SPATIAL ANALYSIS OF THE DROUGHT BY USING SATELLITE REMOTE SENSING AND GIS- A CASE STUDY AT MONARAGALA DISTRICT SRI LANKA

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ABSTRACT: The scientific and geographical identification of weather extremes is an essential component in routine life. Further, the understanding of these weather extremes vital in future planning, policy implementation, and developments. Most of the hazards occurred in a small time and in high magnitude hence people keen on those hazards. But among all hazards, the drought is different due to its silent pattern of spreading from regional to global scale. The remote sensing data integration in Geographic Information Sciences (GIS) in drought assessment provides the best platform for scientific analysis by integrating satellite, meteorological, and other ancillary data in the GIS framework. The Monaragala District of Sri Lanka has been utilized in the investigation as the study area due to the reason that it has been highlighted as one of the prominent drought-affected areas of the country. Precipitation deficiency considered as the foremost factor that affects the drought although drainage, slope, soil, Land use and land cover, wind, temperature could be led to the spreading of the drought. Hence, Meteorological, agricultural, and hydrological related combined drought analysis represent the drought in a more detailed way. The Moderate Resolution Imaging Spectroradiometer (MODIS) satellite images, precipitation data, and the spatial data layers collected over the last 30 years were implemented as the base data sources on the investigation, and further Google earth images were utilized for the cross-validation. Ultimately, the combined drought risk map help to create a correct and meaningful picture of the present situation in a more detailed manner. Rendering to the study it shows that overall, there is a moderate drought condition in the study area while showing the high hydrological drought condition than the meteorological drought condition. Further, it highlighted the importance of having proper water management in the Monaragala area for the prevention of drought.

1. INTRODUCTION

Drought is one of the significant hazards among common risks to individuals' employments and financial improvement (UNISDR, 2009)Regarding individuals influenced and help gave, drought is the massive hazard in Sri Lanka (DMC, 2017). Moreover, it causes enormous harm on the agricultural business. Consequently, droughts are critical in the arranging and the board of water assets as out of the absolute populace in Sri Lanka, 32% participate in agricultural exercises. Hence, it is critical to recognize the drought qualities to limit the drought hazard (Ekanayake and Perera, 2014). Even though drought brought immense influence on the entire country Hambantota, Monaragala and Kilinochchi districts were noted as the highest influence from the drought severity which could be identified by analyzing past drought events from 1974 to 2008 (DMC, 2017). Consequently, the Monaragala District has been selected as the study area of the investigation which was considered as the second largest of the 25 districts among the country.

As the remote sensing and Geographic Information Systems (GIS) make increasingly more demand over time, with the advancement of technology and science, it can be used to analyses and monitor the hazards in a meaningful way other than the conventional methods (Han *et al.*, 2010). Utility of remote sensing data especially satellite data in drought assessment has long been proven and needs no reiteration. It is far superior to conventional methods at an optimal spatial extent. Remote Sensing technology in its current state of art can help in predicting, mitigating, and monitoring of drought. Data from various satellites can be utilized for the purpose irrespective of the perspective that a researcher has towards drought. It enables to understand the manifestations of drought in a larger area more directly than through conventional methods, and of all, in less time-consuming manner. A geographic information system (GIS) is a Software used to capture, manipulate, analyses, manage, store and present spatial or geographic data. In general, the integration between the GIS and remote sensing provides the best platform for the spatial related analysis.

Even though drought mainly occurs due to the lack of rainwater in an unexpected way, it may be affected by some other reasons too. According to the several definitions given by many of the researchers, drought conditions can be classified based on its severity in the environment as Meteorological Drought, Hydrological Drought, Agricultural Drought, and Socioeconomic Drought(Chandrapala and Wimalasuriya, 2003; Bhuiyan, Singh and Kogan, 2006; Patel *et al.*, 2012; Leng, Tang and Rayburg, 2015). Drought is considered as a hydro-meteorological threat. According to the UNISDR (UNISDR, 2009)Definition on Disaster Risk Reduction 2009, hazard is defined as "a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage".

