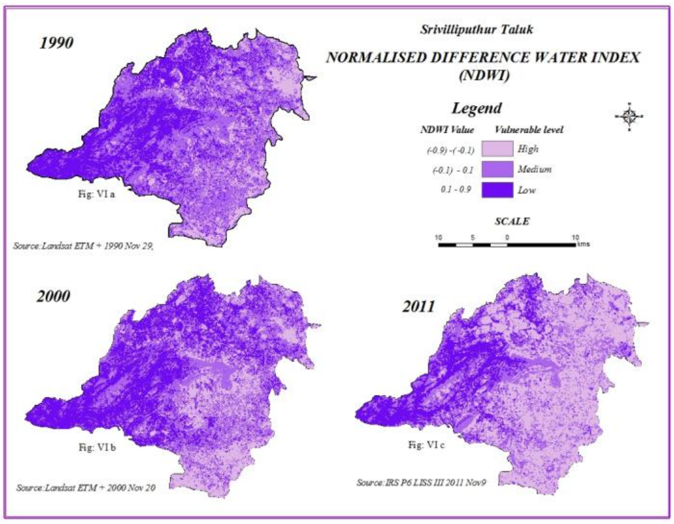

Fig: IVa, IVb, IVc Map Showing NDWI in the year 1990, 2000 & 2011

NDWI is derived using the formula,

$$\mathbf{NDWI = (NIR-SWIR) / (NIR+SWIR)}$$

where NIR and SWIR are the reflected radiations in near infrared and shortwave infrared spectral bands respectively. Higher values of NDWI signify more surface wetness. NDWI is calculated for 1990, 2000 and 2011 and is given in figures VIa, VIb, and VIc respectively.

The result of NDWI shows less vulnerable areas in the southern part and high vulnerable area in the north eastern part. The areal extent under low values of the index increases from 1990 to 2011.

4.4. AGRICULTURAL VULNERABILITY: The present study of agricultural vulnerability in Srivilliputhur taluk is attempted by overlaying the SPI, NDVI and NDWI (8) using ARCGIS 9.3 version. The integrated map shows the index of agricultural vulnerability that is classified as high, medium and Low (See figure Va, Vb, Vc).

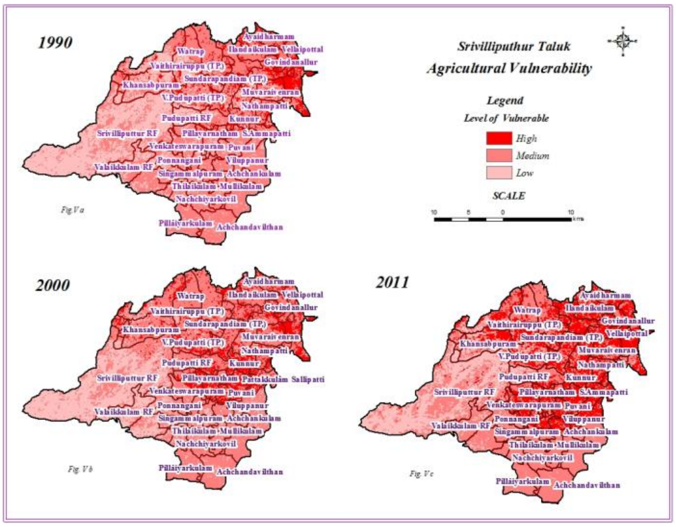

Fig: Va, Vb, Vc Map Showing Agricultural Vulnerable level in the year 1990, 2000 & 2011

4.5. LAND USE / LAND COVER: Land use map of study area was digitized from IRS P6 LISS III data acquired on 9th November 2011 using Arcmap9.3 software based on NRSA classification scheme. The digitized land use map is shown in the Fig.VI. The extent of various Land use / Land cover classes in terms of area in sq.km and its percentage to the total area is estimated. Out of the total geographical area of 686sq.km, 1.1% of the land is used for settlements, 8.6% is under intensively cropped area, 16.2% is under plantation, 25.5% is under fallow land, 27% is covered by forest, 5.7% is under water bodies, 14.7 % is under open scrub area, and 1% is left as barren land.

It is worth mentioning that a total of 175sq.km area is left as fallow land which forms a significant part and is mostly seen in the northern western part of the present study area. The major settlements are Srivilliputhur, Watrap, S.Kodikulam, V.Pudupatti, Sundarapandiam and Mamsapuram. The land under the cultivation is quiet less i.e. 59sq.km in the study area.

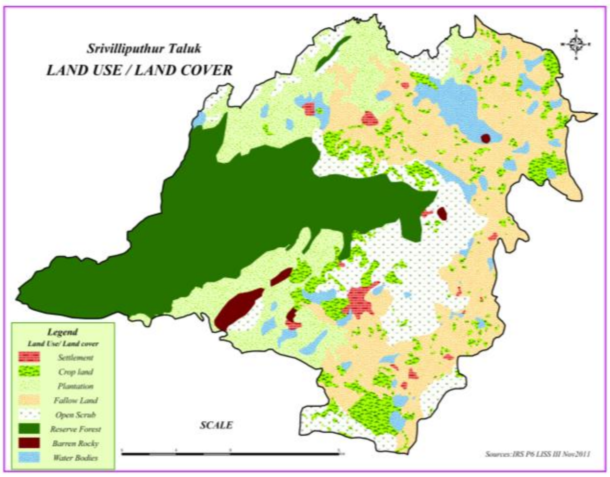

Fig: VI Map Show in Land Use /Land Cover in the year 2011

5. RESULTS AND DISCUSSION: The result of the present study of agricultural vulnerability in Srivilliputhur taluk is discussed below. The SPI, NDVI and NDWI value (1990, 2000 and 2011) as in figures shows dry area in the north eastern part. The low values of SPI, NDVI and NDWI are seen in the southern parts of the study area. This depicts that the North eastern part of the study area is dry and is agriculturally vulnerable.

