" AGRICULTURE DROUGHT ASSESSMENT AND MONITORING (ADAMS) SOFTWARE USING ESRI ArcMap "

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"AGRICULTURE DROUGHT ASSESSMENT AND MONITORING (ADAMS) SOFTWARE USING ESRI ArcMap"

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Abstract:

Growing evidences about global warming, decreasing availability of surface and ground water, and erratic rainfall induced droughts are questioning agriculture sustainability. Over the past few decades, drought has become a major disaster in many parts of South Asia and regular monitoring system is needed for the whole South Asia and in this regard International Water Management Institute (IWMI) has initiated an integrated drought management framework where partner countries share data and collaborate to meet the objective. Under this initiative a collaborative project between BIT, Ranchi and IWMI, Sri Lanka was carried out so as to develop an automated software package specifically addressing drought related models. Authors decided to develop the proposed package under ARCMAP using ArcObjects library in Visual Basic as there is no readymade tools/library for drought applications in ArcMap and this study has developed new tools for quantifying district level drought impacts. The outcomes of this tool development will help decision makers for better preparedness and effective planning.

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Introduction

Drought is a resultant effect of complex processes happening within atmospheric, climatic and environmental dimensions. Agricultural Drought basically refers to stressed and declined vegetation growth condition over a period of time due to shortage of precipitation, high surface temperature and deficit in soil moisture (Son et al., 2012). Over the past decades number of meteorological drought indices such as standardised Precipitation Index – SPI (Guttman, 1999), Palmer Drought Severity Index – PDSI (Palmer, 1965) etc. were successfully used. In recent decades, remote sensing domain has progressed well to map different biophysical variable related to drought such as vegetation condition, surface temperature condition, precipitation condition etc. through continuous satellite observation over a large area. Especially, data from MODIS and TRMM has been extensively used in drought studies as the data is available at global level, high temporal resolution, consistent data compositing and web-data access facility. However, efficient processing of large volume of time series data is one of the main challenge to monitor drought over the large area and there is no commercial software package or ready-made public tool for drought monitoring. Though there are few time series processing tool developed for phenological and crop monitoring purpose such as TIMESAT (Jonsson and Eklundh, 2004), SPIRITS (Eerens et al., 2014), PhenoSat (Rodrigues et al., 2013) etc. but they are not specifically meant for Drought monitoring.

In this regard, to fulfil the aims of South Asia drought monitoring project entitled by "Development of South-Asia Drought Monitoring System", a collaborative initiative was taken by IWMI, Srilanka and BIT Mesra, Ranchi to develop drought monitoring package under ARCMAP using ArcObjects library in Visual Basic. ArcMap was selected due to its wide usability by many organization and ArcMap user has the basic understanding of remote sensing and GIS processing. However, there is no readymade tools/library for time series drought applications in ArcMap and in this study authors have developed an optimised toolset for drought monitoring.

Study area and Data

The study is being carried out over South-Asia and the results presented in this work was mainly focussed over Sri Lanka as a sample case. Three type of datasets namely 8-day interval MODIS Reflectance (500m), 8 day interval MODIS LST (1km) and daily TRMM rainfall (27km), has been used in this research. Data were downloaded from MODIS and TRMM websites. The study area is covered by 12 MODIS tile and study period was over 2001 to 2014. In total 7728 (46 Composite * 12 tiles * 14 years) MODIS surface reflectance composites (MOD09A1), 7728 MODIS LST composites and 5110 TRMM composites were downloaded (around 3TB raw data) for covering study period from 2001 to 2014.

Methodology

The methodology has 3 major sections: (a) Raw data processing and noise reduction; (b) standardised metrics computation (VCI, TCI and PCI) and (c) Integrated drought index development. The figure 1 reveals the schematic diagram about various steps involved in the study.

