Analysis of Standard Precipitation Indices to Identify for Drought Condition in 2015

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ABSTRACT

Drought is a hydro-meteorological disaster and it is a serious problem for human society and ecosystem. Gradual establishment of drought cannot be predicted with a lead time. Generally drought monitoring is done in many countries by analyzing various meteorological data and other environmental data such as rainfall, temperature, winds, soil moisture etc. Meteorological, Agricultural, Hydrological and Socio economic droughts are four categories which depends on monitoring vulnerability of different key sectors. Agricultural and Hydrological droughts are strongly related with meteorological drought whereas socio economic drought depends upon various other factors such as poor infrastructure, political reasons etc. with or without meteorological, agricultural and/or hydrological drought. Therefore, socio economic drought monitoring is not as easy as in case of the other three.

Media announced that 250,000 Civilians belongs to the 80,000 families were affected from six districts of the Northern Province of Sri Lanka due to drought conditions in 2015. Many studies suggested that there is a possibility of establishing drought conditions in Sri Lanka during southwest monsoon (May- September) in the El Nino years. 2015 is an El Nino year and there is a chance for establish drought condition. To identify possible drought conditions in 2015, monthly rainfall data were analyzed using Standard Precipitation Index (SPI). Additional information related to this study gathered from agriculture and irrigation department to monitor agricultural and hydrological drought.

Results clearly confirmed that, there was no meteorological, agricultural and hydrological drought, but there is a possibility for socio economic drought in the above mentioned areas.

1 Introduction

Drought is a hydro-meteorological disaster and mainly occur due to rainfall variability. Droughts are one of the most serious problems for human societies and ecosystems. Drought conditions does not establish suddenly as the other natural hazards such as floods and storms. It gradually establish with the negative anomaly of rainfall for a required period and it is one of the most damaging types of natural disasters over long periods. Impacts from the droughts are different in different areas. The damages and the economic losses due to the flood and droughts are very high and they affect on very large number of people in each year (Wilhite 2000). Drought is the single most important climatological hazard, often aggravated by human actions. Drought may start at any time and reach varying levels of severity (Premalal 1998). Drought is described as a deficiency of precipitation over an extended period of time, which results in shortages of

Water. The impact for the human being is less in developed area having with national water service, compare with the non-developed area. Therefore People in the develop area not much vulnerable and they do not feel The severity as the people in non-develop area. Human beings often increase the impact of drought because of a high use of water that cannot be supported when the natural supply decreases.

Drought is also a normal, recurrent feature of climate that occurs in most climatic zones. Generally, these droughts have a duration of 6 to 9 months (Lyon et al., 2009), but the typical length for humid tropics regions are 6 months (Sheffield and Wood, 2007). Drought is also related to the timing of precipitation. Other climatic factors such as high temperature, high wind, and low relative humidity are often associated with drought.

Basically drought can be classified as meteorological, hydrological, agriculture and socio economic. Meteorological drought is usually measured by how far from normal the precipitation has been over a certain period of time (Agnew, 1990), usually it is degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region (http://drought.unl.edu/DroughtBasics/TypesofDrought.aspx).

If the deficit rainfall affect for the agricultural productivity and if the agricultural productivity is significantly reduce, it can be classified as agricultural drought (Agnew and Warren, 1996). Therefore it directly related to the deficit of soil moisture due to negative rainfall anomaly. But agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and so forth. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil (http://drought.unl.edu/DroughtBasics/TypesofDrought.aspx). Hydrological drought refers to deficiencies in surface and subsurface water supplies (Palmer, 1965).

Socioeconomic definitions of drought associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. It differs from the aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. Therefore it is clear that drought monitoring is different for the different sectors. More variables, such as wind, evaporation are needed for better monitoring of drought. There are different techniques to calculate drought indices. The Palmer Severity Drought Index (PDSI) is one of the best index, because it includes many parameters relevant to meteorological and agricultural droughts. The PDSI is based on a supply-and-demand model of soil moisture. Supply is comparatively straightforward to calculate, but demand is more complicated as it depends on many factors – not just temperature and the amount of moisture in the soil but hard-to-calibrate factors including evapotranspiration and recharge rates. Palmer attempted to overcome these difficulties by developing an algorithm that approximated them based on the most readily available data namely, precipitation and temperature (https://en.wikipedia.org/wiki/Palmer_drought_index).

The other most widely used index is Standardized Precipitation Index (SPI). The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the

Location and desired period is zero (Edwards and McKee, 1997). The value of current rainfall as given in terms of standard deviation of the normal distribution. Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI. Utilize SPI for drought monitoring has also been recommended for National Meteorological and Hydrological Service (NMHS) by World Meteorological Organization (WMO), in addition to the other drought indices that were in use in their service to monitor meteorological drought (WMO 1090, 2012).

The SPI has been designed to quantify the precipitation deficit for multiple timescales. These timescales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, stream flow and reservoir storage reflect the longer-term precipitation anomalies. For these reasons, McKee and others (1993) originally calculated the SPI for 3-, 6-, 12-, 24- and 48-month timescales. A brief description of calculating SPI for above mentioned timescales are given below.