In 1990 (Fig.No:Va), the agricultural vulnerability index in the villages like Ayaidharmam, Govindanallur, Ilandaikulamand, Muvaraivenran, Vadugapatti and Ayankarisalkulam are high. All the six villages belong to the northern western part of the study area. The medium values of vulnerability index is seen in Pattakkulam Sallipatti, Pillaiyarkulam, Achchandavithan, Malli, Puvani, Achchankulam, Villapurnur, Nachchiyarkovil, Kottaiyur, Sundarapandiam, Nathampatti, Ilandaikulam and Kottaiyurvellaipottal whereas low values of vulnerability index is seen in villages namely Vadakku Srivilliputur, Watrap, Venkatesapuram, Singammalpuram, Sundarapandiyam, Thilaikulam, Athikulam, Mullikulam, Ponnangari and Kunnur. These ten villages are seen along the foot hills of Valaikkulam Srivilliputhur reserve forest.

In the year 2000, the index of agricultural vulnerability is high in eight villages namely Ayaidharmam, Govindanallur, Ilandaikulamand, Vadugapatti, Pillayarnatham, Puvani, Kunnur and Sundarapandiyam. Medium values of vulnerability are seen in villages like Pattakkulam Sallipatti, Pillaiyarkulam, Achchandavitham, Malli, Puvani, Achchankulam, Villapurnur, Nachchiyarkovil and Kottaiyur. Low level of vulnerability occurs in villages namely Vadakku Srivilliputur, Watrap, Venkatesapuram, Singammalpuram and Nattampatti. Only five villages belonging to the foot hill region shows low values of agricultural vulnerability, whereas in 1990 ten villages showed low values of agricultural vulnerability.

In 2011 the index of agricultural vulnerability is high in the sixteen villages namely Ayaidharmam, Govindanallur, Ilandaikulamand, Vadugapatti, Pillayarnatham, Puvani, Kunnur, Sundarapandiyam, Watrap, S.Kodikulam, Vellaipottal, Marakalamkathan, Thulukkapattai, Nattampatti, Ponnagani and Mullikulam. Medium values of agricultural vulnerability is recorded in the villages namely Pattakkulam, Sallipatti, Pilalaiyarkulam, Achchandavitham, Malli, Puvani, Achchankulam, Villapurnur, Nachchiyarkovil and Kottaiyur located in the western part of the study area. Most of the villages viz., Puvani, Kunnur, Venkateswarapuram, Muvaraivenran,Pillayarnatham and Pattakkulam sallipatti recorded medium values of agricultural vulnerability in 1991 and 2001, but recorded high values of agricultural vulnerability in 2011. Low values of agricultural vulnerability occur in villages namely Vadakku Srivalliputur, Watrap, Venkatesapuram, Singammalpuram and Nattampatti seen in the western part of the study area. It is clearly evident from the spatial distribution that the level of agricultural vulnerability is increasing from 1990 to 2011. The twelve villages namely Watrap, Pillayarnatham, Puvani, Kunnur, Sundarapandiyam, S.Kodikulam, Vellaipottal, Marakalamkathan, Thulukkapattai, Nattampatti, Ponnagani, and Mullikulam seen eastern part are under threat. These villages recorded low or moderate level of vulnerability in 1990, fall under high level of agricultural vulnerability in 2011. These villages are the area that has to be prepared for mitigation to reduce the impacts of climate variation.

Finally from the study of agricultural vulnerability, the villages are like Vadugapatti, Govindana, Ayaidharamam, Kunnur, Kalathur, V.Pudupatti, Ayankarisalkulam, Kodikulam, Sundarapandiyam, Nathampatti, Thambipatti, Kottaiyur, Pillayarnatham, Venkateswarapuram are highly vulnerable to agricultural drought. The land use/land cover of those villages under threat has been estimated and is found to be open scrub (Fig. VI). This clearly indicates the existing drought condition of the villages in the study area. The villages with low values of agricultural vulnerability namely Valaikkulam, Sivandipatti, Mamsapuram, Nachchiyarkovil, Vadakku Srivilliputhur are predominantly under reserve forest, plantation and water bodies. The other villages with moderate agricultural vulnerability are mostly under cropland.

6. CONCLUSION: From the above study it can be concluded that SPI, NDVI and NDWI are very useful for early detection of agricultural vulnerability and hence should be a better methodology for remote sensing based vulnerability assessment studies. The NDWI also showed a very good and consistent relation with current rainfall at regional scale. Rather NDVI showed a lagged relationship with rainfall. From the study it is found out that the villages viz., Ayaidharamam, Kunnur, Ayankarisalkulam, Kottaiyur, Pillayarnatham are under threat and has to be prepared for mitigation to reduce the impacts of agricultural drought. This study concludes that real time satellite data can be well utilized for regional level agricultural vulnerability detection for early warning of agricultural drought.

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