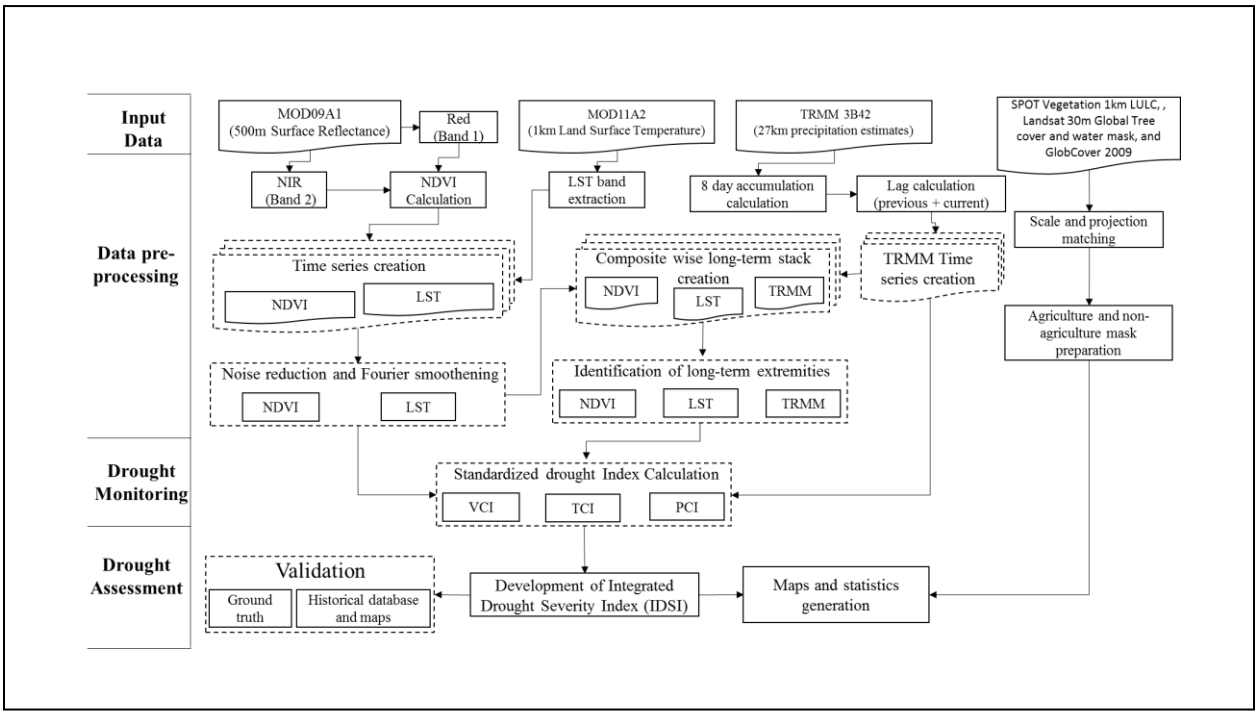

Figure 1: The Schematic representation of methodology of the study

The time series MODIS NDVI (created using RED and NIR reflectance data) and LST product contains data gap and noise caused by cloud contamination and atmospheric instability during satellite overpass, affecting accuracy. In this study, temporal moving window was used to remove dropouts, and noise was eliminated based on neighbourhood statistics. However, the high frequency noise (i.e., day to day fluctuations) still remains in the data series which is normally eliminated using smoothing. Though number of smoothing techniques are available, this study adopted Discrete Fourier Transformation (DFT) due to its advantages in terms of less number of model parameters, ease of implementation and controlled smoothening of high frequency noise (Jeganathan et al. 2010). Finally, smoothed time series MODIS NDVI and LST over South Asia was created for 14 years (2001 – 2014). For rainfall data, noise correction and smoothing will distort actual values and hence the original data were kept as it is even with data gaps which is very much possible if rainfall does not continuously occur for some weeks. Rainfall and vegetation growth has a peculiar relationship.

Current week vegetation vigour depends not on the current week rainfall but rather on previous week(s) rainfall, and hence cumulative rainfall was calculated using two week data (current and previous) to quantify rainfall condition.

Remotely sensed NDVI, LST and TRMM rainfall accumulation information was converted into three standardised indices: Vegetation Condition Index - VCI; Temperature Condition Index - TCI and Precipitation Condition Index - PCI, to derive meaningful and uniformly interpretable information. The VCI helps to detect vegetation stress by evaluating current week vegetation vigour with long-term ranges (i.e., min and max). TCI helps to understand temperature variability. And finally PCI helps to assess the degree of water with reference to long-term levels. The VCI, TCI and PCI were calculated based on following equation.

$$VCI_{ijk} = \frac{NDVI_{ijk} - NDVI_{ijn}}{NDVI_{ijx} - NDVI_{ijn}} * 100 \qquad \text{(Eq. 1)}$$

$$TCI_{ijk} = \frac{LST_{ijx} - LST_{ijk}}{LST_{ijx} - LST_{ijn}} * 100 \qquad \text{(Eq. 2)}$$

$$PCI_{ijk} = \frac{TRMM_{ijk} - TRMM_{ijn}}{TRMM_{ijx} - TRMM_{ijn}} * 100 \qquad \text{(Eq. 3)}$$

Where, 'i' represent a pixel, j represents the composite number and k represents the year, n refers to minimum (long term), x refers to maximum (long term). The value range of all three indices varies between "0" to "100". The value nearby "0" reveals worst case (extreme stress) situation and nearby 100 expresses best case (Healthy) situation.

