AN ASSESMENT OF THE AGRICULTURAL DROUGHT VULNERABILITY USING REMOTE SENSING TECHNIQUES: WITH SPECIAL REFERENCE TO ANURADHAPURA DISTRICT

P.K.V.S. Dananjaya*

Department of Economics and Statistics, Sabaragamuwa University of Sri Lanka

INTRODUCTION

The economy of most developing countries depends on the agriculture sector and it is very sensitive to climatic parameters such as precipitation, temperature, humidity etc. These prolonged changes in climatic parameters adversely affect the productivity of the agricultural sector. Drought is one of the natural disasters which have a severe impact on agriculture. According to Mc Mohan and Arena (1982), "Drought is a period of abnormally dry weather sufficiently for the lack of precipitation to cause a serious hydrological imbalance and carries connotations of moisture deficiency with respect to man's usage of water". Depending on the characteristics, it could be categorised in to four types as meteorological drought, agricultural drought, hydrological drought, and socio-economic drought.

Agricultural drought could be defined as deficiency of soil moisture condition than the ideal level required for the proper growth of plants during the growth cycle stages. This deficiency affects the crop yield. There are two factors behind agricultural drought, (I) reducing soil moisture level as a result of short term precipitation and (II) Evaporation level increases the level above water supply as a result of increasing temperature (Khaled & Quazi, 2016). Agricultural drought has a severe impact on plant growth. If it occasionally happens plants may adapt to the changes. However, sometimes even short drought periods may have an adverse impact on plant growth if it has happened during the crucial stages of the plant life cycle like flowering or graining because these stages require more water supply than the other stages. Agricultural drought has a severe impact on developing countries. Those countries could experience population displacement, death of animals, permanent vegetation failure, reduction of agricultural output, and deterioration of water condition as results of the agricultural drought (FAO, 2011; Huang et al., 2013; Kapoi & Alabi, 2013; Hurgesa et al., 2016). Today, most scholars are using various methods to measure drought risk. These drought monitoring and analysing methods have been divided into three groups as in-situ methods, remote sensing and synergic based indices (Khaled & Quazi, 2016). In-situ based drought monitoring methods ground base meteorological data use (temperature, evaporation, precipitation, humidity) for analysis. These data obtain through ground stations.The remote sensing drought analysis are based on a fact that drought might affect the properties of physical and natural environment and these changes could be used as indicators of drought occurrence. To overcome limitation of the above two methods some researchers are using synergic based agricultural drought monitoring methods which have a combination of above two methods. Most of the researchers use remote sensing techniques to analyse agricultural drought. In 2020, MI Faridatul and B Ahmed in Bangladesh, G. Legesse and K.V. Suryabahagavan (2014) in Ethiopia, H. Hundera, G. Berhan and W. Bewuket (2016) in Ethiopia, O. Rojas, A. Vrieling and F. Rembold (2010) in Africa and Sandamali KUJ and Chathuranga KAM (2020) in Sri Lanka have used remote sensing techniques to assess agricultural drought. Most of them have used Normalized Different Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Vegetation Health Index (VHI) for agricultural drought monitoring and analysing.

Sri Lanka is a continental island. It has approximately 65,610Km^2 of land area and 21 million populations. The country is divided in to three major climatic zones as dry, wet and intermediate depending on the spatial variation of climatic parameters. Agriculture is the backbone of the country's economy, and accounts for over 20% of GDP and provides nearly 70 percent of rural employment (Kamran & Wijesekara, 2017). It could be divided further as rain fed and irrigated agriculture.

The total cultivated area in Sri Lanka is estimated at 1.86 million hectares. About 632,000 hectares of this area are irrigated and rest is rain-fed (Rajakaruna, 2014). According to C.R. Panabokke et al. in 2002 the mean annual rainfall in the dry zone is less than 1,250mm, and 80 percentage of that is received within 4 months from October to January. From May to September the dry zone is under the influence of the southwest monsoon and results in prolonged dry periods and high daily evaporation rate about 5.5 mm to 7.0 mm. The average annual evaporation rate in the dry zone is between 1,700mm to 1,900mm, and it is greater than the average annual rainfall in the area, and it is leading to the water stress. Hence the identification of agricultural drought area is of vital importance to mitigate adverse effect of it. Thus, this study is using NDVI and VCI to assess agricultural drought vulnerability in Anuradhapura district.

Objective of the Research

The objective of the study is to assess the agricultural drought vulnerability in Anuradhapura district using remote sensing techniques.

