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Drought Vulnerability Detection and Mapping in Attapadi, A Part of Southern Western Ghats, India- Using Geoinformation Science and Technology

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Abstract: ***Drought is an insidious hazard of nature which is considered by many to be the most complex but least understood of all natural hazards. It is among the natural disaster that causes damages and affects many people's life in many part of the world. Drought can be divided into four categories of meteorological, hydrological, agricultural and social-economic. Drought vulnerability is a concept which shows the likelihood of damages from hazard in a particular place by focusing on the system status prior to the disaster. Drought vulnerability has been viewed as a potential for losses in the region due to water deficiency at the time of drought. In this study the vulnerability of drought in Attapadi province in Palakkad district is investigated by providing vulnerability maps which demonstrates spatial characteristics of drought vulnerability.Modern technology has made substantial contribution in the identification of drought vulnerable area. The modern technology used in present system for drought prone area identification is remote sensing and geographic information system. Drought is one of the climatic, natural disasters, having an impact on both the economy and the society, with its long-standing problems. Drought by nature is a result of inter-related parameters. The study is based on the concept that the severity of the drought is a function of rainfall, hydrological and physical aspects of the landscape, leading to meteorological, hydrological and physical drought. In the present study a Geographic Information Systems (GIS) and remote sensing -based tool for drought vulnerability assessment at a micro level has been developed. The result of this study can be used for preparedness planning and for allocating resources for facing droughts in this region.***

Keywords: Drought, Geographic Information System, Remote Sensing, Attapadi, Vulnerability Maps

1. Introduction

Drought is considered by many to be the most complex but least understood of all natural hazards, affecting more people than any other hazard (Abdel Aziz Belal ,2014). Drought risk is a product of a region's exposure to the natural hazard and its vulnerability to extended periods of water shortage (Nishadi,2015). Drought is a period of abnormally dry weather sufficiently for the lack of precipitation to cause a serious hydrological imbalance and carries connotations of a moisture deficiency with respect to man's usage of water. GIS is an information system that is designed to work with data referenced by spatial or geographic coordinates. GIS combined with MCE (Multi-Criteria Evaluation) can achieve measurable evaluation of drought risk. Karamouz *et al,* 2015, introduced Technologies for evaluating agriculture meteorological drought risk with GIS-MCE. The results indicated that technology of GIS-MCE can combine multiple source information associating with agriculture meteorological drought risk and achieve measurable result. Satellite remote sensing provides a synoptic view of the land and a spatial context for measuring drought Impacts, which have proved to be a valuable source of spatially continuous data with improved information for monitoring vegetation dynamics. Sierra-Soler *et al,* 2015 used the newly developed LULC methodology to determine the effects of drought in specific classes with great precision.

According to Jerrod *et al,* 2016, Earth observation satellites could prove useful for the assessment and evaluation of drought effects in forest ecosystems. The objective of his study were to briefly review the existing sources of remote sensing data and their potential to detect drought damage; to review the remote sensing applications and studies carried out during the last two decades aiming at detecting and quantifying disturbances caused by various stress factors, and especially those causing effects similar to drought. If nations and regions are to make progress in reducing the serious consequences of drought, they must improve their understanding of the hazard and the factors that influence vulnerability. It is critical for drought-prone regions to better understand their drought climatology (i.e., the probability of drought at different levels of intensity and duration) and establish comprehensive and integrated drought information system that incorporate climate, soil, and water supply factors such as precipitation, temperature, soil moisture, snow pack, reservoir and lake levels, ground water levels, and stream flow. All drought prone nations should develop national drought policies and preparedness plans that place emphasis on risk management rather than following the traditional approach of crisis management, where the emphasis is on reactive, emergency response measures. Crisis management decreases self-reliance and increase dependence on government and donors. India is predominantly an agrarian country as more than 70% of its population is dependent on agriculture. Due to the vagaries of rainfall more than 68% of the net sown area in the country is drought prone, out of which 50% is severe in nature. The country experiences drought every 2 to 3 years in one part or other (Jeyaseelan et al., 2001). The nation experienced phenomenal drought condition in the years 1972, 1979 and 1989 (C.S.E, 2001). UNICEF reported that 'an estimated 130 million people – 15 percent of the population – in more than 70,000 villages and 230 urban centres were at risk due to severe drought and resultant crop failure in India during years 1998-2000 (Subin, 2015). The prime aim of this study was to develop a method for geospatial prognosis of drought hazards using satellite remote sensing and ground-based information through the application of geographic information system (GIS).

