Drought Monitoring for Sri Lanka: Spatial Extent and Temporal Evolution during the 2016-17 Drought

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Abstract: *Drought is the most common disaster in Sri Lanka with the largest number of impacted persons. While the present response is substantially on post-disaster relief provision, prior disaster risk management and adaptation to mitigate the impacts of hazards is better all around. Such risk management and adaptation needs anticipation of the spatial and temporal variation of drought through the use of meteorological and hydrological data. However, meteorological data is not freely available and exorbitantly priced. As an alternative, we see to demonstrate the use of satellite derived data which is free and accessible in time.*

In this paper, we investigate (a) the quality of the satellite based rainfall data in comparison with ground observations for one of the most severely droughts affected districts – Polonnaruwa, (b) use a drought index to develop a comparison of the current drought in Polonnaruwa with those in the recent past and (c) map the spatial extent of rainfall anomalies across Sri Lanka.

We show that (a) the satellite based data quality is adequate for most drought monitoring in Sri Lanka, (b) the 2016/2017 drought in Polonnaruwa is of medium-intensity drought, (c) drought in Sri Lanka was built up over 2016. Drought can be punctuated by floods in some places – it is only by considering monthly or finer scale data that we could narrow down the impact of these high rainfall events. In general, the use of satellite based drought monitoring protocols are shown to be viable for Sri Lanka.

Keywords: *drought, monitoring, precipitation, disaster risk management.*

1. Introduction

Drought is the most common disaster in Sri Lanka with the largest number of impacted persons (Zubair et al., 2006). Drought management in Sri Lanka is largely limited to relief provision but it is now recognized that risk management and ongoing adaptation are needed. Such adaptation needs anticipation of the spatial and temporal variation of drought. Drought is a slowly evolving phenomenon and thus having a good monitoring system alone is a good start. An early warning system could be developed based on environmental data for surface hydrology, weather, and other terrestrial, economic and societal data. Of this meteorological data, has the potential to be available in timely manner However, it is not freely available and exorbitantly priced– and in case there is no timely access to it, except for a few stations such as maintained by our institute. Our institute has pioneered the use of satellite based data for drought assessment after conducting studies on the quality of the data. We have also pioneered the use of maps of monitored drought indices in collaboration with the International Research Institute (IRI) for Climate and Society (Lyon et al., 2009).

Sri Lanka experienced a severe drought in 2016/17 punctuated by a deluge of rain in May. Part of the Yala season of 2016 (June to September) and Maha season of 2016/17 (October to March) was affected by the drought. The total water capacity at 73 major reservoirs were reported at 29%, which is 1,040 MCM as of 22nd December 2016 and showed no signs of improvement in the ensuing months. This was well below the 2,220 MCM required for the Maha season. During this Maha season 612,223 hectares of paddy was cultivated of which 50,615 ha was damaged due to the drought and it amounts to a loss of 4, 053,395 bushels of paddy. According to the Disaster Management Center, 1.8 million people across 20 districts were affected as of September 2017.

Polonnaruwa was for a while the epi-center of the drought in Sri Lanka as there were severe impacts (Disaster Management Center 2017). In Polonnaruwa district, 24,099 people from 6,714 families are suffering from the drought as of September this year. Government was distributing dry rations among the affected people and trucking safe drinking water. Rice production, which is water intensive, is expected to be halve this year along with many other crops with many reservoirs dry (Economy Next 2017). Therefore, we use Polonnaruwa as a case study for investigating the use of satellite data and construction of drought indices.

Drought indices have been developed to capture the drought from environmental observations (Hayes et al., 2012). For Sri Lanka, extensive work has been reported of the use of The Standardized Precipitation Index (SPI) (Lyon et al., 2009) and Weighted Anomaly Standardized Precipitation (WASP) index (Zubair et al., 2006).

In this paper, we investigate (a) the quality of the satellite based rainfall data in comparison with ground observations for Polonnaruwa, (b) use a drought index to develop a comparison of the current drought in Polonnaruwa with those in the recent past and (c) show the spatial extent of rainfall anomalies across Sri Lanka and its temporal evolution.