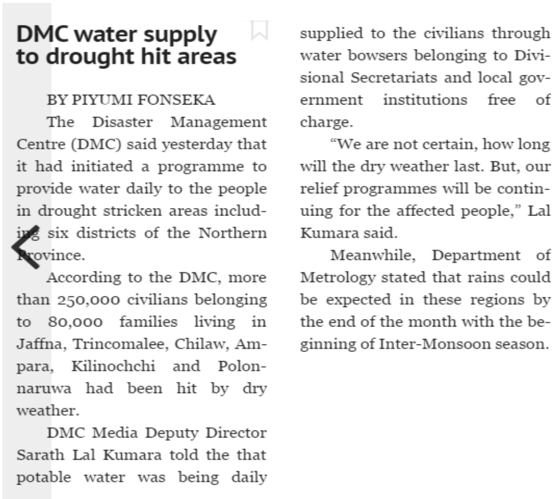
1. A 1-month SPI typically compares well for the percent of normal precipitation for the month. However, compared with other SPI time scales, it is actually considered to be a more accurate representation of monthly precipitation for a given location because the long-term precipitation record (over 30 years or more) is fitted to a probability distribution (Edwards and McKee, 1997). It does not reflect the wet condition in previous months.
2. The 3-month SPI provides a comparison of the precipitation over a specific 3-month period with the precipitation totals from the same 3-month period for all the years included in the historical record. Therefore it reflects dry and wet conditions in previous 2 months also. As drought establish gradual, studying 3 months SPI is better to understand the soil water storage (Edwards and McKee, 1997).
3. The 6-month SPI compares the precipitation for that period with the same 6-month period over the historical record. The 6-month SPI indicates medium-term trends in precipitation and is still considered to be more sensitive to conditions at this scale than the Palmer Index. A 6-month SPI can be very effective showing the precipitation over distinct seasons. Information from a 6-month SPI may also begin to be associated with anomalous stream flows and reservoir levels (Edwards and McKee, 1997).

Considering the above three, it indicated the importance of monitoring SPI for 3 different time scales to understand meteorological, agricultural and hydrological drought. But the scenario is different to understand socio economic drought. It basically depends on the social and economic condition of the specific area.

Occurrence of drought has become more frequent in the recent years, which may be due to climate change. Studies have shown that droughts are related to global tele-connections such as El Nino Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), and North Atlantic Oscillation (NAO) etc. Several recent studies have characterized the influence of ENSO on rainfall over Sri Lanka (Rasmusson and Carpenter, 1983; Suppiah, 1996). Others have addressed the influence of Indian Ocean Sea Surface Temperatures (SSTs) and the Indian Ocean Dipole (IOD) Mode (Saji and Yamagata, 2003) on rainfall over Sri Lanka (Malmgren et al., 2007;

Zubair et al., 2003). Premalal, 2013, has also mentioned that there is a possibility of negative rainfall departure during southwest monsoon with the El Nino situation.

According to the media (Figure 1), Disaster management Centre (DMC), Sri Lanka announced that six districts of the Northern Province 250,000 Civilians belongs to the 80,000 families were affected by the drought conditions in 2015. Therefore, the study focuses on analyses the drought condition for the year 2015 and identify the possibility of having drought condition in the year 2015 as year 2015 is categorized as an El Nino year.



DMC water supply to drought hit areas

BY PIYUMI FONSEKA

The Disaster Management Centre (DMC) said yesterday that it had initiated a programme to provide water daily to the people in drought stricken areas including six districts of the Northern Province.

According to the DMC, more than 250,000 civilians belonging to 80,000 families living in Jaffna, Trincomalee, Chilaw, Ampara, Kilinochchi and Polonnaruwa had been hit by dry weather.

DMC Media Deputy Director Sarath Lal Kumara told the that potable water was being daily supplied to the civilians through water bowsers belonging to Divisional Secretariats and local government institutions free of charge.

"We are not certain, how long will the dry weather last. But, our relief programmes will be continuing for the affected people," Lal Kumara said.

Meanwhile, Department of Metrology stated that rains could be expected in these regions by the end of the month with the beginning of Inter-Monsoon season.

Figure 1 : Media Announcement

http://www.pressreader.com/sri-lanka/daily-mirror-sri-lanka/20150907/281947426621834/TextView)

2 Methodology

Standardized Precipitation Index (SPI) was calculated for the island to monitor possible drought condition for the year 2015. Continuous data is important for the analysis. It was observed that data were not continuous in some rainfall measuring stations and Kriging technique was used to interpolate the available data to fill the gaps of non-available rainfall data. Hence 1981-2015 period was used for the SPI analysis for time scales of 1 month, 3 month and 6 months. The output data were plotted using the SURFER software and the results are shown in the figure 2 (a-J).

Since the SPI is calculated on monthly basis as the shortest time scale, shorter period fluctuations such as heavy rain in a few days are not captured and not shown. In fact, heavy rain in a few days can exceed average monthly rainfall. Therefore, cumulated weekly rainfalls for year 2015 is compared with the average weekly cumulative rainfall and weekly anomaly of rainfalls were also analyzed to detect such shielding effects enabling to see the actual situation. These results are shown in the figure 3 (a-u).