METHODOLOGY

Study Area

Anuradhapura district is situated in Sri Lanka and it belongs to the dry zone of the country. According to the 2013/14 census report, the total agricultural land area of the Anuradhapura district is about 213,875 hectares and the paddy cultivation is about 76,793 hectares, which is 35% from the total agricultural land (DCS, 2014). Hence, it is crucial to identify agricultural drought vulnerability in order to mitigate its adverse impact. The study covers 22 divisional secretariats in the Anuradhapura district.

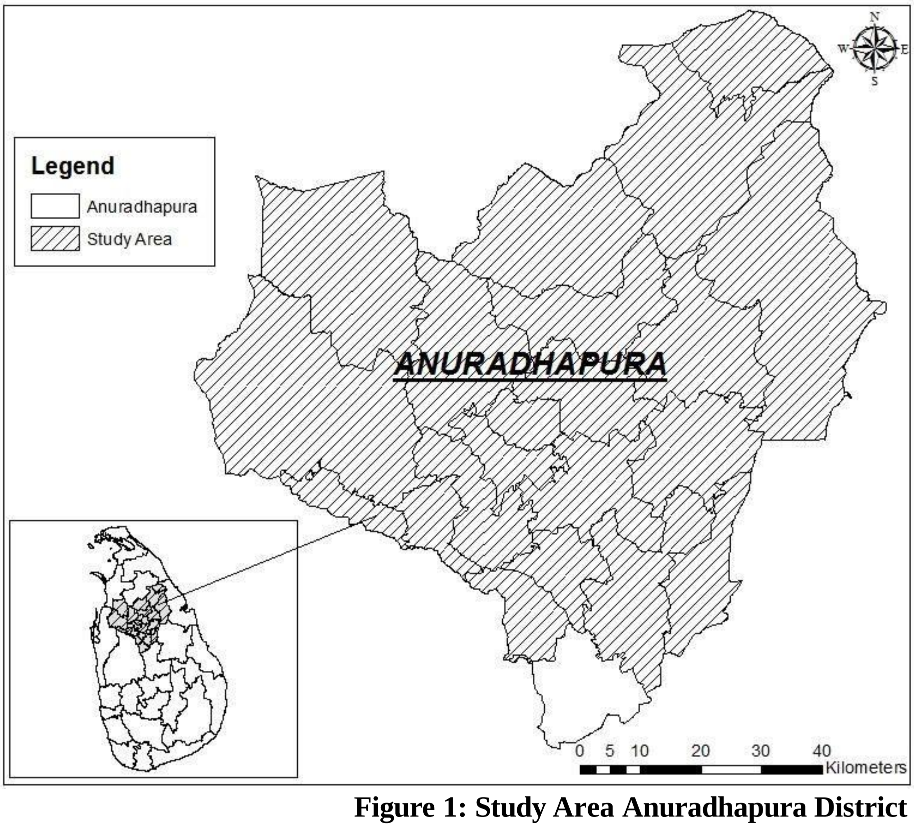

Figure 1: Study Area Anuradhapura District

Source: Digital Data Survey general department of Sri Lanka

Data

This study was based on secondary data. Landsat 5 satellite images from 2006 to 2011which were freely downloaded from USGS Earth Explore website used for the study. The major 2 cultivation seasons (Maha Season - September to March and Yala Season - May to August) are covered by the satellite images.

Table 1: Landsat 5 bands details

Acquisition year	Sensor	Path	Row	Wave Band		Spectral R.		Resolution
						B3	B4	
2006-07-10	MSS & TM	141	054	B3	B4	0.5753--0.0025	0.6946--0.0047	30×30
2007-03-23	MSS & TM	141	054	B3	B4	0.5528--0.0024	0.6675--0.0045	30×30
2007-05-26	MSS & TM	141	054	B3	B4	0.5711--0.0025	0.6896--0.0047	30×30
2008-02-22	MSS & TM	141	054	B3	B4	0.5445--0.0024	0.6574--0.0044	30×30
2008-05-28	MSS & TM	141	054	B3	B4	0.5716--0.0025	0.6902--0.0047	30×30
2009-10-22	MSS & TM	141	054	B3	B4	0.5513--0.0024	0.6656--0.0045	30×30
2009-05-15	MSS & TM	141	054	B3	B4	0.5688--0.0025	0.6868--0.0046	30×30
2010-02-27	MSS & TM	141	054	B3	B4	0.5458--0.0024	0.6531--0.0045	30×30
2010-06-03	MSS & TM	141	054	B3	B4	0.5726--0.0025	0.6914--0.0047	30×30
2011-11-13	MSS & TM	141	054	B3	B4	0.5452--0.0024	0.6583--0.0044	30×30

Method

NDVI (Normalized Different Vegetation Index) and VCI (Vegetation Condition Index) methods used to measure agricultural drought vulnerability. The equation 1 used to generate NDVI for each Yala and Maha seasons from 2006-2011.