2. Methodology

2.1 Data

Data collection is based on the needs and is obtained from available sources at recording institutions as noted below. The data processing was done with the IRI Data Library installation at Foundation for Environment, Climate and Technology (FECT). The satellite data was processed by the IRI/FECT portal for obtaining rainfall data for Sri Lanka.

- *Surface observed weather data for Polonnaruwa*
  Monthly rainfall data for the period 1960-2017 from Minneriya, Kaudulla, Bakamuna, Aralaganwila, Angamedilla, Diyabeduma, Giritale, and Polonnaruwa Department of Agriculture weather station supplemented by data from Padawiya (in Anuradhapura district) were used in this analysis.
  Data was obtained from the Department of Meteorology, Department of Irrigation and Natural Resources Management Center of the Department of Agriculture.
- *Satellite observed rainfall estimates*
  Gridded daily rainfall estimates at a grid size of 10 km is available from the National Oceanic and Atmospheric Administration (NOAA)/Climate Prediction Center (CPC) (Climate Data Library 2017). The interface allows users to analyze

recent rainfall via maps and location-specific time series. We use IRI/FECT tool that focuses on rainfall estimations for Sri Lanka to download data for our analysis.

2.2 Methodology

Established methodologies to undertake quality control, construct regional climate indices, estimate satellite rainfall and construct drought indices were used. These are detailed in Zubair et al., (2006) and Lyon et al. (2009).

- *Quality Control of Ground Data*
  To check the consistency of the rainfall data among these stations, a correlation matrix was created using MS Excel. High cross correlations, greater than 0.8 were observed among stations except for Padawiya station which ranged from 0.74-0.79.
- *Construction of Average Rainfall for the "Polonnaruwa District"*
  The averages of the monthly rainfalls of these nine stations were used as Ground observed data in the analysis due to the strong relationship (high correlation, consistent seasonality) across stations and reasonable spatial distribution of the data across the Polonnaruwa district.
- *Obtaining equivalent satellite rainfall estimates for "Polonnaruwa District"*
  The Rainfall estimations that correspond to the rectangular area that roughly maps on to Polonnaruwa district (7.7 ^{0}N, 80.8 ^{0}E, 8.3 ^{0}N, 81.4 ^{0}E) was used.
- *SPI*
  SPI was developed by McKee et al., 1993 primarily for defining and monitoring droughts at different time scales (temporal resolutions), an important characteristic that is not accomplished with typical drought indices (Wu et al., 2001). The SPI can be created for differing periods of 1-to-36 months, using monthly input data. 6-SPI drought index calculations were done by the SPI_SL_6 tool developed by National Drought Migration Center of University of Nebraska.
- *WASP*
  WASP index and is based solely on monthly precipitation data. It gives an estimate of the relative deficit or surplus of precipitation for different time intervals ranging from 1 to 12 months. WASP maps were generated by WASP functions in IRI Data Library. (Lyon et al., 2009)

Zubair et al., 2006 and Lyon et al., (2009) have shown that the Weighted Anomaly Standardized Precipitation (WASP) Index and the Standardized Precipitation Index (SPI) is able to capture drought in Sri Lanka at fine-scale as represented by relief payments between 1960 and 2000. The WASP index takes the deficits in each month.

Note that if the WASP index is between -1 and -2 it is defined as "moderately dry", and between -2 and -3 is "very dry" and if the index is below -3 it is "extremely dry".

3. Results and Discussion

3.1 Comparison of Satellite and Ground based Rainfall Estimates for Polonnaruwa

The monthly averages of these ground observed data shows a strong correlation of 0.8937 and Spearman's rank-correlation of 0.8222 with the satellite observed rainfall estimations as evident in Figure 1.