Therefore, study was extended to analyze weekly rainfall situation in addition to the SPI analysis. Figure 3 shows the graphs of weekly cumulative averages (dotted line) for different districts. Cumulative rainfall received in 2015 is shown in the same graph in a straight line (pink). Final aim is to compare the SPI values with the anomalies and the departures with cumulative rainfall and come to a better conclusion about the situation.

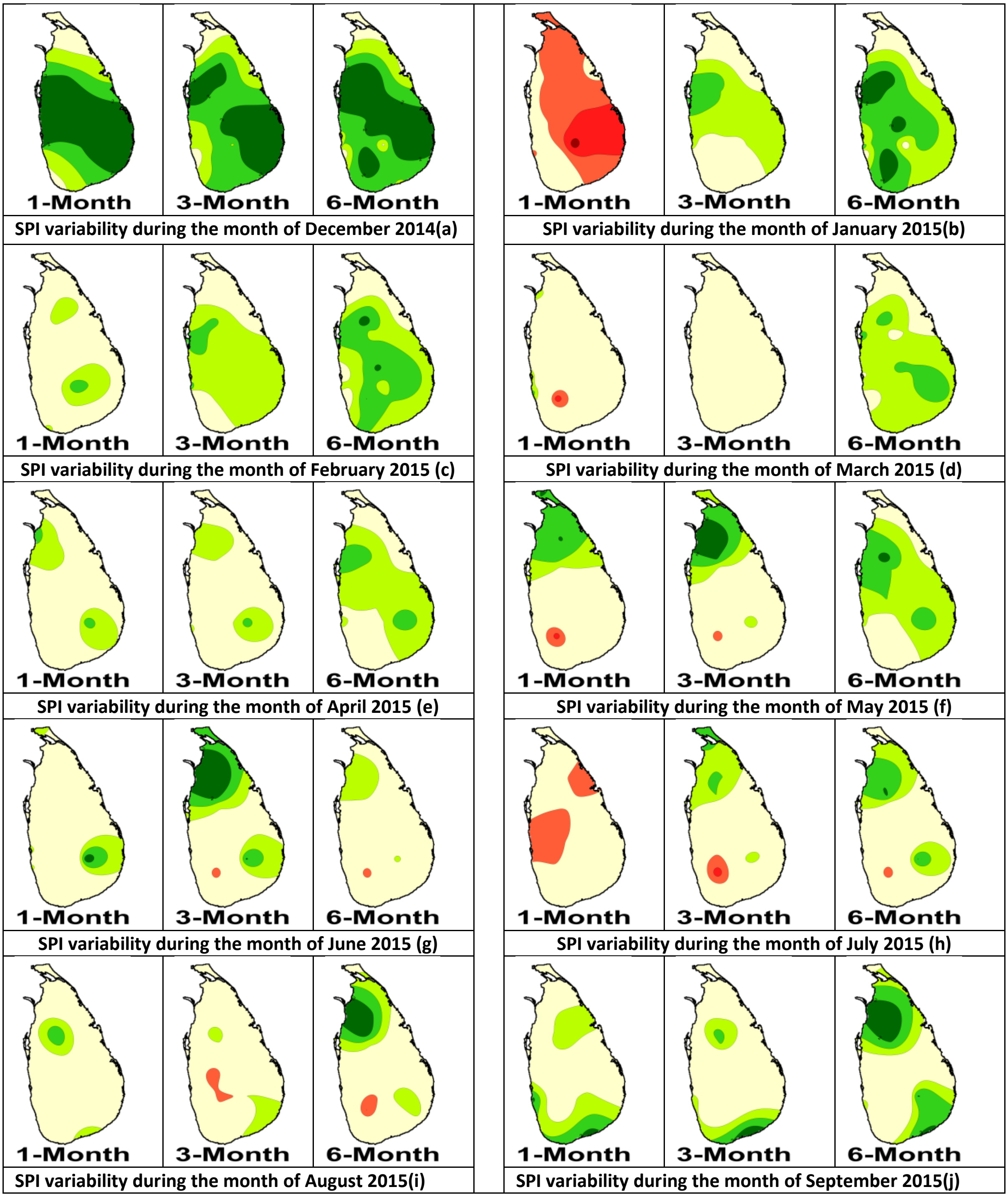
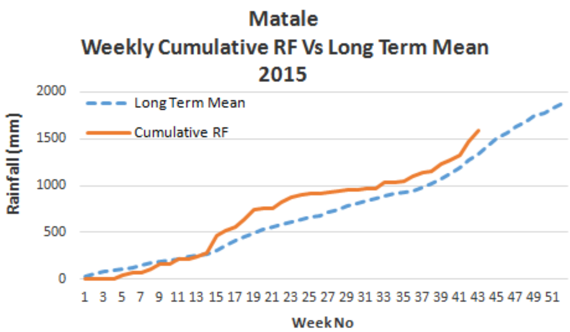


Figure 2: Analysis of Standard Precipitation Indices for the time intervals 1 month, 3 months and 6 months period From January to September (Legend for the categorization is shown below).