2. Materials and Methods

Drought vulnerability has been viewed as a potential for losses in a region due to water deficiency at the time of drought. In this section, the development of drought vulnerability map is discussed. For this purpose seven parameters have been selected which are precipitation, landuse- land cover, geomorphology, geohydrology, slope, soil texture, drainage density. The data needed was obtained from Survey of India (SOI), Geological survey of India (GSI), Geomorphological map of India, LISS III images of 2009. For each parameter a category map has been created using GIS which shows variability of that parameter in the region. Vulnerability has been divided into several categories. In the end a weight has been assigned to each categories and finally all seven categories maps have been overlaid and a unique drought vulnerability map has been developed.

Precipitation: one of the most important parameters in assessing drought vulnerability in a region is precipitation . Average rainfall for east Attapadi is less than 1500 mm.

Landuse: The way the lands are used in a region has a direct impact on water resources and as a result it is considered in the drought vulnerability analysis. Landuse could influence on water resources through changes in catchment yields, infiltration rates, dissolved organic carbon and nutrient transfers. In this study water demand for each landuse type has been assumed as a factor that directly influences drought vulnerability. For instance, grassland or grazing land have low water demand and as a result it is considered to have the lowest vulnerable to drought. On the other hand, agricultural areas have a large water demand which makes them the most vulnerable land use type when it comes to having water shortage. Different land uses types have been recognized in the study region which are agricultural land, built up areas, forest, grassland, grazing land, water bodies.

Geomorphology: Here, the terrain was classified into plain area (planation and vally flat), and hilly terrain (structural hills, linear structural hills and structuro-denudational hill). The hilly terrain mainly comprising the runoff zone over the steeply sloping land and characterized by shallow depth of soils (less than 2 m) is highly prone to drought. On the contrary, the plain areas with gentle slopes and due to deep soil cover (about 10–20 m) have high surface water retention capability and shallow ground water conditions are least prone to drought.

Slope: Slope maps represent topography of the region. Larger slope could produce larger amount of runoff, therefore, less ground water storage could be produced. As a result, larger slope is considered to be more vulnerable to drought. This may not always be the case but it is assumed by Weatherhead (2009). Slope map of the terrain is prepared with digitized contours on GIS platform using TIN (Triangulated irregular Network) Slope in the region varies from 0 to 90 degrees which represent a wide topography in the region.

Geohydrology: Geohydrology deals with the distribution and movement of groundwater in the soil and rocks of the earth's crust (Deb Sutton, 2016). The main geologic area outlined here are foot hills and mountainous area. These two categories are grouped together in most cases. In mountain regions, water level is deep and gradient steep (Borneuf, 1980).

Soil: The type of soil and permeability affects the water holding and infiltrating capacity of a given soil. Soil permeability and soil moisture is an indication of potential zone. Mainly three orders of soils are found in the area- ultisols, inceptisols and mollisols. High saturation is attached to mollisols and low to ultisols (subin.k.jose et al, 2012). Low temperature or low precipitation favors the development of inceptisols (Sabine grundwald, 2009).

Drainage density: Drainage map of the area was prepared from topographical map of Survey of India (SOI-GOI), on 1:50,000 scale. The drainage map was categorized based on visual interpretation into three classes of drainage density, viz. low, moderate, and high. It is considered that an area with high drainage density has more water contact areas as compared to area with no drainage. Negating the influence of other factors, it can be remarked that areas with high drainage density are less prone to drought and vice versa.

Framework for the derivation of drought hazard map : To produce an individual drought hazard map various drought hazard factors were considered for analysis through the 'union' mathematical function in ARC GIS. Spatial Analyst extension of ArcGIS 9.3 was used for converting the features to raster and also for final analysis.