Meteorological drought is a typical occasion that outcomes from climatic causes, which vary from place to place(Bhuiyan, Singh and Kogan, 2006). Agricultural, hydrological, and socioeconomic drought, however, place more noteworthy accentuation on the human or social parts of drought. They feature the communication between the regular attributes of meteorological drought and human exercises that rely upon precipitation to give satisfactory water supplies to fulfil cultural and ecological needs. Meteorological drought is usually defined by a precipitation deficiency over a pre-determined period of time. Agricultural drought is characterized all the more ordinarily by the absence of accessibility of soil water to help harvest and forage development than by the take-off of typical precipitation over some predetermined timeframe. The connection between precipitation and penetration of precipitation into the soil is regularly not immediate(Mannocchi, Todisco and LORENZO, 2004). Penetration rates differ contingent upon precursor dampness conditions, slope, soil type, and the power of the precipitation occasion. Soil qualities likewise contrast. For instance, a few soils have a higher water-holding limit, which makes them less powerless against drought. Agricultural Drought This kind of drought happens when there is not sufficient dampness to help normal harvest creation on ranches. Albeit farming drought frequently happens during dry, hot times of low precipitation, it can likewise happen during times of normal precipitation when soil conditions or agrarian strategies require additional water (SAARCDMC, 2010). Hydrological drought is normally defined by deficiencies in surface and subsurface water supplies relative to average conditions at various points in time through the seasons. In Hydrological drought, there is immediate connection between precipitation sums and the status of surface and subsurface water supplies in lakes, repositories, springs, and streams in light of the fact that these hydrological framework parts are utilized for various and contending purposes, for example, water system, entertainment, the travel industry, flood control, transportation, hydroelectric power construction, local water supply, security of endangered species, and natural and environment safeguarding and so on.

Nonetheless the problem is still we did not identify the magnitude of this silent threat over the country. However, as a developing country, it is essential to have good food security and better water management. As well as we depend on the farming culture and most of the Sri Lankans occupation is farmers. Therefore, drought is a main threat to their livelihood. Thus, a systematic approach is required to identify and quantify the drought hazard and it is essential for the development of the country. The outcomes of the study could be exploited in the drought management process. Hence, in this study, it proposes to address the essential needs of the drought monitoring of the country by using remote sensing and GIS. Then in later this proposed methodology could be used by any department or individual for the management of the drought.

2. METHODOLOGY

2.1 The Study Area

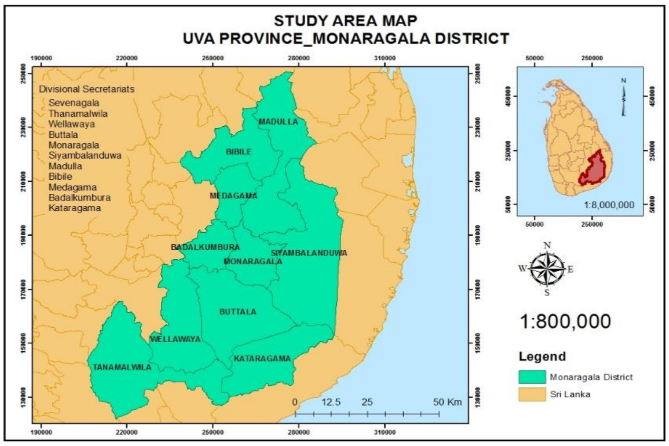


Figure 1 Study Area, Monaragala District, Uva Province of Sri Lanka

According to the Disaster Management Centre (DMC) among all the 25 administrative districts the Monaragala district was a highlighted as one of highest drought affected region. Monaragala District is situated on the southeast part of Sri Lanka between 6°17' to 7°27' north latitudes and 80°54' to 81°27' east longitudes. Total land area of Monaragala District is approximately 5545.6 Square Kilometers. The district is bordered by Hambantota District on the South, Badulla and Rathnapura districts on the West, Ampara district on the North and East directions. Monaragala district is the second-largest district of the country. The main occupation of the people in the agricultural sector as well as noted as one of the poorly developed districts in the country (D.M.S Dissanayake, 2018). Monaragala district located between dry and intermediate zones. In Monaragala district the intermediate zone locates in the North-western hilly area and the dry zone locate in the south-western and eastern sectors. The district receives around 1500 mm of rainfall in average annually. This is usually limited to 4-5 months of the year. However, one sixth of the district receives less than 1000 mm of rainfall per year.