The legend for SPI maps		
	+2.0 and above	Extremely Wet
	+1.50 to +1.99	Very Wet
	+1.0 to +1.49	Moderately Wet
	-0.99 to +0.99	Near Normal
	-1.0 to -1.49	Moderately Dry
	-1.5 to -1.99	Very Dry
	-2.0 and below	Extremely Dry



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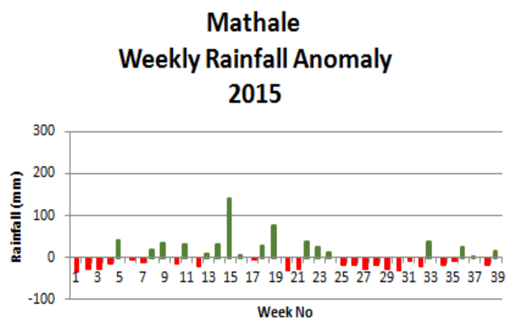

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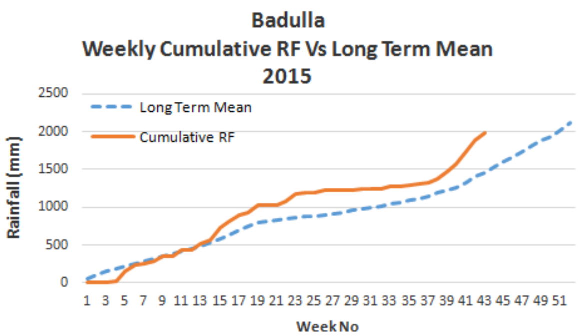

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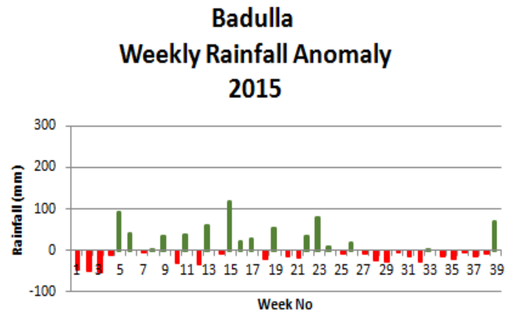

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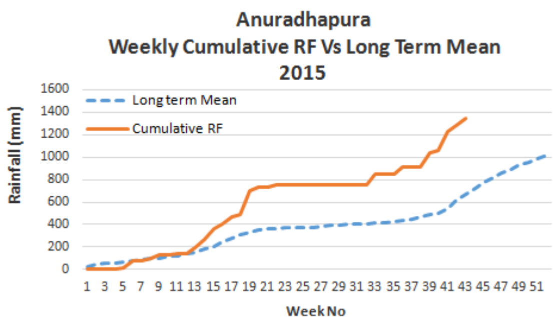

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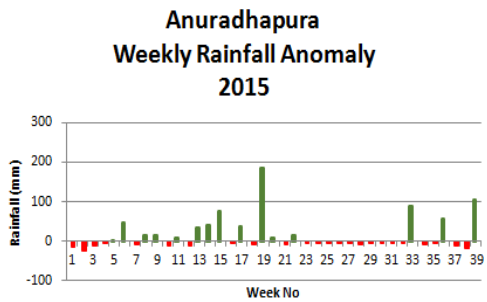

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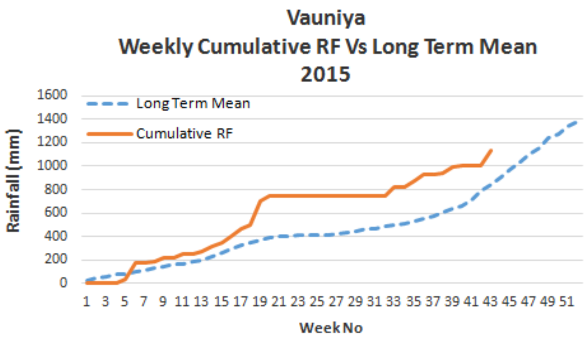

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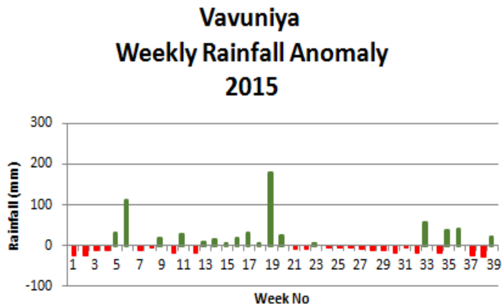

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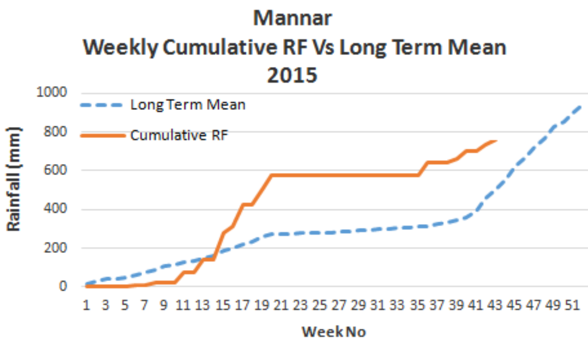