Globally, researchers have clubbed VCI and TCI to derive vegetation health status or used all the three indices to under Principal Component technique (PCA) to derive integrated drought information. PCA has its own limitation as it depends on size of data, distribution of data, and PCA results from two MODIS tiles will not have continuity. Because of these problems in this study we developed a new index called Integrated Drought Severity Index (IDSI) which was developed based on the data fusion technique which successfully resolved multi-resolution effect of VCI, TCI and PCI products. The IDSI is calculated based on following equation-

$$IDSI_{ijk} = \left[L * VCI_{ijk} * \left\{1 + \frac{1}{(L*(VCI_{ijk} + TCI_{ijk} + PCI_{ijk} + c)} * \left(TCI_{ijk} + PCI_{ijk}\right)\right\}\right] \qquad \text{(Eq. 4)}$$

The IDSI value range will be 0 to 100; L is the normalization factor to keep the output value as per expected range (L=0.33) and c is a constant to avoid null in denominator (c=1). The IDSI value nearby 0 reveals extreme drought situation meaning vegetation is under extreme stress, precipitation is very low and temperature is very high. Likewise, the value 100 reveals a very healthy situation meaning vegetation growth is good, precipitation is high and temperature is favourable.

Results and discussion

Time series Drought monitoring over large area is a challengeable task due to many aspects such as handling huge volume of data, addressing the inherent noise in time series data, integration of multi-scale biophysical variable (VCI, TCI & PCI) and availability of efficient data processing platform. Most of the available and widely used GIS and Image processing packages do not have dedicated time series data processing functions.

To overcome this limitation, we have developed a tool set named ADAMS (Agriculture Drought Assessment and Monitoring System) which is an integrated time series drought analysis and monitoring package developed using ArcObject VBA under ArcMap for monitoring drought over South Asia. ADAMS contains three major sections: (a) Data pre-processing, (b) Drought Monitoring and (c) Drought assessment. The main menu of ADAMS tool in ArcMap environment is represented in figure 2.