Equation 1

$$NDVI = ((NIR - RED) / (NIR + RED))$$

In the Landsat 5 images B4 represents Near Infrared Radiation (NIR) and B3 represents visible radiation (RED). To calculate NDVI value, near infrared radiation minus visible radiation divided by the near infrared radiation plus visible radiation ((B4-B3)/ (B4+B3)). The calculated NDVI given result which in between -1 to +1. When NDVI value is near to -1 it indicates less vegetation and if it is near to +1 (0.8/0.9) its indicates the highest possible density of green leaves (NASA, 2000).

Following equation (Eq:2) used to calculate VCI (Faridatul & Ahmed, 2020).

Equation 2

$$VCI = (100 \times ((NDVI_i - NDVI_{min}) / (NDVI_{max} - NDVI_{min})))$$

NDVIi = NDVI value for the specific season of the year (Yala/Maha)
NDVI min = Minimum NDVI value from 2006 to 2011
NDVI max = Maximum NDVI value from 2006 to 2011

VCI values were calculated for each Yala seasons and Maha seasons respectively. Calculated VCI layers were reclassified in to three groups as 0-30, 30-50 and 50-100. If the calculated VCI value is near to 0% and this indicates the extreme drought condition. If it is in-between 50%-100% it is normal vegetation condition and if it is in between 35%-50% it indicates agricultural drought condition and if it is 35%-0% there is a severe drought condition (Kogan, 1995).

The calculated VCI layers were overlaid by using "Weighted sum overlay method" to create agricultural drought maps for Yala season and Maha season respectively. Created agricultural drought vulnerability layers (Yala and Maha) were overlaid by using "Weighted sum overlay" method in ArcMap 10.4 to create agricultural drought vulnerability map. In here drought vulnerability is calculated as follows.

Table 2: VCI values and Drought Vulnerability Category

VCI Percentage (%)	Drought
0-30	Severe Drought
30-50	Drought
50-100	Normal

To calculate the land extent in square kilometers, which belong to each agricultural drought vulnerability zones, following equation (Eq:3) was used.

Equation 3

$$Land\ area\ (km^2) = ((Cell\ count \times (30 \times 30)) / 1000000))$$

Cell count = number of cells belong to each vulnerability zone
30×30 = resolution of satellite images 30m×30m
1000000= convert square meters in to square kilometres

RESULTS AND DISCUSSION

According to the analysis data (Figure:2) for Maha season from 2006-2011 from the total study area approximately 12.2% of land area is under sever agricultural drought vulnerability zone. From total land extent 53.9% under the normal area has not been impacted by the agricultural drought. There are approximately 2328.9Km^2 of land under the area of drought vulnerability it is about 33.7% from the total study area.

Analysis of data for the Yala season (Figure:3) from 2006-2011 reveals that from the total study area 11.7% of land area belongs to the severe drought vulnerability zone. It is about 815.8Km^2 of land. According to the calculation 42.6% of land is under the drought vulnerability zone and the rest 45.5% land area does not belong to the drought vulnerability zone.

