SPATIO-TEMPORAL ASSESSMENT OF DROUGHT SEVERITY MAPS USING AGRICULTURAL DROUGHT SEVERITY INDEX FOR SEVEN AGRO CLIMATIC ZONES OF TAMIL NADU, INDIA

***Venkadesh Samykannu [1], Pazhanivelan Sellaperumal[2], Prajesh P. J[2], K.P.Ragunath[2], and R. Kumaraperumal[2]**

venkadeshacrc@gmail.com; pazhanivelans@gmail.com; iamprajesh17@gmail.com; ragunathkp@tnau.ac.in; kumaraperumal.r@gmail.com

[1] Agro Climate Research Centre, [2] Department of Remote Sensing and Geographical Information System, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu (INDIA)

Corresponding author: venkadeshacrc@gmail.com;

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ABSTRACT: In this study, spatial and temporal variations of drought severity maps were generated using agricultural drought severity index (ADSI) for seven agro-climatic zones over Tamil Nadu during the two seasons of the northeast monsoon (October – December) for the year of 2015 and 2016. For ADSI mapping purpose reclassification was done and a new set of severity classes has been assigned *viz.*, Severe (less than 0), High (0.0 to 0.2), Medium (0.21 to 0.4), Low (0.41 to 0.6), Very Low (more than 0.61) each of which comprises of different consecutive ranges of values. The results indicated that the agricultural land in Northwestern zone was under high severity in both the periods and the severe risk has been found to be more during the period of 2016. This was very well related to the fact that 2016 was the worst drought year in Tamil Nadu in the last 140 years due to rainfall deficiency.

INTRODUCTION

Drought has a wide spatial and temporal variability and has a significant effect on the socio-economic stability of a country. Indian agriculture is characterized by a high degree of complexity in the distribution of rainfall and wide changes in physiographical and climatic conditions, where over 68 per cent of the total area is susceptible to drought. Agricultural drought happens during the growing season resulted in declining soil moisture and crop failure in many cases. The adverse effects of meteorological, hydrological, vegetative on the economic products and social needs cause a socio-economic drought (Zhang and Jia, 2013). Tamil Nadu experienced one of the worst droughts due to the failure of the north east monsoon of 2016 in 144 years (Gazette, 2017). This imposed a severe threat to both agriculture and hydrology and resulted in huge economic loss to the State. It is also noticed that the frequency of drought years has increased over Tamil Nadu during recent decades. Satellite remote sensing provides a promising opportunity for large-scale measurement with high temporal resolution and has been successfully used in numerous studies for hydro-meteorological monitoring and analysis (Balenzano *et al*., 2010; Bitew and Gebremichael, 2011; Mattia *et al*., 2012). There are no comprehensive contingency plans for drought mitigation or preparedness for facing the drought. Many attempts were made at district level, but none of the studies have been conducted in detail to assess the aspects of drought at agro climatic zones level, where such interventions would be more significant. Therefore, it is necessary to monitor spatial and temporal variations of drought for different agro climatic zones using remote sensing based agricultural drought severity index over Tamil Nadu during the two of the northeast monsoon (October – December) seasons for the year of 2015 and 2016.

STUDY AREA

The State of Tamil Nadu is located between the latitude of 08° 05′ to 13° 35′ N and 76°15′ to 80° 20′ E longitude in Southern most part of the Indian peninsular region with total

geographical area is 130.33 Lakh Hectare. The State has tropical climate regions and entirely dependent on monsoon rainfall for agriculture and recharging water resources with average annual rainfall is around 921 mm and North-East Monsoon contributes over 48 % (October - December). The State has been divided into seven agro-climate zones namely, North Eastern Zone (NEZ), North-Western zone (NWZ), Western zone (WZ), Cauvery delta zone (CDZ), Southern zone (SZ), High rainfall zone (HRZ) and Hill and high-altitude zone (HHAZ).

DATA AND METHODS

The Moderate Resolution Imaging Spectra-radiometer (MODIS) data used in this study are from the Land Processes Distributed Active Archive Center (LP DAAC) and accessed from the Earth Observing System (EOS) Data Gateway during North East Monsoon of 2015 to 2016. The entire study area was covered by two 16-day composite product (MOD13A1) tiles (h25v07 and h25v08) at 500 m of available spatial resolution for vegetation's primary growing season.

The development of Vegetation Condition Index (VCI) has generalized the concept of drought detection using remote sensing data by scaling the vegetation index (VI) value ranges (Kogan, 1995). Hence, scaled seasonal wise normalized difference vegetation index (NDVI) and normalized Difference Water Index (NDWI) raster‘s were generated in ArcGIS. The scaled vegetation index showed (Table 1) a minimum to maximum value ranging from 0 to 1, respectively for each pixel, where 0 meant driest condition and 1 meant the wettest condition. In order to apply a common measurement scale of values to diverse and dissimilar inputs the scaled NDVI raster images and scaled NDWI raster images were subjected to weighted overlay analysis, where equal weightage was assigned to both of the vegetation indices for carrying an integrated analysis. The two indices layers representing agricultural drought were prioritized according to their degree of influence using pair wise comparison and the vegetation indices based agricultural drought condition map was obtained.