2.2 Methodology

Several drought risk parameters have been utilized for the multicriteria drought risk assessment of the Monaragala District such as rainfall, sub-surface water, stream density, surface water and irrigation, DEM, slope, soil drainage, and land use. Each parameter analyzed by using different indices in order to obtain Meteorological Drought, Agricultural Drought and Hydrological Drought and finally the Drought severity of the entire area. The data considered as secondary data which were obtained from satellite images and existing data collected from the respective department of Sri Lanka. Rainfall data collected from the Annual statistical abstract which published by the Statistical department of Sri Lanka. In order to obtain better accuracy 15 years of annual rainfall data record collected as a point database for investigation. It is difficult to collect only Monaragala District data for better predictions, therefore entire country rainfall data was considered for the study. With the purpose of monitoring the Agricultural drought, 15 years of satellite images were used. 180 satellite images were collected in each month from the Moderate Resolution Imaging Spectroradiometer (MODIS) for the duration of 15 years. Worldwide MODIS vegetation lists are intended to give reliable spatial and transient correlations of vegetation conditions(Myneni *et al.*, 2002; Karnieli *et al.*, 2010). The MODIS Normalized Difference Vegetation Index (NDVI) supplements NOAA's Progressed Exceptionally High-Resolution Radiometer (AVHRR) NDVI items and gives congruity to time arrangement verifiable applications(Lp Daac, 2014).

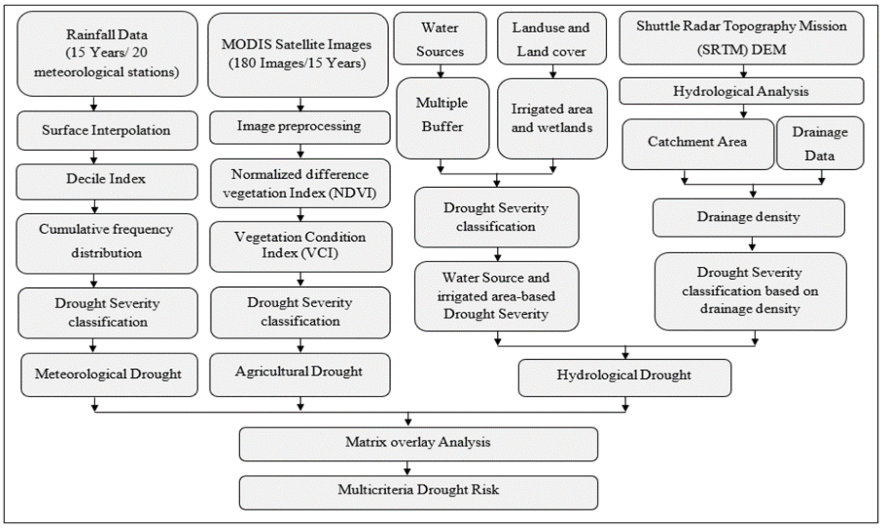


Figure 2 The Complete workflow of the experiments conducted under the study

3. RESULTS AND DISCUSSION

3.1 Meteorological Drought of Monaragala District

Meteorological drought is characterized generally based on the level of and the span of the dry time frame. In this way, it is commonly characterized by looking at the precipitation in a specific spot and at a specific time with the normal precipitation for that place. The definition is, thus, explicit to a specific area. Meteorological drought prompts a consumption of soil dampness, and this quite often affects crop creation. The range of annual rainfall was then identified using a decile index to create the decile rainfall (Monkolsawat *et al.*, 2001; Suwanwerakamtorn *et al.*, 2005). Deciles is a meteorological drought estimation list that utilizes just precipitation. The deciles list gives an exact factual estimation of precipitation given that long climatic information is accessible. In particular, month to month recorded precipitation information is arranged from most reduced to most elevated and separated into ten equivalent classifications or deciles (Gibbs, 1975). The month-to-month precipitation circulation over an extensive stretch of time is partitioned into tenths of the dissemination. Every one of these 10 classes is known as a decile. By definition, the fifth decile is the middle (center) precipitation sum and is not surpassed by half of the precipitation events over the whole record of the station (Salehnia *et al.*, 2017). At that point, the decile rainfall of 10 classes was assembled into 4 degrees of drought seriousness, as appeared in Table 1.