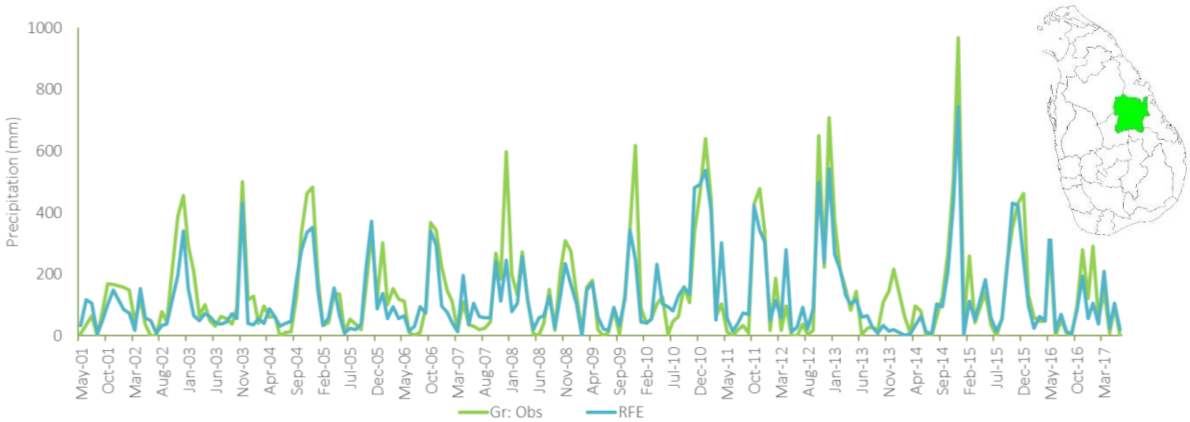

Figure-1. Comparison between Ground Observed Data and Satellite Estimated data

3.2 Use of Drought Indices – Case of Polonnaruwa

The WASP drought index time series for 2001 to 2017 shows that the succession of very dry periods (<-2) has occurred in the 2016 to 2017 period. However, it is not as severe as was the case from 2013 to 2014. The WASP has been shown here in Figure 2 and the SPI graph (not shown) is similar. We have used the SPI with a 6-month for work below.

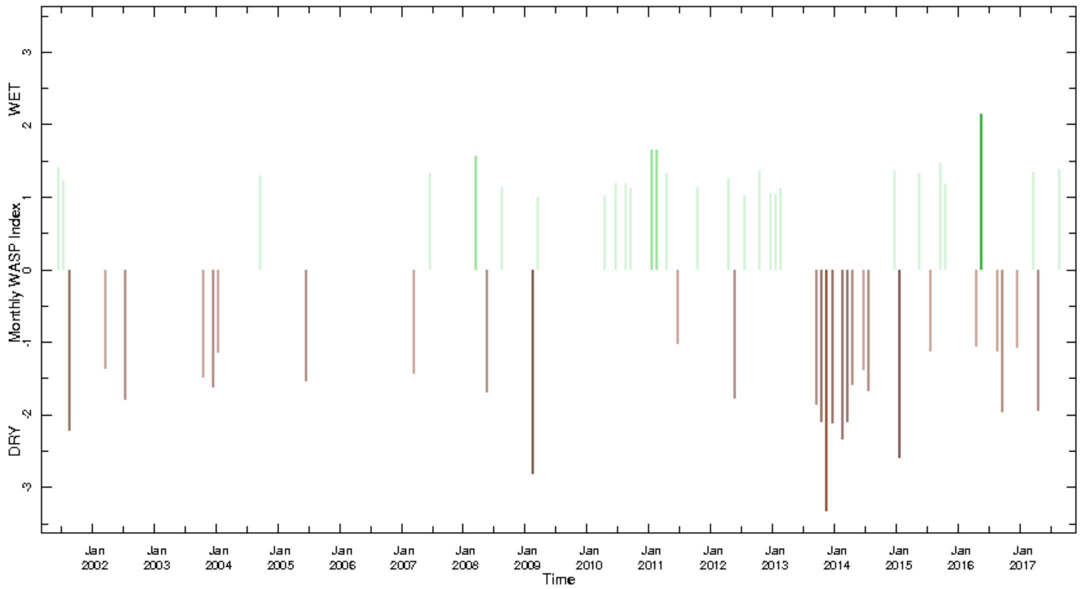

Figure-2. The monthly WASP drought index for a 3 month window for the Polonnaruwa district since 2001

Drought events that have six-month SPI values of less than -1.0 for at least two consecutive months were considered from average precipitation of the nine stations from 1960 to June 2017. Using this measure, drought onset is defined as the first month that the SPI indices becomes negative; it terminates when the index becomes positive.