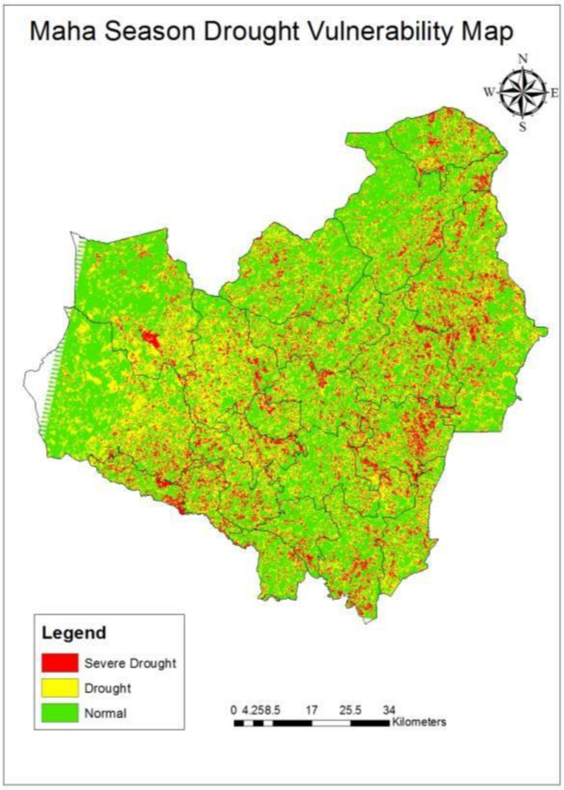

Figure 2: Drought Vulnerability Map Maha

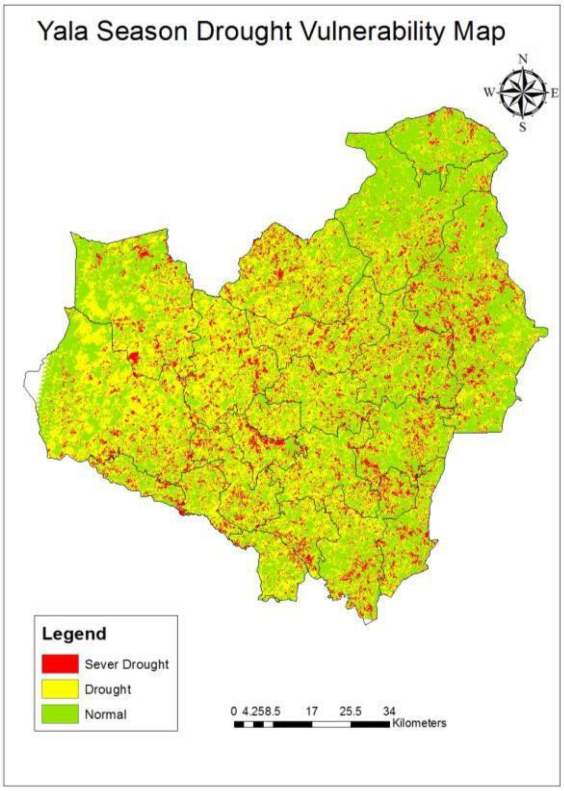

Figure 3: Drought Vulnerability Map Yala

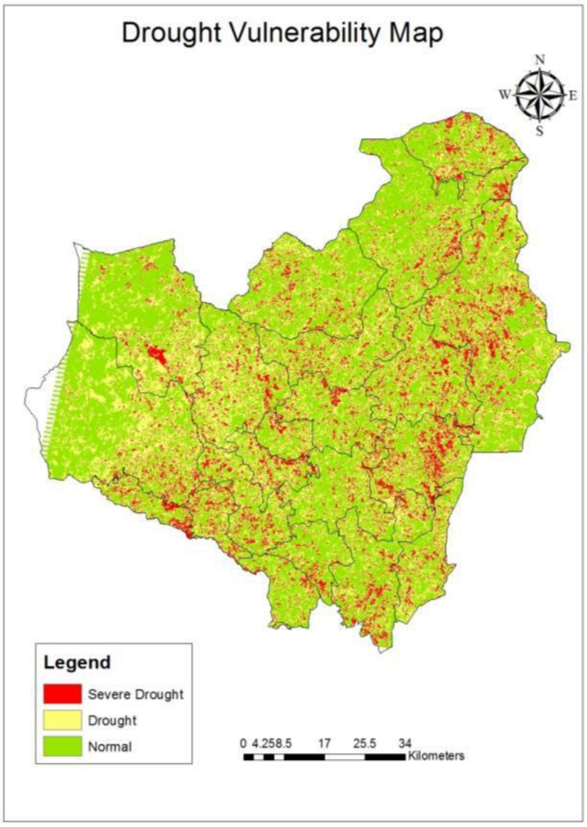

Figure 4: Drought Vulnerability Map for study area

Source: Data analysis results ArcMap 10.4

Map was created (Figure:4) overlaying both Maha and Yala seasons agricultural drought vulnerability maps. According to the analysis, from the total land area 12.2% under the severe drought zone, 33.7% belongs to the drought vulnerability zone and the rest 53.9% belongs to the normal zone that has not been impacted by the agricultural drought. The agricultural drought vulnerability results are same with the agricultural drought vulnerability results of Maha season.

When comparing seasonal drought vulnerability according to the results, during the Maha season the land extent that belongs to the severe drought zone is 12.2% but in the Yala season it is about 11.7%, there is a slight difference between the land area and that variation is about 0.5%. When considering the land area below the 50% of VCI (land belongs to drought and severe drought zones) in the Maha season 45.9% under the drought vulnerability. In the Yala season it is about 54.3% from the total land extent. Thus it is clear that the land area that is vulnerable for the agricultural drought is higher during the Yala season when compared to Maha season.

CONCLUSIONS & RECOMMENDATIONS

The study reveals that more than 45% of the study's total land area under the agricultural drought vulnerability zone during both major cultivation seasons. Thus, it is crucial to follow proper mitigation activities to reduce the adverse impacts of agricultural drought. Conducting awareness programme on water management, introducing crop varieties which are resilient to drought conditions and introducing agricultural practices such as agroforestry could be suggested as proper mitigation activities to mitigate adverse outcomes of agricultural drought.

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