Table 1 Rainfall Decile ranges and respective Drought severity class

(Source: modified from Charat et al, 2001 and Gibbs and Maher, 1967)

Decile range	**Decile classification**	**Drought severity class**
1 (lowest 20%)	much below normal	Severe drought
2 (lowest 20%)	much below normal	Severe drought
3 (next lowest 20%)	below normal	Moderate drought
4 (next lowest 20%)	below normal	Moderate drought
5 (middle 20%)	near normal	Moderate drought
6 (middle 20%)	near normal	Slight drought
7 (next highest 20%)	above normal	Slight drought
8 (next highest 20%)	above normal	No drought
9 (highest 20%)	much above normal	No drought
10 (highest 20%)	much above normal	No drought

The data were collected by twenty meteorological observation station spread among the country and the data were brought into the GIS platform in order to obtain spatial relationships. A number of methods have been proposed for the interpolation of rainfall data. The simplest and frequently used technique uses the weighted average of surrounding values to estimate the rainfall at a given location would be well estimated by using geostatistical techniques such as kriging. Kriging is a geostatistical estimation technique for spatial interpolation which uses a linear combination of surrounding observed values to make predictions. The resulted meteorological drought map which generated from the integration between decile index and the kriging interpolation is presented in the figure 3.

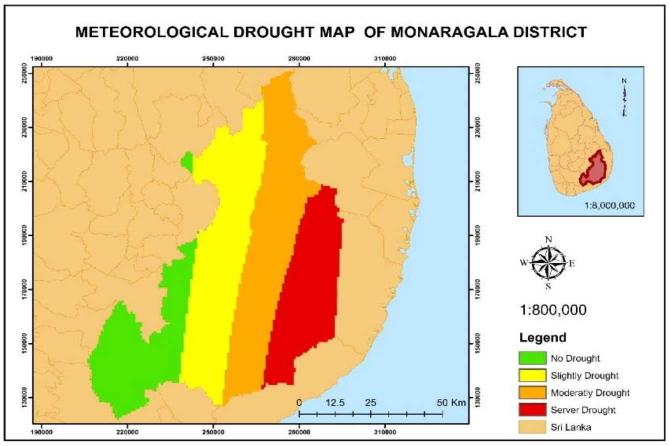


Figure 3: Rainfall data based Meteorological Drought analysis

map of Monaragala District Sri Lanka

3.2 Agricultural Drought of Monaragala District

3.2.1 Normalized Difference Vegetation Index (NDVI)

Tucker first recommended NDVI in 1979 as an index of vegetation health and density (Thenkabail and Rhee, 2017). NDVI is defined as:

NDVI= (NIR-RED)/ (NIR+RED) equation 01

Where NIR and RED are the reflectance in the close infrared and red bands. NDVI is a decent marker of green biomass, leaf region list, and examples of creation (Han *et al.*, 2010; Thenkabail and Rhee, 2017)

3.2.2 Vegetation Condition Index (VCI)

It was first suggested by Kogan in (1997) (Thenkabail & Rhee, 2017). VCI is an indicator of the status of the vegetation cover as a function of the status of the vegetation cover as a function of the NDVI minimum and maxima encountered for a given ecosystem over many years. VCI is defined as:

VCIj = (NDVIj- NDVImin)/ (NDVImax- NDVImin) *100 equation 02

Where NDVI max and NDVI min is determined from a long-term record for a specific month, and j is the list of the present month. The state of the ground vegetation introduced by VCI is estimated in percent(Bhuiyan and Kogan, 2010). The VCI esteems between half to 100% demonstrate ideal or better than average conditions while VCI values near zero percent mirror an extraordinary dry month. The examinations recommend that VCI catches precipitation elements better than the NDVI, especially in geologically non-homogeneous territories. Additionally, VCI values show how much the vegetation has progressed or weakened in light of climate. It was finished up from the above examinations that VCI has given an appraisal of spatial attributes of the dry season, just as its span and seriousness, and were in acceptable concurrence with precipitation designs (Bhuiyan, Singh and Kogan, 2006; Sharma, 2006; Dutta *et al.*, 2015).

Table 2 Agricultural drought risk classification using VCI
Source: (Bhuiyan & Kogan, 2010)

VCI Range (%)	Drought severity class
Above 40%	No drought
30% to 40%	Slight drought
20% to 30%	Moderate drought
Below 20%	Severe drought

Accurate assessing of condition of vegetation was vital for drought-related studies. Therefore, VCI used for the analysis in order to obtain the condition of vegetation according to the NDVI anomalies. Hence VCI was calculated for each image by using NDVI variances. Time series of NDVI anomaly used to detect agricultural drought. The threshold values used in this study to classify agricultural drought risk. According to the VCI anomaly ranges drought severity was classified into four severity classes by considering the percentage of different harshness levels and the resulted map shows in the figure 4.