The following numerical weighting scheme was used to assess the relative drought hazard potential of each factor. Each class of seven hazard factor map has been assigned a relative weight as 1, 2, 3… with 1 being considered least significant in regard to drought hazard and highest number being considered most significant. The choice of weights was based on an informed assumption on relative contribution of each class to drought hazard. The given weights were normalized for each map so that difference in the number of classes in all maps can be brought to same scale with value of weights in the range of 0 less than 1. For normalization, weights of each class were recalculated by dividing the class weight by cumulative weight of all the classes. All the maps in the polygon (vector) format were converted into raster format with a grid cell size of 25 m. The grid cell size of 25 m was selected for deriving output map with the high spatial accuracy as the drought scenario changes at short spatial dimension in undulating plateau terrain.

The weighted maps were cumulated by spatial join in GIS using the parameters selected for each types of drought. As all the weighted maps in GIS database were co-registered with their respective cell coordinates, weights of individual cell in all input maps were joined by adding their normalized values in the attribute table. A high numeric value within each category was assumed to be indicative of a geographic area that is likely to be more susceptible to drought. The resulting map was reclassified into five classes, identifying geographic areas with 'very low', 'low', 'moderate', 'high', and very high hazard using natural break method.

3. Result and Discussion

Droughts are one among the most devastating natural hazards in the world, claiming more lives and causing extensive damage to agriculture, vegetation, human and wild life and local economies. In this study, a drought vulnerability map has been created for Attapadi based on 7 parameters The result of the study shows that GIS and remote sensing could be successfully employed in identification of drought vulnerable areas in Attapadi. The general trend observed in the present study is increase in the drought risk area due to the decrease in the forest cover. The drought vulnerability scenario developed by combining all the seven criterias indicated that very high and high chances of drought vulnerability is more pronounced across Agali and kallimala and comparatively lesser in Kottathara and sholayur. Areas under low drought hazard are mainly found over ultisol soil, situated over regions with relatively higher slope (> 33 degree) in the vicinity of forest areas that receive higher rainfall (2,600-3,000mm)

Areas with high and very high drought hazard are coinciding with areas receiving 2200 - 1000 mm of monsoon rainfall, The rain shadow effect in the eastern side is due to the high and steep hills on the Western region and over lower slope areas (< 26 degree) with low and moderate drainage density and, inceptisol type of soil, landuse type in this region is agriculture. Geomorphologically, the areas over planation and structural cum denudational hills are under high drought hazard, whereas over linear structural hills, very high drought hazard exists.

4. Conclusion

The map of drought hazard synthesized a variety of data and serves as an indicator of areas deserving a detailed drought hazard and risk evaluation. The drought hazard map can help authorities to visualize the drought proneness and its severity to support people engaged in agriculture and allied sectors with suitable drought mitigation measures. The present study using Remote Sensing and GIS techniques has helped in identifying drought vulnerable area which is classified into Very high, high, Moderate and Low. Such a zonation assumes importance in planning strategies for effective management of the water resources. In this study integrated Remote Sensing and GIS can be used as a powerful and an effective tool for planning in local and government organizations. GIS can play a key role in documenting natural condition, documenting the impacts on resources, exposing conflicts, and the revealing cause effect relationship. Attappady is a continuing hot spot of ecological destruction. Despite it had been blessed with fertile soil, three perennial rivers, well spread adequate rainfall, equitable climate, a forest cover ranging from sub-temperate montane shola-grasslands to evergreen forests and semi-deciduous vegetation and also with people capable of maintaining the ecological balance its degradation is dramatic within the past few decades. The ecological degradation of the area had begun since the colonial government's intervention through its forest policies and it became acute since it had been integrated with the Kerala state in 1957 The major activity that destroyed the eco-system of a deep forest into a desert like landscape is the conversion of forest into arable land by settlers. Deforestation and the introduction of non-eco friendly agriculture practices have degraded the vegetation cover almost beyond regeneration. With the loss of vegetation, subsequent massive soil erosion changed the local climate and made rainfall erratic. This has resulted in the loss of perennial nature of the rivers of Attappady as their catchments area has become relatively drier due to ecodestructive human involvement, which is continuing till now, thereby increasing the risk to cause drought. The reason for introducing the chance of drought is not due to the natural causes but due to the immoral activities that had taken place and changes in the life style of modern humans causing a widespread disaster in the study area. It's a great shame to human society that we are exploiting our mother earth for our selfish needs.

