Designing and Implementing Drought Monitoring Model in Hambantota District using SPI and NDVI

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***Abstract*— *Drought is a natural hazard that threatens mainly our development of agriculture and causes environment, social and economic consequences. Hambantota district mostly faces to drought due to irregular precipitation patterns. Drought heavily affects people and arid region due to lack of efficient assessment and warning systems. In this research drought assessment in Hambantota district is done using various type of geospatial techniques. Standard Precipitation Index (SPI) and Normalized Difference Vegetation Index (NDVI) are used as the drought assessment indices. Metrological drought is monitored using Standard Precipitation Index (SPI) and finally, agricultural drought is monitored using Normalized Difference Vegetation Index (NDVI). By monitoring the ground data, remote sensing provides direct spatial information on vegetation stress occurred due to drought conditions. Near Infrared (NIR) and Red bands which contains in Landsat satellite images are used to calculate the Normalized Difference Vegetation Index (NDVI) using ArcGIS. Data has been extracted based on Grama Niladhari division (GN) points using a created model. Co-relation was built monthly based on Standard precipitations Index (SPI) and Normalized Difference Vegetation Index using the extracted data by Machine Learning (ML). Multiple Linear Regression (MLR) and Support Vector Regression (SVR) was used for predicting respectively SPI and NDVI. Predicted SPI values Root Mean Square Error (RMSE) was 0.4127 and NDVI values Root Mean Square Error was 0.1947 as results.*

***Keywords*— SPI NDVI ML GN NIR RMSE MLR SVR**

I. INTRODUCTION

Drought is also a major hazard related to water. Drought occurs due to prolonged period of abnormal low rainfall, increasing temperature, air circulation, weather patterns, soil moisture levels etc. Drought can be last for a month or for many years. Drought is not like other natural hazards it differs in various ways. Drought is a slow-spread natural hazard that is often referred to as a creeping phenomenon. Sri Lanka contain many dry zones like Moneragala, Hambantota, Eastern Province, North Central Province, North Province, and North Western Province. In this dry zones drought is occurring several times in the year. As an agricultural country this drought is effected to the occupation of people in the country. Sri Lanka mostly depends on paddy cultivation. Paddy cultivation is cultivating in two seasons in the year (Yala and Maha).

Not only present days, has drought done major damage to livelihood of people in Sri Lankan history. The history of the drought in Sri Lanka coming from king's era. According to the Mahawansa, drought has occurred even in 161-137 BC. During the last century the droughts of 1908 and 1911 were the most extensive droughts, affecting more than 20 districts in the "Yala" agricultural season while the most extensive drought during the "Maha" agricultural season occurred in 1938 and affected 20 districts (Amaradasa-2001).Most recent severe droughts was in 2001. It affected severely in the dry zone and intermediate zone, but Hambantota area experienced a prolonged and very severe drought in 2001 and 2002. The total affected families from the drought were more than 800000 in the year 2001.

Droughts are occurring in different types. Mainly there are 4 types.

A. SPI (Standard Precipitation Index)

This guide demonstrates the Standardized Precipitation Index (SPI) for multiple monthly accumulation periods for the globe.

The Standardized Precipitation Index (SPI; McKee 1993) is a generally utilized index to portray meteorological drought on a scope of timescales. On short timescales, the SPI is firmly identified with soil dampness, while at longer timescales, the SPI can be identified with groundwater and reservoir storage. The SPI can be contrasted crosswise over areas and particularly unique atmospheres. It measures watched precipitation as a standardized takeoff from a chose probability distribution function that models the crude precipitation data. The crude precipitation data are commonly fitted to a gamma or a Pearson Type III distribution, and after that changed to an ordinary distribution. The SPI esteems can be translated as the quantity of standard deviations by which the watched abnormality veers off from the long haul mean. The SPI can be made for varying times of 1-to-36 months, utilizing monthly input data. For the operational network, the SPI has been perceived as the standard index that ought to be accessible worldwide for evaluating and detailing meteorological drought. Concerns have been raised about the utility of the SPI as a proportion of changes in drought related with environmental change, as it doesn't manage changes in evapotranspiration. Elective files that arrangement with evapotranspiration have been proposed.