According to 6-SPI (Figure 3), drought lasted from 2016 Nov to 2017 May (7 months) with an accumulated rainfall deficit of 234.06 mm. The median duration of a drought and accumulated deficit for Polonnaruwa district from 1960 onward is 9 months and 428.0 mm respectively.

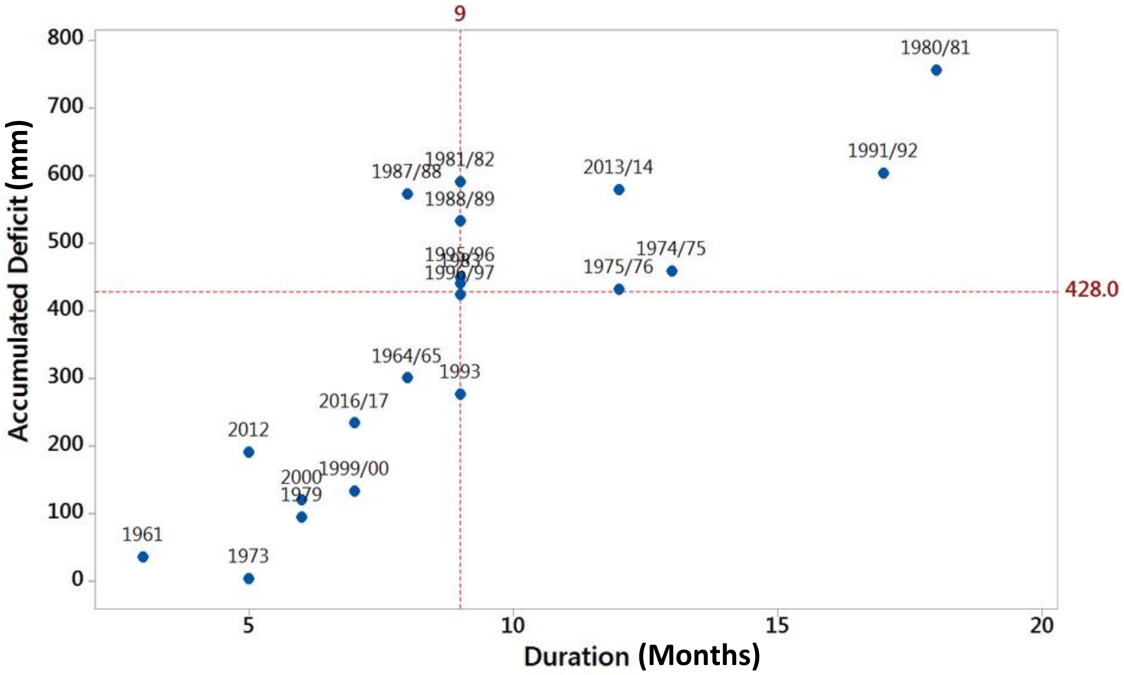

Figure-3. Accumulated Deficit of Precipitation Versus Duration for Drought Events Identified Using the Six-Month SPI

3. 3 Spatio-Temporal Distribution of Rainfall Anomalies

The monthly rainfall anomalies shown in Figure 4 shows that apart from extreme rainfall received in May the rainfall largely remained below average throughout 2016. In 2017, the island received above average rainfalls in the months of March, May and August. Mostly below average rainfall conditions were observed in the rest of the year.

4. Conclusions

Here, we show that (a) the satellite based data's quality is adequate for most drought monitoring in Sri Lanka given that it is free and easily accessible. However, further analysis should be done of the quality for its capacity to capture the spatio-temporal variation at finer scales in space and time, (b) the drought index of SPI is able to contextualize the ongoing drought for Polonnaruwa as a medium drought when compared to those in the past based on rainfall deficits and (c) drought in Sri Lanka was built up over a the entire 2016 going on the Maha 2016/2017 and that drought in Sri Lanka can be punctuated by floods in some places – as happened in South-West parts of Sri Lanka for about a week - it was only by considering monthly or finer scale data that we could narrow down the impact of these high rainfall events on the drought. In general, the use of satellite based drought monitoring protocols are shown to be viable for Sri Lanka and thus can be skillfully used drought early warning systems.