Table 1.Scaled vegetation indices generation

S.No.	Vegetation Index	Formula	Reference
1	Scaled NDVI	(NDVI - NDVImin) / (NDVImax - NDVImin)	(Kogan,1995)
2	Scaled NDWI	(NDWI - NDWImin) / (NDWImax -NDWImin)	

An overall agricultural drought severity index (ADSI) map was generated for the dominant rainfall season of Tamil Nadu by combining the weighted-scaled NDVI raster and weighted-scaled NDWI raster of NEM season using python scripting. For mapping purpose reclassification was done and a new set of severity classes were assigned *viz.,* agricultural drought in Tamil Nadu was classified into five levels of severity *viz.,* very low risk (0.8 to 1.0), low risk (0.8 to 0.6), medium risk (0.6 to 0.4), high risk (0.4 to 0.2) and severe risk (0.2 to 0). Finally, to estimate the area under agricultural drought occurrence, the reclassified images were subjected to zonal statistics and zonal histogram using district shape file as well as land use shape file of Tamil Nadu.

RESULTS AND DISCUSSION

Assessment of drought severity map using ADSI

The spatial-temporal study of long-term agricultural drought for monsoon dependent state like Tamil Nadu is highly essential in order to develop various strategies and increase the crop productivity of the state. During the North East monsoon season of 2015 (Fig. 1a) the distribution of agricultural drought showed that Western zone, Southern zone and North Eastern zone were mainly under the influence of high agricultural drought. While the Cauvery Delta zone and the High Rainfall zones were having very low level of agricultural drought. The spatio-temporal distribution of agricultural drought (Fig. 1b) showed severe to high classes of agricultural drought over the western zone. Presence of very low to low agricultural drought situation was noticed over the High Rainfall zone, High Altitude zone and Cauvery delta zone.