B. NDVI (Normalized Difference Vegetation Index)
Among numerous lists dependent on remote sensing, the Normalized Difference Vegetation Index (NDVI) has been most generally utilized for drought monitoring. The photosynthetic limit of vegetation amid developing seasons is influenced by drought, NDVI can be utilized to identify drought of vegetation conditions.
Green and healthy vegetation reflects much less solar radiation in the visible (RED) compared to those in near infrared (NIR). More importantly, when vegetation is under stress, RED values may increase and NIR values may decrease.
The NDVI is defined as the following equation;

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

NDVI ranges from -1 to +1. Water has negative NDVI while clouds and barren lands have zero NDVI. Vegetation always has positive NDVI which represent the density and also the vigor and the higher index values being associated with greater green leaf area and biomass.

Existing researches for drought in Sri Lanka conducted using SPI and NDVI separately. In those researches MODIS satellite images was used as resources in NDVI. The research gap was recognised when studying existing research which used MODIS satellite images with low resolutions. In this research combination of both SPI and NDVI values are used to monitor drought. Landsat satellite images are used in here for high resolution accurate data.

II. METHODOLOGY

A. Study Area

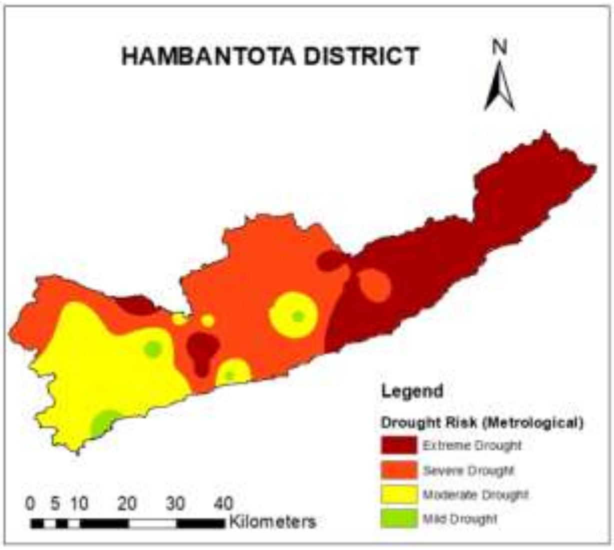


Figure 1. Drought Risk (Metrological) in Hambantota District

Hambantota district situated in Southern Sri Lanka in latitude and Longitude coordinates 6.124593°N, 81.101074°E total area with 2,609 km² (2,496 km² Land / 113 km² Water). Hambantota is delivered on average 1045 mm (41.1 in) of rainfall per year mostly by southwest (May-September) monsoon season. Drought has affected heavily to the district most of the time in the history.

B. Materials and Methods
1) Rainfall data for SPI: Monthly collected rainfall data from 1988 to 2018 were used for calculation of the Standard Precipitation Index which collected from Metrological Department, Sri Lanka in their 18 station located in Hambantota district.

2) Satellite image data NDVI: NDVI derived by calculating Infrared and red bands of the satellite images. This satellite images are freely downloaded from United States Geological Survey (https://earthexplorer.usgs.gov/). Data collected from Landsat satellite monthly base for 19 years from 2000-2018 which have 30m resolution. Band 4 and 3 in Landsat5, band 5 and 4 in Landsat7 and Landsat8 used to calculate the NDVI values. NDVI value ranging from -1 to +1.

C. Pre-processing of data
From 2000- 2018 there were some satellite data not available. There were some images which covered by clouds. Therefore NDVI value cannot obtained from the missing and covered satellite images. Those values are covered by calculating the mean from adjoining months. Most of the Landsat7 satellite images contained scan line errors. Therefore the point located in the scan line errors are replaced with monthly average values.

There were unavailable values in rainfall data in some stations and they were completed using mean of the station rainfall values. Due to lack of SPI values for each and every location, SPI values were interpolated with available stations points.