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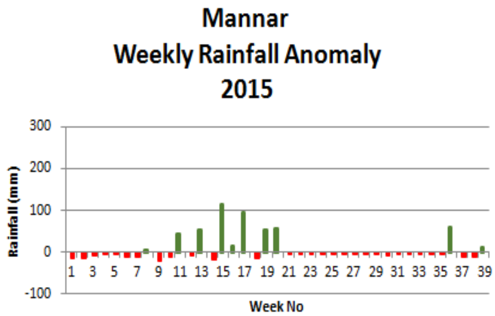


(j)

Figure 3: Behavior of weekly cumulative rainfall in 2015, with the average cumulative rainfall

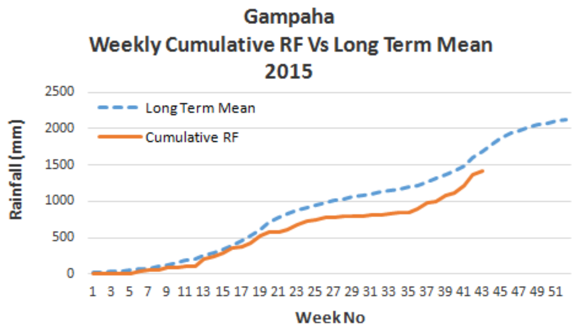
3 Results and Discussion

In the figure 2 (a-j) shows the SPI analysis for the months January to September for the periods 1 month, 3 months and 6 months. In the figures, yellow colour indicates the normal situation and green and brown indicates the wet and dry situation respectively. It is clear that most of the months indicated the normal situation for the 3 different time scales except in January and July. Where January and July shows dry conditions in some parts of the island for one month analysis. One month analysis does not indicate the drought condition as it is not a sufficient long period. In addition 3 months analysis shows an indication for moderate drought conditions over the western slopes of central hills. No drought conditions indicated over the other area for the period concern.

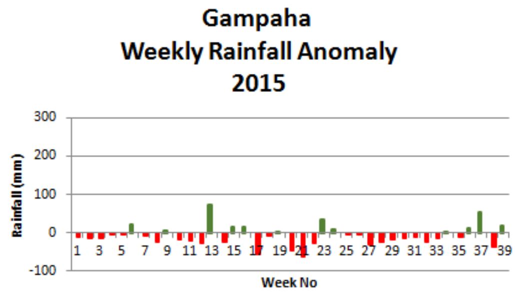
However weekly cumulative rainfall analysis clearly shows that slightly above normal rainfall during the southwest monsoon, has been received in the districts Matale, Badulla, Anuradhapura, Vauniya and Mannar (Figure 3 (a-e)). In addition, no or less rainfall received during the period 20th to 35th week (southwest monsoon period). The situation is not much affected for the drought conditions, because all these districts belongs to dry and intermediate zones and those are not monsoon dominated area. Therefore the area does not affect for the drought condition with slightly negative rainfall anomaly (figure 3 (f-j)).

The weekly anomaly rainfalls of Anuradhapura, Mannar, Matale, Badulla and Vavuniya (fig 3 (f-J)) during the southwest monsoon period (20-35th week) are predominantly below normal, although the cumulative

Weekly rainfalls (fig 3 (a-e)) are above average. In fact, these five districts receive very low rainfalls during the southwest monsoon. Cumulative rainfalls prior to the monsoon period have been above average hence, this positive offsets continue for the monsoon as well. In other words, the deficit of rainfall during this period is not significant even if the rainfall is zero. Therefore, these areas have not been affected by meteorological drought.



(a)



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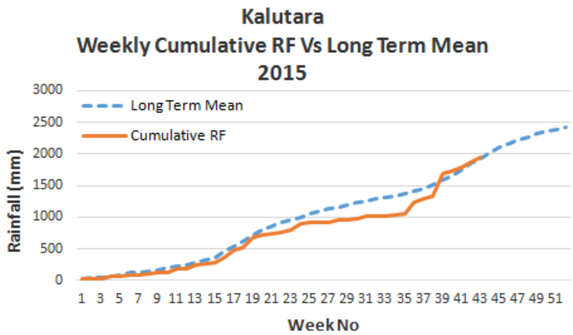

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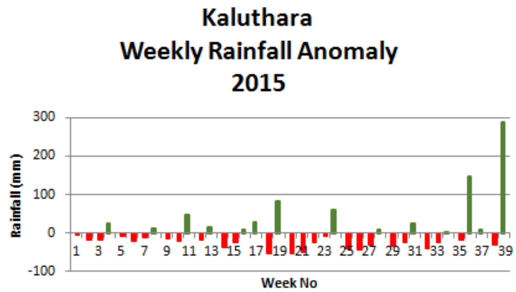