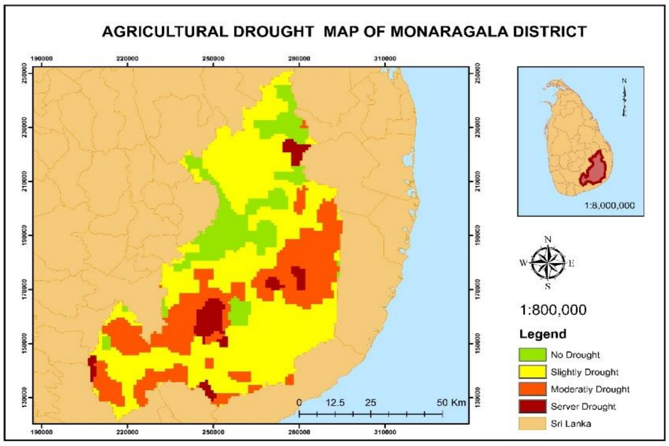


Figure 4 MODIS Satellite Image data based Agricultural Drought analysis map of Monaragala District Sri Lanka

3.3 Hydrological Drought of Monaragala District

In order to obtain Hydrological drought, the Hydrological analysis will perform over the study area. Which based on three parameters such as surface water source, irrigated area, and stream density in sub-watershed(Bhuiyan, Singh and Kogan, 2006). Stream density will be play major role in the study and planned to classify severity of the drought depend on the density distribution of each surface water source and streams (Monkolsawat *et al.*, 2001). Catchment areas of the Monaragala district were delineated by using Shuttle Radar Topography Mission Global Digital Elevation Model (SRTM DEM) with the resolution of 30 m, a data product of USGS, in order to analyses the drought risk based on drainage density. Terrain preprocessing functions in Arc Hydro, were used to delineate catchment areas of Monaragala District. Subsequently, drainage density (i.e., proportion of drainage line length to catchment area) of each catchment was calculated. The drainage density layer was classified into 4 classes of drought severity using quantile classification and converted to a polygonal feature class as per shown in the Table 3.

Table 3 Drought severity parameters based on stream density in Monaragala District, Sri Lanka
Source: (Suwanwerakamtorn et al., 2005)

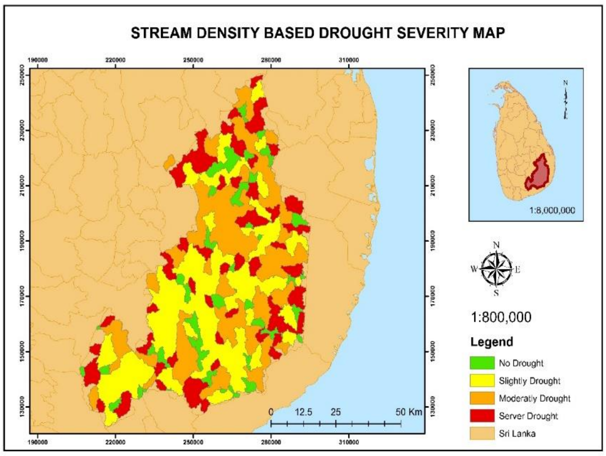
Stream density	**Drought severity class**
0.1 – 0.35 km/ km2	Severe drought
0.36 – 0.70 km/ km2	Moderate drought
0.71 – 1 km/ km2	Slight drought
> 1 km/ km2	No drought

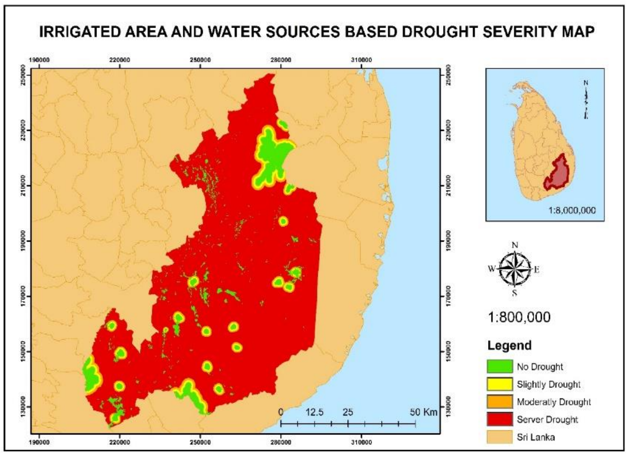
In order to analyses the drought risk based on distance from water source, water sources in Monaragala district were classified into 3 classes in relation to their surface area and subsequently multiple buffers were created around water sources to define drought severity as shown in Table 4. Irrigated areas were then assigned with the lowest drought risk class value (i.e., No drought). Thereafter, irrigated area layer was union overlaid on a GIS platform with the layer representing drought risk based on distance from surface water sources. Hydrological drought risk map was generated by a matrix overlay between the resultant layers with the stream density layer.