D. Methodology
Total 18 stations of Hambantota district were chosen to analyse the data of SPI from 6 month scale method. According to the Metrological Department information 6 month scale is the most suitable method with the actual drought periods. Only from using this total stations of 18, the value for the SPI for every point in district cannot be obtained. Therefore value of SPI from 4 rainfall station points near to the district also used. Monthly calculated SPI values in 18 stations within the district and SPI values in 4 stations near to the district are used to interpolate SPI values from 2000 to 2018. After interpolating, every point in the district gets a SPI value for every month from 2000-2018 (224 months). IDW tool was used to interpolate data in Arc GIS. SPI values were extracted Grama Niladhari

divisions based from 2000-2018 for every month by using GIS techniques. Model was created using model builder in Arc GIS to extract the data.

Landsat satellite images were used to get NDVI values for 2000-2018. NDVI values were extracted in 520 Grama Niladhari using another model built.

Those extracted data was used to train Machine Learning model to predict SPI and NDVI values. Multiple Linear Regression model is used to predict SPI values. Support Vector Regression model is used to predict NDVI values. Methodology of the research is illustrated by figure 2.

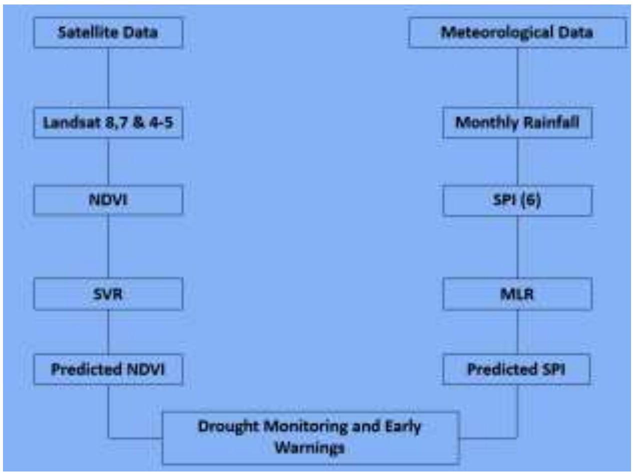


Figure 2. Methodology

III. RESAULTS

SPI was calculated to observe the performance of SPI to identify the drought conditions for the year 2001 August and 2014 August. Since SPI of month of August represent the cumulative rainfall in the 2001 July that can detect the drought stress occurrence and same as 2014 July. A great difference between SPI values in drought and non-drought year fond in all stations in the study area. An event of drought can be occurred when the SPI value is less than -1 and the index value get positive that represent non-drought situation.

In figure A, the most of the stations SPI values are below -1 in the drought year of 2001 month of August. Bundala Lewaya, Tangalle, Ridiyagama Farm, Kirama, Muruththawela Wewa, Hambantota, Liyangahatota, Ambalantotoa Govt. Farm and Agunukolapellessa stations were experienced extreme dry weather condition in the drought year of 2001.In 2014 most of the station SPI values are below -1. According to the McKee's classification scheme of SPI, -1.0 to -1.49 indicates moderate dry condition, -1.5 to -1.99 indicates severe dry condition and less than -2 indicates extreme drought. Year of 2008 and 2013 indicate non drought conditions according to the below figure 3 graph.

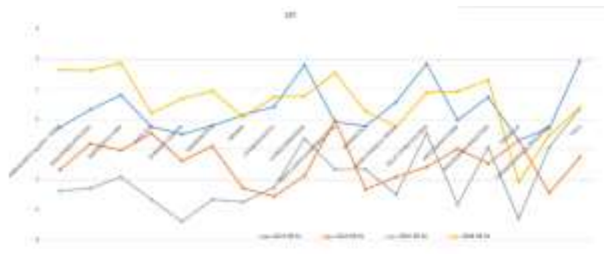


Figure 3. Drought and non-drought condition in August 2001 and April 2007

NDVI values are taken to 520 Grama Niladhari division from 2000 – 2018. The following figure 4 shows NDVI values for the drought year from 2001 to 2002 for selected GN divisions which indicate minus vales for drought period. The minus values indicate the damage occurred to the vegetation of that area. But, because of clouds incorrect values can appear in the dataset and because of the scan line error the exact value cannot be taken in some points.