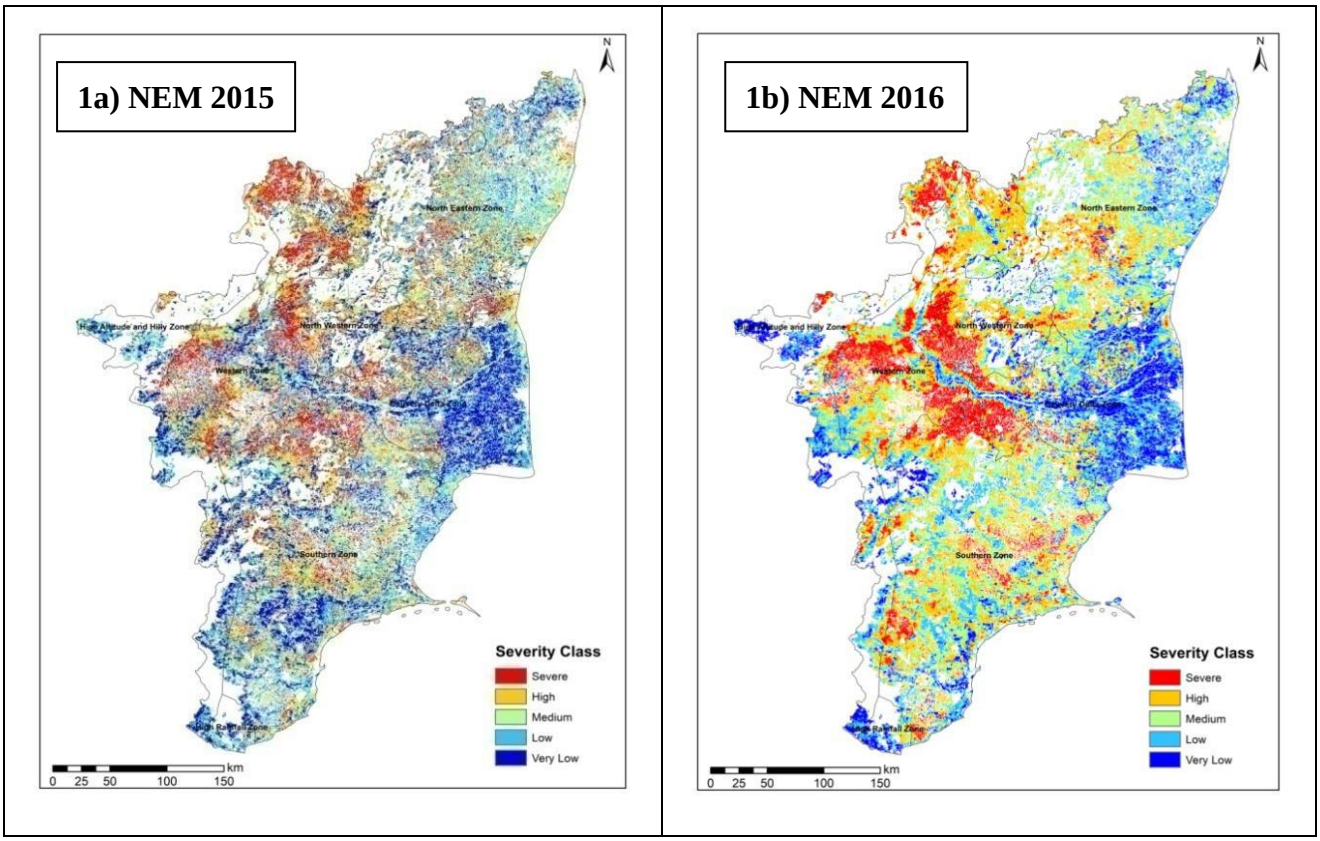

Fig. 1a & 1b. Agricultural Drought Severity Map of Tamil Nadu during the NEM 2015 and 2016

Based on agricultural crop-land (Table 2), it was noticed that in the southern agro-climatic zone, maximum area was under the class of low agricultural drought severity (6, 30,375 ha), while only 2, 13,725 ha was under severe level of agricultural drought.

Table 2. Agro climatic zone wise area (ha) under agricultural drought during NEM of 2015

Classes	SZ	NEZ	HRZ	CDZ	WZ	HZ	NWZ
Severe	2,13,725	1,60,775	575	1,10,375	1,76,475	1,05,275	1,87,275
High	5,39,025	4,00,175	4,450	1,78,450	2,13,575	1,28,150	2,56,400
Medium	5,03,775	3,77,650	16,175	2,61,400	1,43,600	1,47,650	1,08,475
Low	6,30,375	5,27,025	19,025	3,57,700	2,14,125	1,83,975	1,42,300
Very Low	4,92,025	2,51,350	22,975	4,75,800	1,49,000	2,08,300	1,33,525

Based on agricultural crop area (Table. 3), it was noticed that in the Southern agro climatic zone maximum area was under the influence of medium agricultural drought severity (8,52, 975 ha), while only 1,63,000 ha was under very low level of agricultural drought.

Table 3. Agro climatic zone wise area (ha) under agricultural drought during NEM of 2016

Classes	**SZ**	**NEZ**	**HRZ**	**CDZ**	**WZ**	**HZ**	**NWZ**
Severe	2,30,175	46,975	775	86,525	3,10,000	1,13,275	1,34,200
High	6,70,400	4,12,925	7,125	1,41,400	2,67,200	1,52,200	3,69,450
Medium	8,52,975	6,53,475	10,200	2,70,975	1,72,075	1,58,600	1,90,800
Low	4,74,425	4,55,850	18,975	3,99,575	1,04,850	1,82,525	75,225
Very Low	1,63,000	1,50,825	25,275	4,88,350	39,775	1,70,750	64,375

Analysis of drought severity during NEM season of 2015 to 2016 indicated that the High Rainfall zone was under the influence of low to very low level of agricultural drought. This could be possibly related to the geographical location of this area, as this zone receives high rainfall which suggests the consistent growth of vegetation (Kundu *et al*., 2017). While the presence of bi-modal climatic conditions over this zone contributes to presence of good to dense vegetation cover (Sukumar, 2013). In the North Western zone of Tamil Nadu, it was noticed that the agricultural lands were under high agricultural drought severity during NEM 2015 and NEM 2016. This variation between the years might be due to the variation in land cover influenced by the presence or absence of dry periods or wet periods.

Comparison of variation in cropland areas between the NEM of 2015 and 2016 showed that severe risk of agricultural drought occurred during the NEM period of 2016. This was very well related to the fact that 2016 was the worst drought year in Tamil Nadu in the last 140 years as a result of rainfall deficiency. Rainfall received during the months of October to December from the North East Monsoon season played major role in Tamil Nadu (Nathan, 1998). As a result, Western zone, North Western zone and Southern zone showed severe agricultural drought during the NEM.

CONCLUSION

Among the two years of study in Tamil Nadu, 2016 was classified under severe risk category of agricultural drought based drought severity index. While Western, North Western and Southern Zone were classified under severe agricultural risk during the NEM of 2016. In the North Western zone of Tamil Nadu, it was noticed that the agricultural land was under high risk of agricultural drought during NEM 2015 and NEM 2016.

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