Table 4 Drought severity parameters based on water source in Monaragala District, Sri Lanka
Modified from Mongkolsawat et al., 2001

Surface area of the water body	**Buffer distance as area beyond water source**	**Drought severity**
0 - 0.5 km^2	0 - 0.25 km	No drought
	0.25 - 0.5 km	Slight drought
	0.5 - 0.75 km	Moderate drought
	> 0.75 km	Severe drought
0.5 - 5 km^2	0 - 0.5 km	No drought
	0.5 - 1 km	Slight drought
	1 - 1.5 km	Moderate drought
	> 1.5 km	Severe drought
> 5 km^2	0 - 0.75 km	No drought
	0.75 - 1.5 km	Slight drought
	1.5 - 2.25 km	Moderate drought
	> 2.25 km	Severe drought

Hydrological droughts are usually out of phase with or lag the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, stream flow, and groundwater and reservoir levels (Hisdal and Tallaksen, 2003). Therefore, hydrological drought analysis was significant for completing drought severity analysis as well as the meteorological and hydrological drought investigation. The distribution of drainage patterns, water sources, and irrigated areas play a vital role in hydrological drought. In addition, catchment delineation and drainage density calculation also imperative for hydrological analysis. Raster-based digital elevation models (DEMs) play an important role in distributed hydrologic modeling supported by the GIS. With the intention of analyses drought severity based on drainage density, the first catchment area was generated by using SRTM DEM via ArcGIS hydrological analysis tool. Distance from the water source to nearby features is an essential calculation in drought monitoring(Hisdal and Tallaksen, 2003; Bhuiyan, Singh and Kogan, 2006). Therefore, accurate analysis of water sources and proximity class vital in the study. With the aim of examining the drought risk based on distance from the water source, water sources in the Monaragala district were classified into three classes in relation to their surface area and subsequently multiple buffers were created around water sources to define drought severity as shown in Figure 5.





(a) (b)

Figure 5 **(a)** Stream density-based Drought severity classification map and **(b)** Irrigated area and water source-based Drought severity classification map of Monaragala District Sri Lanka

Afterward obtaining results for Stream density-based drought severity and Irrigated area and water source-based drought severity, to fulfil a complete hydrological analysis, the irrigated area layer was union overlaid on a GIS platform with the layer representing drought risk based on distance from surface water sources in order to obtain Hydrological drought. Then the resulted map shows the combined effect as a hydrological drought in the study area as in figure 6.

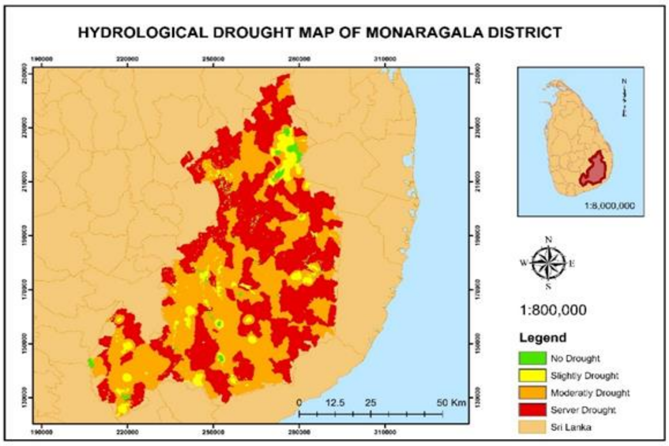


Figure 6 Stream density, Irrigated area and water source based Hydrological Drought analysis map of Monaragala District Sri Lanka

Even though there were seven river basins located within the Monaragala District there was severe hydrological drought due to the lack of water scarcity. The hydrological drought was the foremost affected drought in the entire area. As a result, these impacts are in the phase with impacts in other economic sectors. For example, a precipitation deficiency may result in a rapid depletion of soil moisture that is almost immediately affected by agriculturalists. Therefore, it is badly affected the cultivation which was considered as the main occupation of mainstream of the people in the area.