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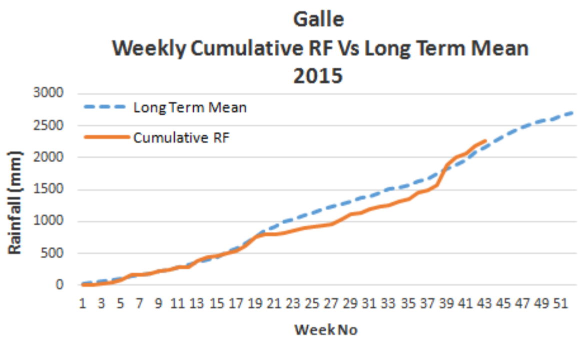

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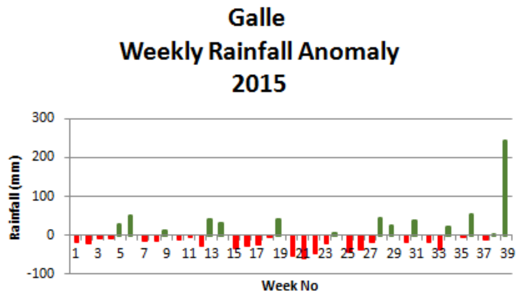

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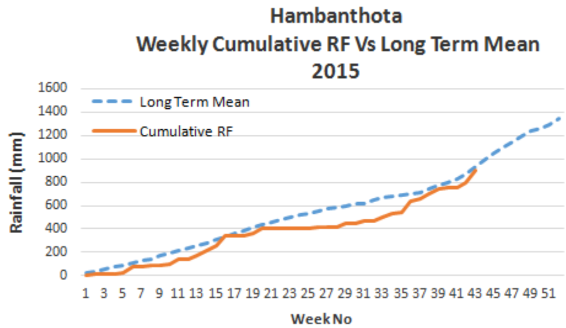
Hambanthota
Weekly Cumulative RF Vs Long Term Mean
2015
Long Term Mean
Cumulative RF
Rainfall (mm)
Week No

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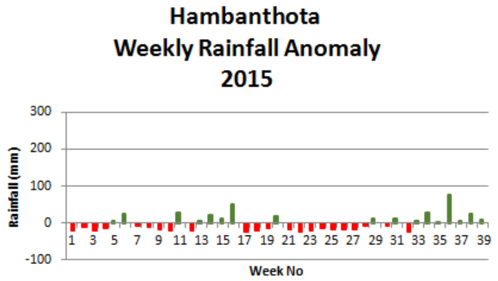
Hambanthota
Weekly Rainfall Anomaly
2015
Rainfall (mm)
Week No

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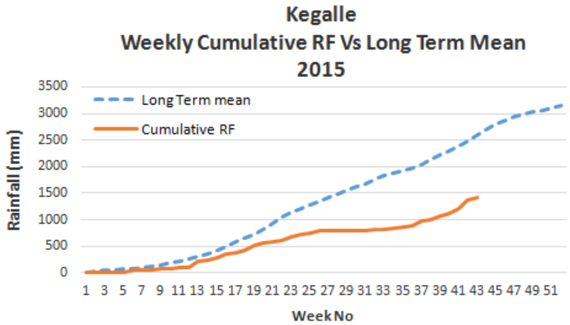
Kegalle
Weekly Cumulative RF Vs Long Term Mean
2015
Long Term mean
Cumulative RF
Rainfall (mm)
Week No

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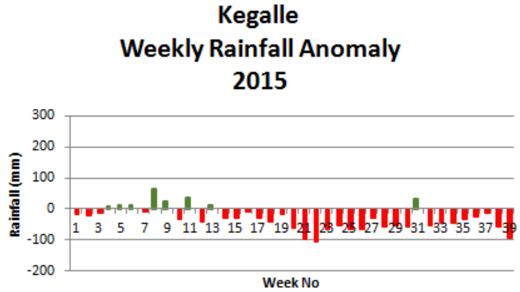
Kegalle
Weekly Rainfall Anomaly
2015
Rainfall (mm)
Week No

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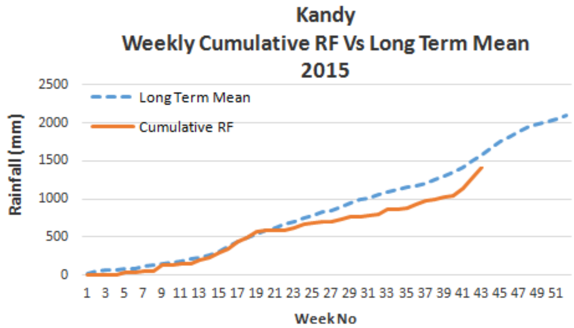
Kandy
Weekly Cumulative RF Vs Long Term Mean
2015
Long Term Mean
Cumulative RF
Rainfall (mm)
Week No