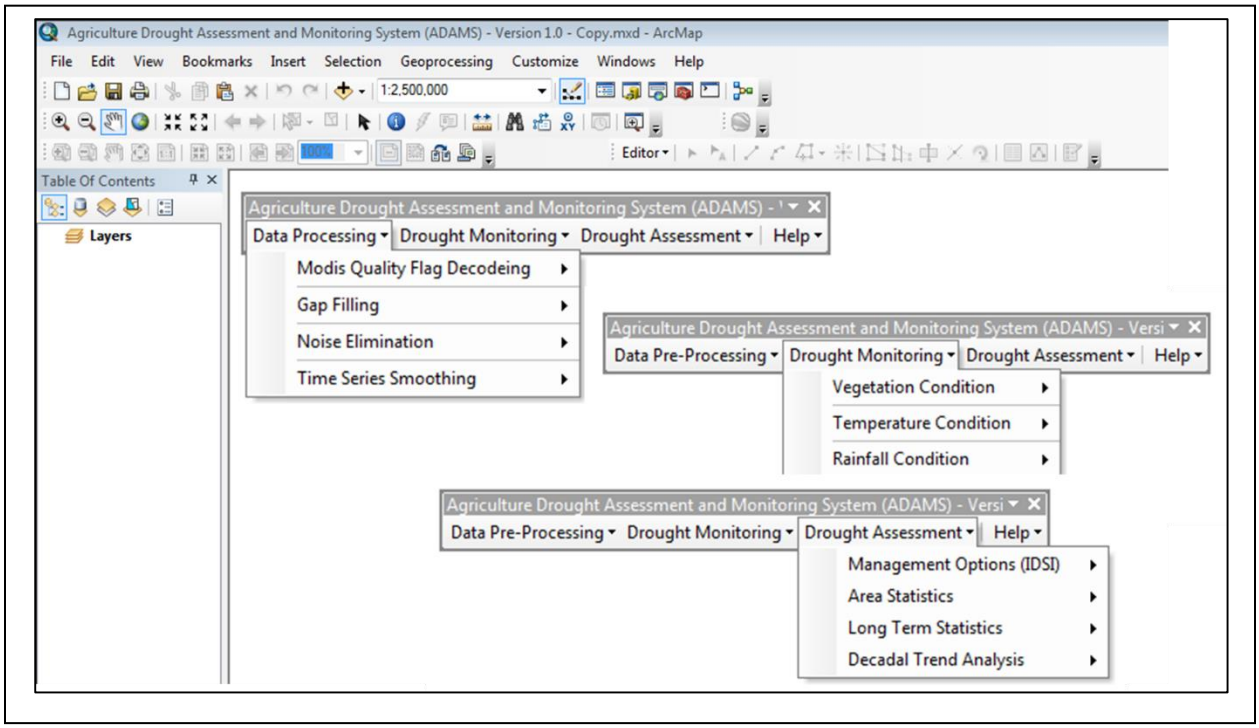

Figure 2: The ADAMS tools in ArcMap environment.

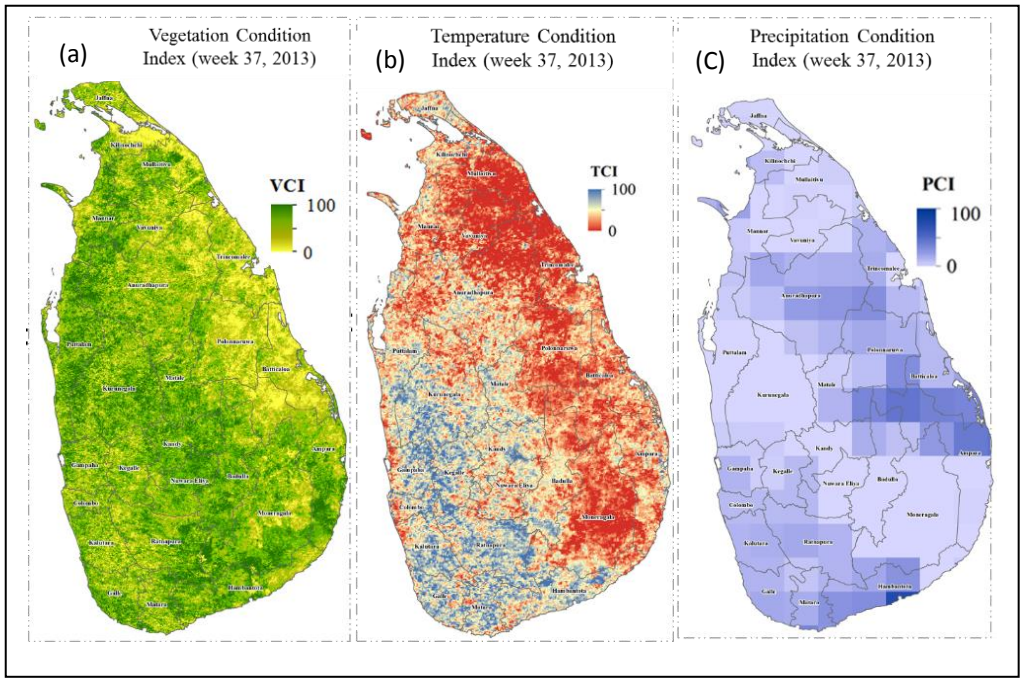

Figure 3: Derived indices - VCI (a), TCI (b), PCI (c) of week 37 in 2013.