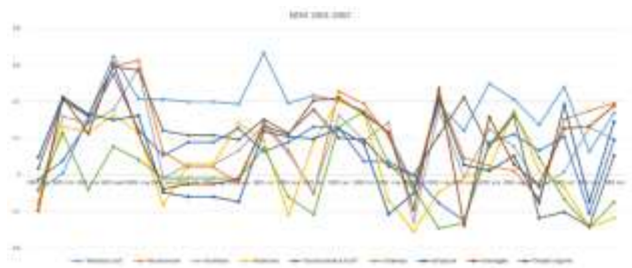


Figure 4. NDVI values for drought period 2001-2002

Two GN divisions Padavigama and Yahangala west are shown in the figure 5 individually. The variation of NDVI values in the year of 2001 is in the graph and it shows minus values for June to September which indicate more drought period. From that values can monitor the damage happen to the vegetation.

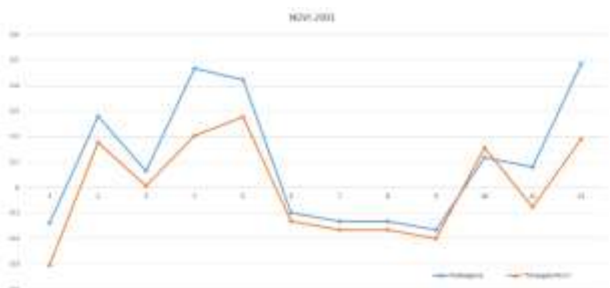


Figure 5. NDVI values for 2001 drought year

The figure 6 is shown the non-drought year values for the same two stations. Most of the values are greater than zero that indicates fine vegetation condition.

Figure 6. NDVI values for 2013 non - drought year

Before predicting, actual SPI values of the previous month are considered for the correlation of SPI values for each month. Six months period of time are considered to predict seven month SPI values. Because six month scale is used to calculate the SPI values. The correlation of SPI values of each month are shown in following figure 7 below.

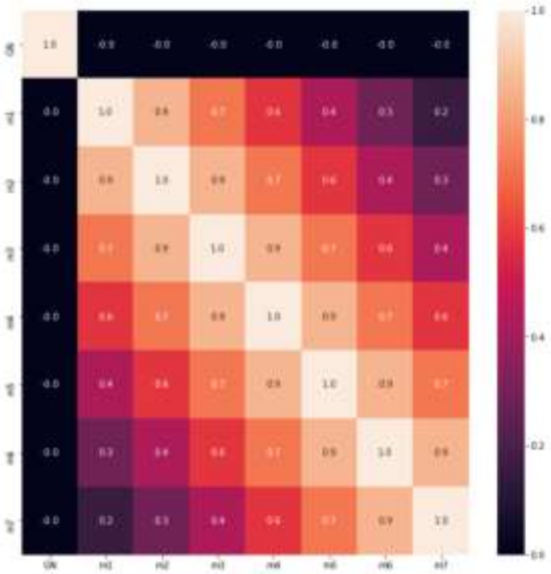


Figure 7. Correlation matrix of SPI values

Multiple Linear Regression model is used to predict SPI values with the above figure e correlation of SPI values. The below figure 8 is shows predicted SPI values and actual SPI values. The calculated Root Mean Square Error (RMSE) is 0.4127 for Predicted SPI values.