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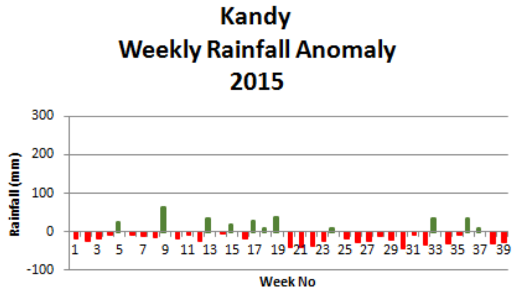
Kandy
Weekly Rainfall Anomaly
2015
Rainfall (mm)
Week No

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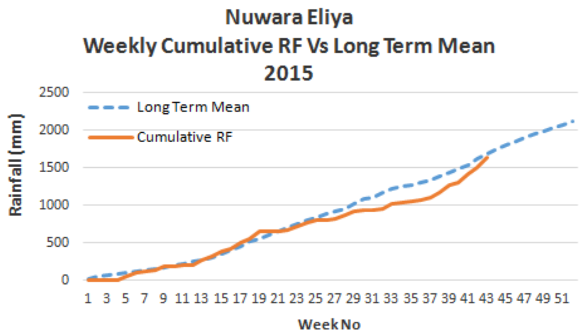
Nuwara Eliya
Weekly Cumulative RF Vs Long Term Mean
2015
Long Term Mean
Cumulative RF
Rainfall (mm)
Week No

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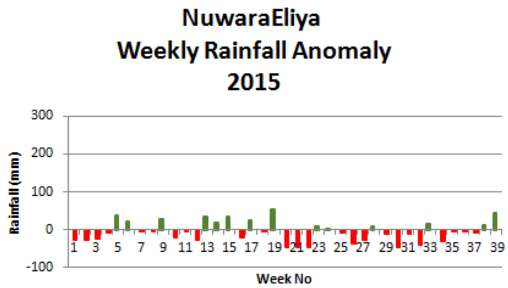
NuwaraEliya
Weekly Rainfall Anomaly
2015
Rainfall (mm)
Week No

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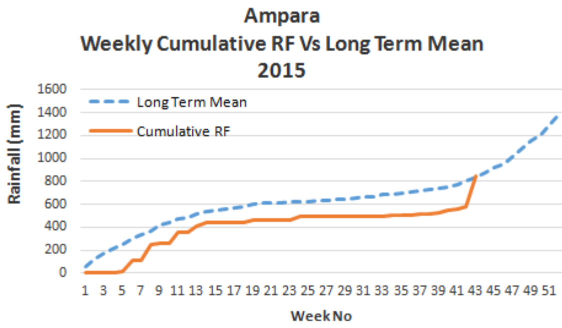

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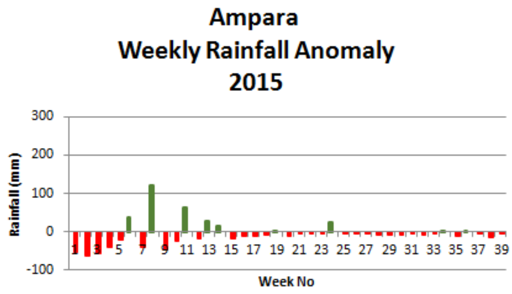

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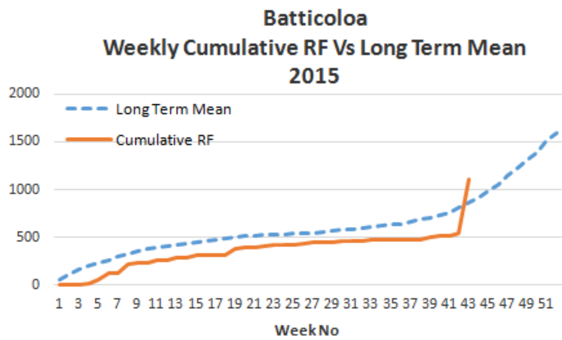

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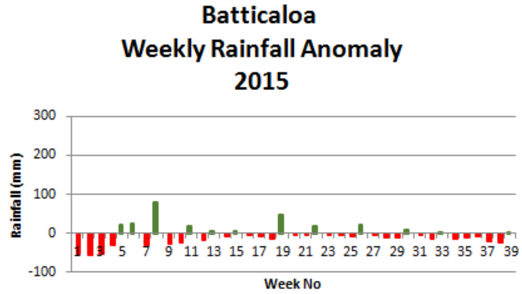

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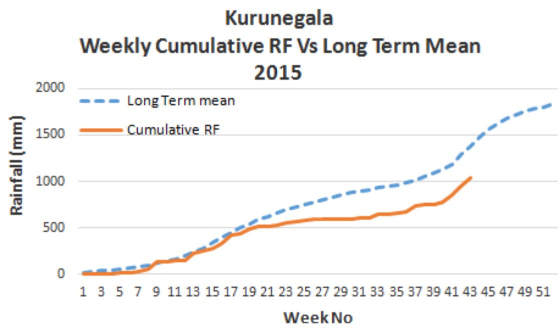