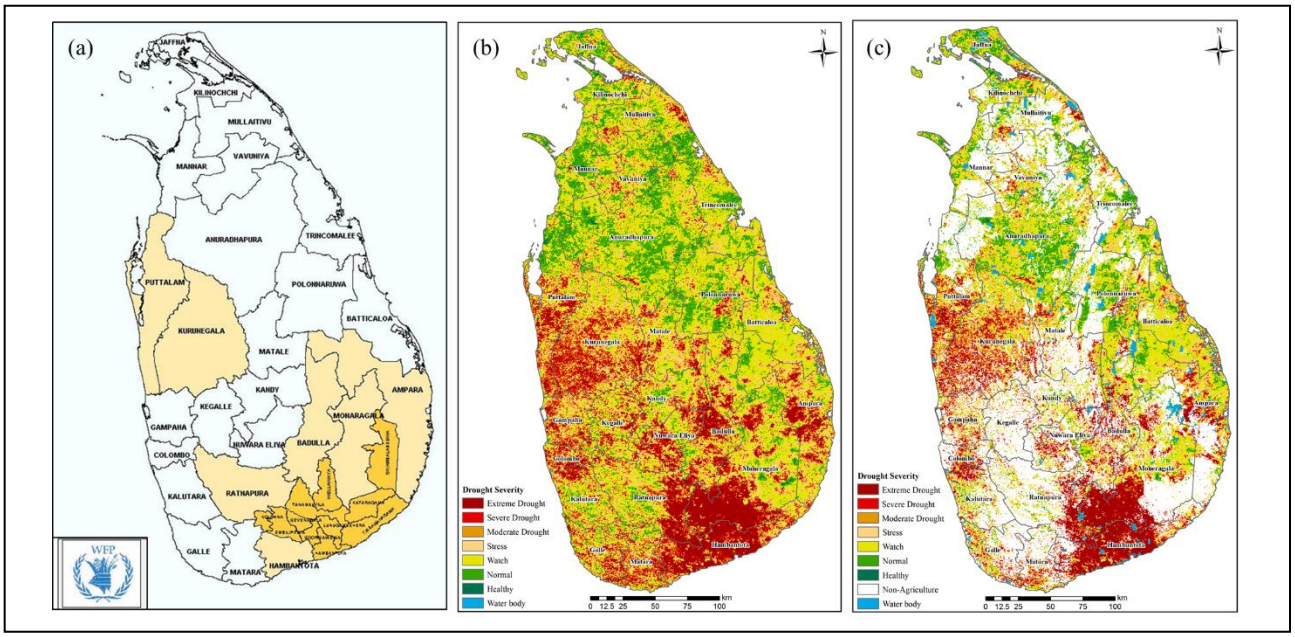

Figure 4: Validation of results during 1st week of September, 2001 over Sri Lanka. (a) The Drought intensity map produced by United Nations World Food Program, (b) Classified IDSI (c) IDSI over Agriculture area.

The new drought index (IDSI) developed in this study has successfully integrated multi-resolution variables (500m VCI, 1km TCI & 27km PCI) (as revealed in the figures 3, 4, 5) and it could address quantitative relationship among three variable in terms of drought magnitude.