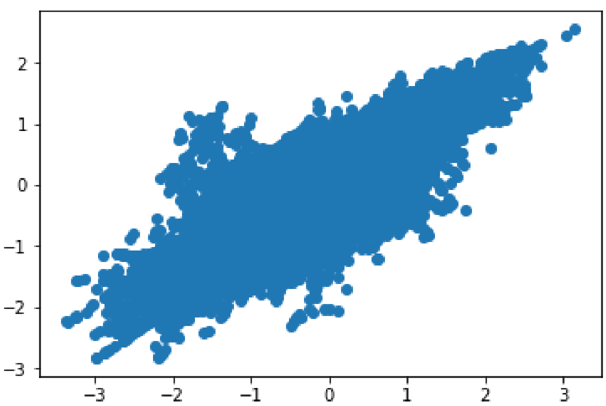
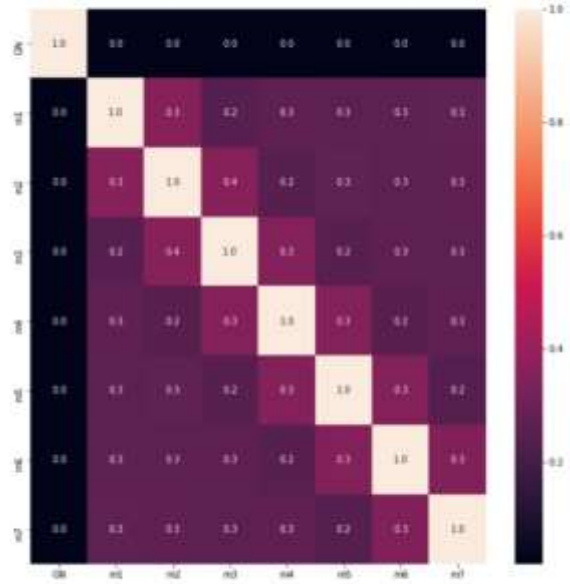


Figure 8. Actual SPI vs predicted SPI values

Before predicting, actual NDVI values of the previous month are considered for the correlation of NDVI values for each month. Six months period of time are considered to predict seven month NDVI values. The correlation of NDVI values of each month are shown in following figure



9 below.

Figure 9. Correlation matrix of NDVI values

Support Vector Regression model is used to predict NDVI values with the above figure 8 correlation of NDVI values. The below figure 10 is shows predicted NDVI values and actual NDVI values. The calculated Root Mean Square Error (RMSE) is 0.1947 for Predicted SPI values.

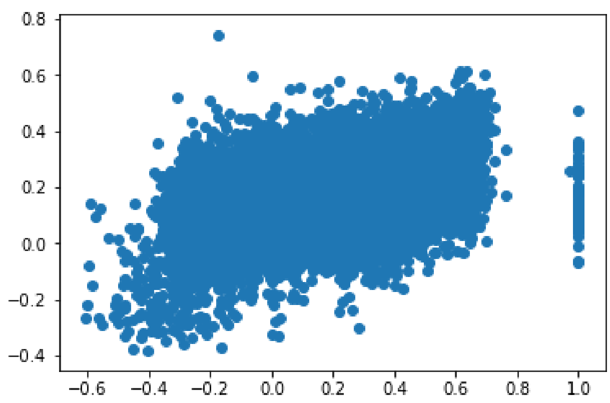


Figure 10. Actual NDVI vs predicted NDVI values

IV. DISCUSSION AND CONCLUTIION

Metrological drought can be monitored using SPI and vegetation condition can be monitored by processing satellite images. In this research SPI was calculated using 18 stations data and NDVI was calculated based on GN division. SPI values can create for each and every point by interpolating values using GIS techniques. More accurate satellite images (30m resolution) can be obtained using Landsat images. SPI and NDVI values can be predicted using Machine Learning methods. In this research Multiple Linear Regression model used for SPI and Support Vector Regression model used for NDVI prediction. But some rainfall stations had missing data and some satellite contained with clouds and scan line errors. Therefore accuracy level of prediction can be reduced for some extends. Behaviour of the drought can be monitored using the predicted values of SPI and NDVI.

A. *Future Developments*

As future developments, from this research, seasonal crop yield can be predicted using the past crop yield data, predicted SPI and NDVI values. Furthermore, a web-based early warning monitoring system can be developed using the predicted SPI and NDVI values.

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