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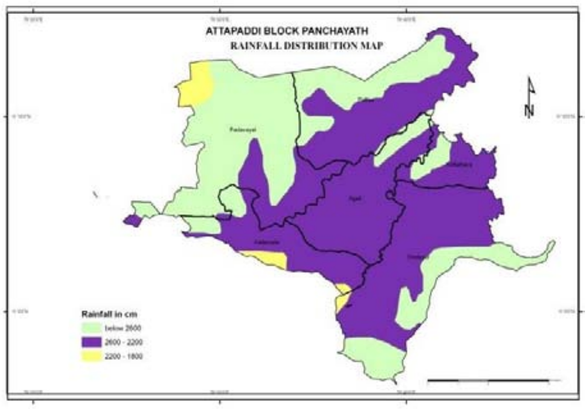

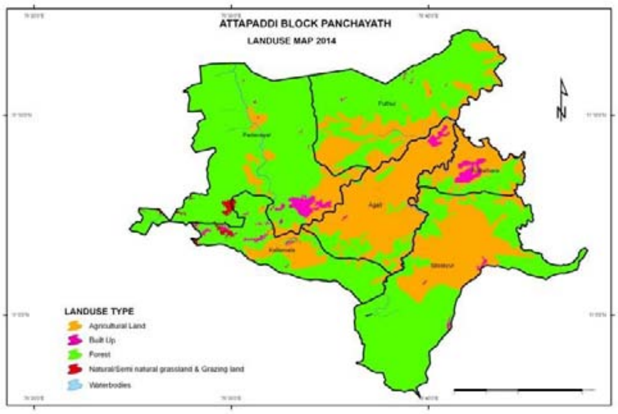

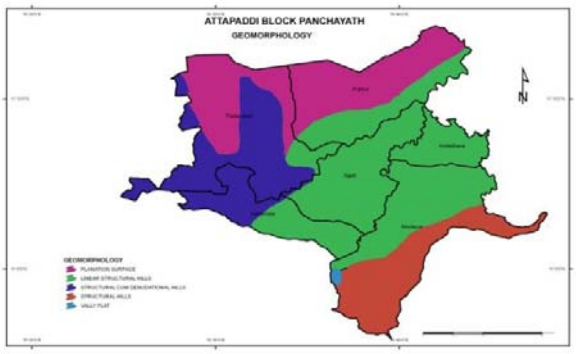

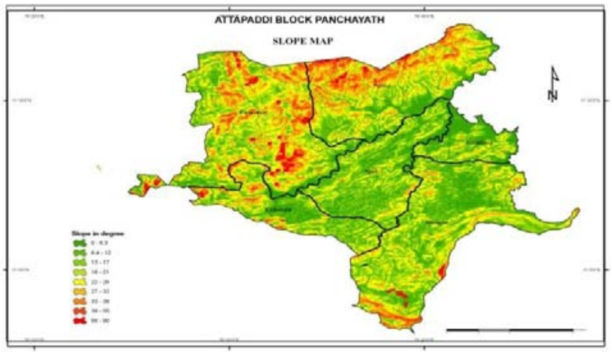

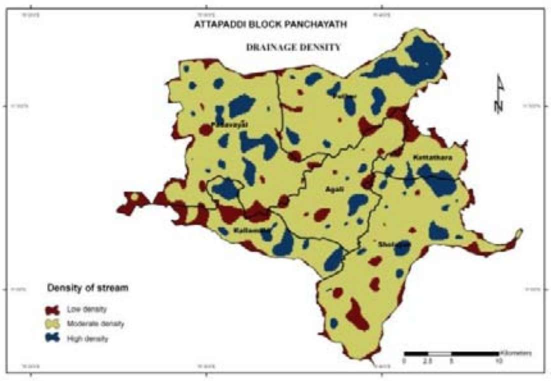
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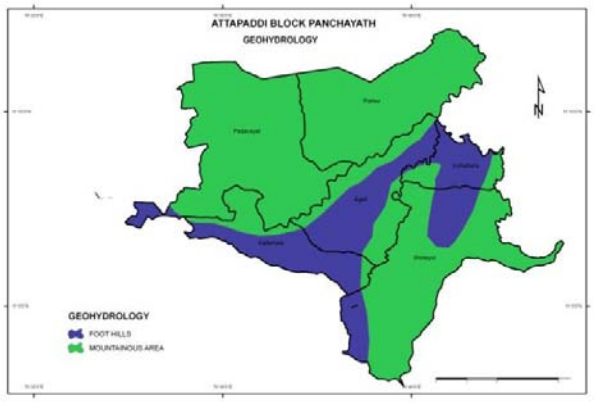
DRAINAGE DENSITY
Density of stream
Low density
Moderate density