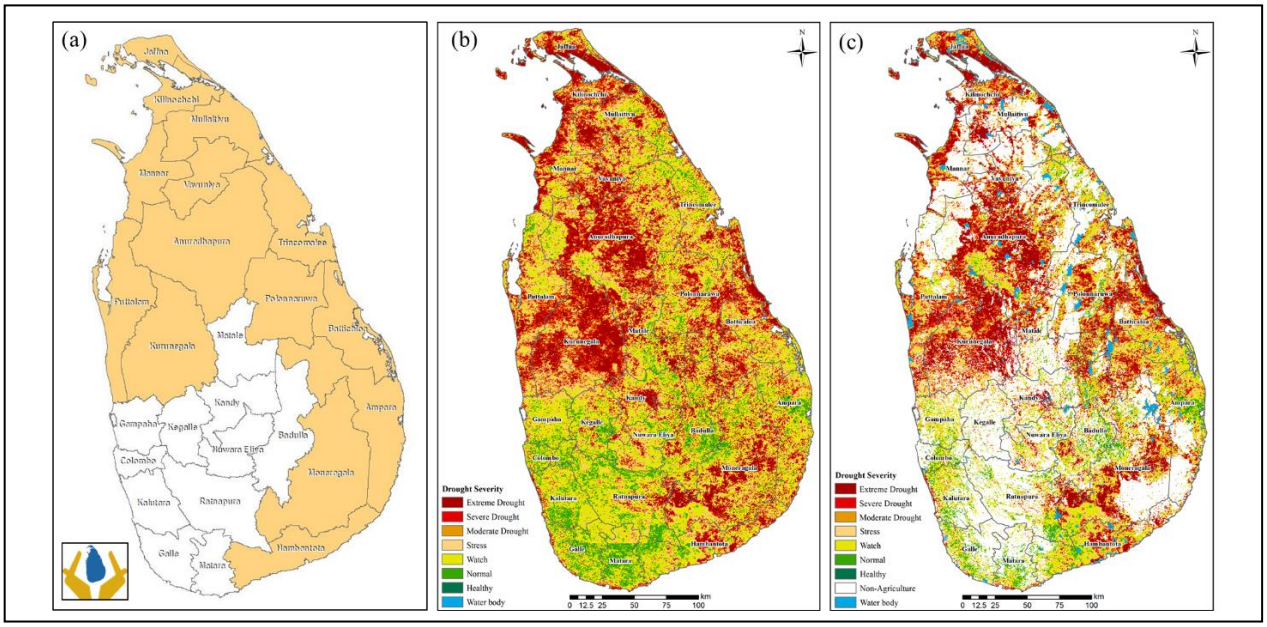

Figure 5: Validation of results during 3rd week of March, 2014 over Sri Lanka. (a) The Drought intensity map produced by National Disaster Management Centre, Sri Lanka; (b) Classified IDSI; and (c) IDSI over Agriculture area.

The results from IDSI was validated using published reports from UN World Food Program maps and with Sri Lanka's National Disaster Management Centre's maps.

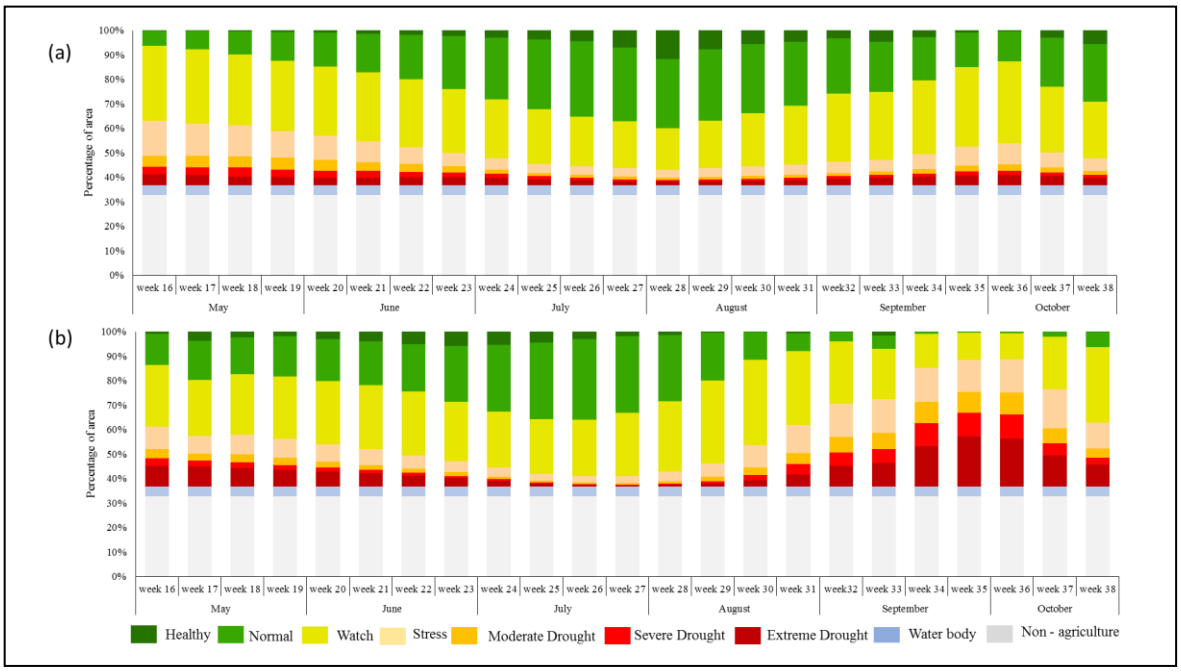

Figure 6: Temporal dynamics (agriculture area) of different IDSI class during monsoon season over Polunneruwa district, Sri Lanka during (a) 2007 (Normal year) and (b) 2013 (drought year).

The results showed very good match with published reports. In addition, the spatial variation and distribution of different drought classes were also revealed which was not provided in the reference maps (Figs. 4a, 5a). To present the temporal response and behaviour of IDSI, this study compared the temporal drought area dynamics of different IDSI class (figure 6) over Polunneruwa district of Sri Lanka in two different years: 2007 (for Normal year) (fig. 6a) and 2013 (for drought year) (fig. 6b). The results again matched well with the ground information.

Conclusion

Overall the study has revealed the issues, developments and validation aspects of spatial time-series data analysis and processing package in relation to drought monitoring. ArcGIS package has helped the developmental aspects of this study through useful libraries for handling images (especially reading, writing and memory management), and with the user friendly customisation environment which has greatly accelerated the development of ADAMS.

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