3.4 Drought Risk Area Map of Monaragala District

The overall approach of the study was to find the drought severity of the Monaragala in a spatial context. Other than relay on traditional meteorological drought mapping here used main three aspects of the drought in order to obtain the severity of the drought. In previous steps obtained drought according to the different characteristics of it. In addition, in here built a drought map which is the combined representation of all three aspects. Hence, the drought risk area map of the Monaragala district was generated by using matrix overlay operations. In raster overlay, each cell of each layer references the same geographic location. That makes it well suited to combining characteristics for numerous layers into a single layer. The drought severity values were assigned to each characteristic and mathematically combine the layers and assign a new value to each cell in the output layer. Therefore, raster overlay manipulates between, meteorological, agricultural, and hydrological drought risk map layers as illustrated in Figure 7. This map was integrated using ArcMap 10.1 Software environment.

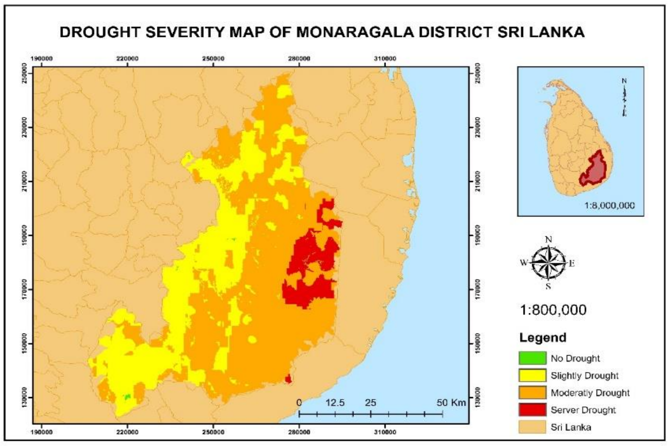


Figure 7 Drought Risk area map (Combination of Meteorological, Agricultural and Hydrological drought) of Monaragala District Sri Lanka

The accompanying percentage area affected by the combined risk. High risk prevails in nearly 7% percentage, and more than half of the area (58%) affected moderate drought conditions as shown in Figure 8.

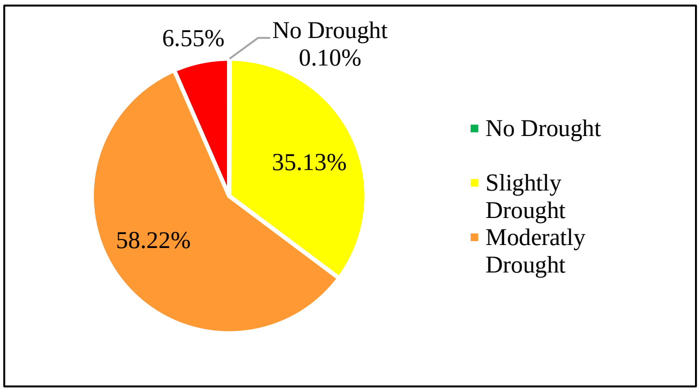


Figure 8 Spatial percentage of coverage of the Drought Risk area (Combination of Meteorological, Agricultural and Hydrological drought) in the Monaragala District Sri Lanka

The methodology utilized in this study facilitates drought risk identification meteorologically, agriculturally, and hydrologically. Subsequently, the major causes affected for severe drought risk areas can be identified through the results of the research and the Table 5 explains the contribution of each factor relating to the drought conditions of Monaragala district.

Table 5 Percentage areas of Meteorological, Agricultural and Hydrological drought severity in Monaragala District, Sri Lanka

Type of drought	**No Drought**	**Slightly Drought**	**Moderately Drought**	**Server Drought**
Combined Drought	0.1%	35.1%	58.2%	6.6%
Meteorological drought	19.9%	30.0%	30.2%	19.9%
Agricultural drought	14.7%	53.7%	26.7%	4.8%
Hydrological drought	1.1%	5.7%	44.8%	48.3%

The percentage of severe drought risk areas was calculated to be 19.9%, 4.8%, and 48.3% in meteorological, Agricultural, and hydrological drought, respectively. Hence, hydrological drought can be identified as the major cause of the drought in the Monaragala district with 48.3% of the severe drought risk area. But when carefully observing the results could be able to identify Moderate drought condition was the dominant pattern of drought in Monaragala.