High density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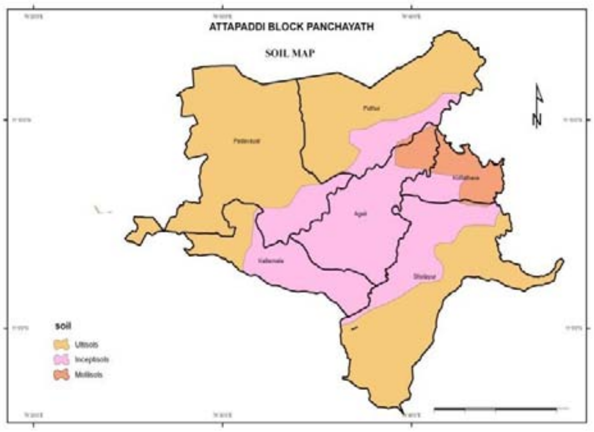
FOOT HILLS
MOUNTAINOUS AREA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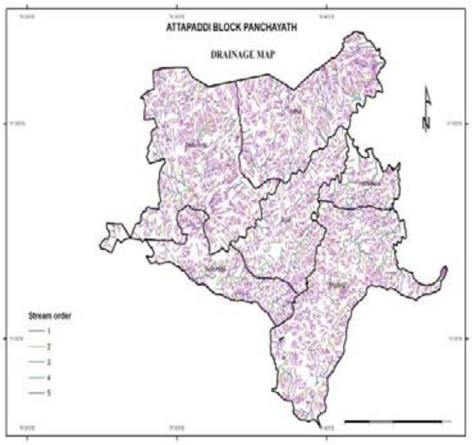
SOIL MAP
soil
Ultisols
Inceptisols
Mollisols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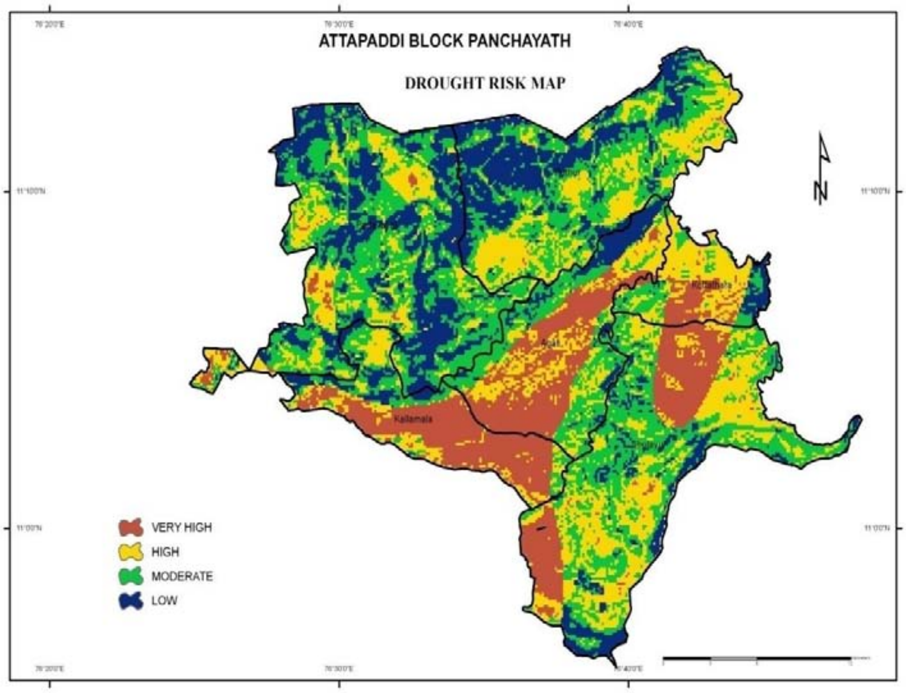
DRAINAGE MAP
Stream order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DROUGHT RISK MAP
VERY HIGH
HIGH
MODERATE
LOW