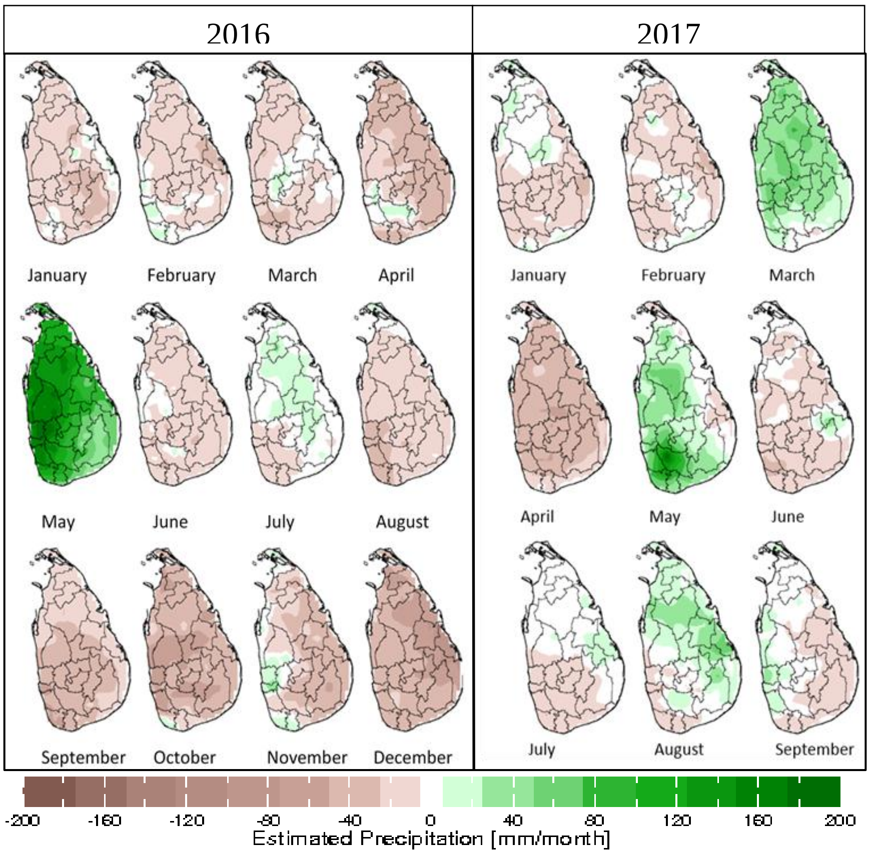

Figure-4. Monthly precipitation anomalies for 2016 and 2017

References

- Dmc.gov.lk. (2017) DMC-SL (Disaster Management Center - Sri Lanka) [online] Available at: http://www.dmc.gov.lk/index_english.htm [Accessed 31 Oct. 2017].

- Hayes, Michael J.; Svoboda, Mark D.; Wardlow, Brian D.; Anderson, Martha C.; and Kogan, Felix, "Drought Monitoring: Historical and Current Perspectives" (2012). Drought Mitigation Center Faculty Publications. 94.
http://digitalcommons.unl.edu/droughtfacpub/94
- Lyon, B., Zubair, L., Ralapanawe, V. and Yahiya, Z., 2009. Finescale evaluation of drought in a tropical setting: case study in Sri Lanka. *Journal of Applied Meteorology and Climatology*, *48*(1), pp.77-88.
- McKee, T. B., N. J. Doesken, and J. Kleist, 1993: The relationship of drought frequency and duration to time scales. Preprints, Eighth Conf. on Applied Climatology, Anaheim, CA, Amer. Meteor. Soc., 179–184.
- Wu, H., Hayes, M. J., Weiss, A. and Hu, Q. (2001), An evaluation of the Standardized Precipitation Index, the China-Z Index and the statistical Z-Score. Int. J. Climatol., 21: 745–758. doi:10.1002/joc.658
- Zubair, L., Ralapanawe, V., Tennakoon, U., Yahiya, Z. and Perera, R., 2006. Natural disaster risks in Sri Lanka: Mapping hazards and risk hotspots. *Natural disaster hotspots case studies*, p.109.
- Zubair, L. and Chandimala, J., 2006. Epochal changes in ENSO–streamflow relationships in Sri Lanka. *Journal of hydrometeorology*, *7*(6), pp.1237-1246.