4. CONCLUSION AND RECOMMENDATIONS

The main objective of this study is to find out the drought severity in the Monaragala district. In addition, analyzing drought severity in a spatial context such as meteorological drought, agricultural drought, and hydrological drought was in the sub-objectives. In meteorological drought, it identifies the relationship between rainfall and drought severity, in agricultural drought, it identified the interconnection between the present condition of the vegetation and its severity and moreover under the hydrological drought, it identified the spatial distribution of the water sources and the severity of the drought in a scientific and analytical way. Finally, it found the appropriate drought risk areas can be delineated by the integration of satellite, meteorological, and other ancillary data. When considering drought, it has a strong positive correlation with the above three factors such as the precipitation, vegetation cover, and the location of hydrological resources in particular area, and by the results it proves that relationship.

Drought is a natural hazard that involves many factors, including meteorological and climatological parameters, having complex inter-relationships. Drought definitions vary from region to region and may depend upon the dominating perception, and the task for which it is defined. Other than relying on conventional drought event counting method here present most effective method of drought mapping in spatial context by using the three aspects of drought such as meteorological, hydrological, and agricultural. Identifying patterns of drought and finding its associations with various indices derived from the conventional method and remote sensing techniques are becoming important for monitoring of this natural hazard. Rainfall varies spatially and temporally throughout the whole Monaragala district. On analyzing the rainfall for all the 20 stations in the country from 2005 to 2019 indicate how to change the pattern of precipitation with the time. It was found that there is a large variation in rainfall especially in the two monsoon periods. The occurrence of drought cannot be monitored by comparing the relative rainfall observed in various stations. To overcome these limitations, the use of a Decile for drought monitoring was highlighted. Further ordinary Kriging interpolation techniques were used in order to visualize it spatially. Among all the techniques Ordinary kriging was the most suggested method for Sri Lanka and manipulated over the study.

MODIS NDVI is found to be widely and extensively used for the detection and monitoring of the drought phenomenon for almost all regions of the world affected by drought effectively and efficiently. With the existence of such a dataset, it becomes easy and effective to monitor a natural phenomenon. But the datasets generally contain some of the errors introduced to the data by instrumental and data processing. So, in order to identify and remove such unwanted noise and signals from the data, the atmospheric and geometric procession was used. NDVI times-series was subjected to scale to VCI in order to estimate the vegetation health and monitored drought. To monitor drought effectively and for the identification of false alarm regions, drought identified with NDVI helped in monitoring the drought effectively thereby eliminating the false drought detected areas. It was observed that NDVI generally have positive strong correlations with the forest, wasteland land cover classes, the correlations were found to be negative in woodlands, urban, and croplands. The vegetation of the area is totally dependent on the rainfall. This correlation defines rainfall as a basic and major factor in prone to drought, arid area. The NDVI is very low in a particular area, this place is more vulnerable to drought. Stream density and the delineation of catchment provided the impact of hydrological drought on the area which was conceded as the highest influencing type of drought to the Monaragala district as indicated in the study. The pattern of circulation of water resources and the streams network was significant for the drought analysis. The distribution of water bodies' s and the density of the streams show the importance of having better water management for the area in order to get rid of the hydrological drought.

Furthermore, as the final risk map gives the areas facing a high drought risk, a detailed study of these areas in terms of soil, water availability, temperature conditions, rainfall, crops grown, the economic importance of the area and the social conditions prevalent can further help in preparing better management plans. Final risk areas delineated from the integration of various data sources have given a correct pattern of the risk areas based on last fifteen years of spatial data. However, since no published reports were available for the validation of the results, therefore there is an urgent requirement of the validation of the maps being prepared.

Moreover, it recommends using appropriate water management for the Monaragala district which was highlighted as the server in the aspect of hydrologically. And also, there was significant demand for proper water management especially for the Siyambalanduwa area which was identified as the most vulnerable divisional secretariat division from the drought. Further presented methodology was significant for future analysis and recommend using respective departments in order to generate a correct reflection of the drought.

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