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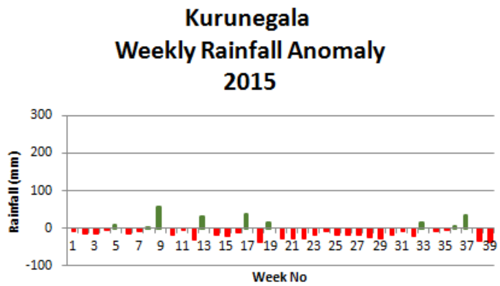

(t)

Figure 4: Behavior of weekly cumulative rainfall in 2015, with the average cumulative rainfall

Gampaha, Kalutara, Galle, Hambantota, Kegalle, Kandy, Nuwaraeliya and Kurunegala didtricts as well as Ampara and Batticaloa show remarkable below normal rainfall during the southwest monsoon period in year 2015 (Fig : 4 (a – j). By comparing the behavior of cumulative weekly rainfall with the weekly anomaly rainfall, even though some rainy spells occurred within the period. Therefore rainfall deficit has not been occurred for wider period in the said areas. Due to this reason, SPI values has predominantly been positive for the whole island. That is the reason for positive SPI values for whole Sri Lanka, except some isolated regions over the southwestern slopes of the hills.

According to the analysis, there has not been significant meteorological drought. According to the Department of Agriculture, there has not been adverse impact for the paddy crop and other crops during “Yala” season.

Therefore it is very clear that no Meteorological and Agricultural drought prevailed over Sri Lanka during southwest monsoon in 2015. Hydro-meteorological drought has also not visible in Sri Lanka as no drying up of water streams. According to media, the Disaster Management Centre (DMC) announced that 250,000 Civilians belongs to the 80,000 families in the Northern part were affected due to drought conditions in 2015. That conclusion may have come after interviewing the people in those areas, therefore the condition probably be socio economic drought.

4 Conclusion

Occurrence of drought in unavoidable due to abnormal fluctuations of climate. Climate change may increase the frequency and severity of drought. SPI were calculated for different time scales as 1, 3 and 6 months, but the analysis do not show any indication for drought condition in 2015. Cumulatative rainfall analysis show above normal rainfall in Matale, Badulla, Anuradhapura, Vauniya and Mannar while below normal rainfall in other areas. However rainfall was below normal during the southwest monsoon periods in all districts.

However, in broad scale, there has not been drought in Sri Lanka during the first nine month of the year 2015. Yet, some communities in the northern parts may have been affected during the southwest monsoon period due to other factors such as inadequate water retention, distribution or other socio economic factors etc. These situations may be further analyzed with more details.

REFERANCES

Agnew, C., 1990, Spatial Aspects of Drought in the Sahel", Journal of Arid Environments, 18, 279-293.

Agnew, C. and Warren, A., A Framework for Tackling Drought and Land Degradation", Journal of Arid Environments, 33, 309-320, 1996.

Edwards, D. C. and T. B. McKee, 1997: Characteristics of 20th century drought in the United States at multiple time Scales. Climatology Report 97-2, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado.

Lyon, B., Zubair, L., Ralapanawe, V. and Yahiya, Z., 2009. Fine Scale Evaluation of Drought Hazard for Tropical Climates, Journal of Applied Meteorology and Climatology, 48(1): 77-88

Malmgren, Björn, Hullugalla, R, Lindeberg, G, Inoue, Y, Hayashi, Y, 2007, Oscillatory behavior of monsoon rainfall Over Sri Lanka during the late 19th and 20th centuries and its relationships to SSTs in the Indian Ocean and ENSO, Theoretical and applied climatology 89 ,

Premalal, D.S. 1998, Drought- Implications, Strategies and policies in Sri Lanka, Faculty of Agriculture, University of Peradeniya, Sri Lanka

Rasmusson, Eugene M., andCarpenter,Thomas H., 1983: The Relationship Between Eastern Equatorial Pacific Sea Surface Temperatures and Rainfall over India and Sri Lanka. Mon. Wea. Rev., 111, 517–528.

Saji NH, Yamagata T, 2003, Structure of SST and surface wind variability during Indian Ocean Dipole Mode years: COADS observations. Journal of Climate, 16, 2735–2751

Sheffield, Jand Wood, Eric F., 2006 :Global Trends and Variability in Soil Moisture and DroughtCharacteristics 1950–2000, Journal of Climate, 21, 432–458.

Suppiah, R. 1996. Spatial and temporal variations in the relationships between the Southern Oscillation phenomenon and the rainfall of Sri Lanka. International Journal of Climatology, 16,1391-1407.

Wilhite, D.A., 2000, Drought as a natural hazard: Concepts and definitions. Droughts: A Global Assessment, D.A Wilhite, Ed., Routledge, 3-18.

World Meteorological Organization (WMO) Technical Document, 1090, 2012

Zubair, L., S. A. Rao, and T. Yamagata, 2003, Modulation of Sri Lankan Maha rainfall by the Indian Ocean Dipole, Geophysical Research. Letter. 30(2),1063, doi:10.1029/2002GL015639.

URL'S
https://en.wikipedia.org/wiki/Palmer_drought_index

DMC statement
(http://www.pressreader.com/sri-lanka/daily-mirror-sri-lanka/20150907/281947426621834/TextView)