Synopsis of Proposed Study Submitted For the Degree of Doctor of Philosophy in Geography

Title of the study:

The Potential Use of Geospatial Data and Development of Spatial Decision Support System for Drought Management: a case Study of Nakhatrana and Lakhpat Taluka of Kutchh District, Gujarat

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The Potential Use of Geospatial Data and Development of Spatial Decision Support System for Drought Management: a case Study of Nakhatrana and Lakhpat Taluka of Kutchh District, Gujarat

Background:

Drought is a natural hazard that differs from other hazards like Flood, landslides, cyclones etc. since drought has a slow onset, evolves over months or even years, affects a large spatial extent, and cause little structural damage. Its onset, end and severity are often difficult to determine. Among the different natural hazards; drought is most disastrousus with untold numerous miseries on the human society. India has been traditionally vulnerable to natural disasters on account of its unique geo-climatic conditions.

Drought planning is generally accepted tool to reduce the future risks for governments at all levels. At present drought mitigation plans are more of generic nature, that are applied commonly to any drought prone areas, and majority of drought plans are fundamentally response oriented to the society or livelihood.

Drought occurrence is a gradual phenomenon having long lasting impact. The vulnerability assessment and analysis helps in quantifying the impacts on various sectors like agriculture, hydrology, socio-economic and environment.

Definition of Drought

Drought is the most complex and damaging natural hazard. It can recur frequently and cause considerable damage to agriculture, economy, nature, and property, potentially affecting the lives of many people. Despite all the problems that droughts have caused, drought has proven to be difficult to define and there is no universally accepted definition because drought is repeatedly, result of many complex factors such that drought often has no well-defined onset nor end and the impacts of drought vary by affected sector, thus often making definitions of drought specific to affected groups and geographical regions.

Many researchers or specialists from agriculture stream characterizes dry spell as a product disappointment condition because of absence of soil moisture conditions for crop growing while meteorologists characterize dry spell as absence of present precipitation from normal precipitation (climatology). Researcher from hydrology basis, characterize dry spell as diminished surface and ground water level and for the Socio-economic specialists it is lack in drinking water that influences lives in the public eye.

In general, drought can be defined as an extended period- a season, a year or more having deficient rainfall relative to the statistically multi-year average of a region. In other words, drought is a period drier than normal conditions that lead to water scarcity. When rainfall is below normal for weeks, months or even years, it brings about a decline in the flow of river, streams and drop-in water level in reservoirs and wells.

Types of Drought

Four major types of droughts are broadly defined and agreed upon in the scientific literature. As per the review of various literature, four essential ways to pact with measuring drought: meteorological, hydrological, agricultural, and socio-economic. The initial three methodologies manage approaches to quantify drought as a physical parameter. The last manages dry spell as far as free market activity, following the impacts of water setback as it swells through financial and social frameworks.

A. **Meteorological Drought:** Meteorological droughts occur when there is deficit in precipitation compared to long term average precipitation. Meteorological drought occurs probably in combination with high evapo-transpiration. Meteorological drought results from reduction of precipitation. Meteorological drought occurs more frequently and commonly than other three kinds of droughts; meanwhile, it normally triggers other types of drought, including agricultural, hydrological, and socioeconomic drought.

B. **Agricultural Drought:** Agricultural drought happens after meteorological drought but before hydrological drought. In other term, agricultural drought occurs when there is insufficient soil moisture to meet the needs of a particular crop at a given stage.

C. **Hydrological Drought:** Hydrological drought refers to deficiencies in surface and subsurface water supplies. There is the time lag between lack of rain and less water in streams, rivers, lakes and reservoirs, so hydrological measurements are not the earliest indicators of drought.

D. **Socio-economic Drought:** Socio-economic drought occurs when physical water shortages start to affect the health, well-being, and quality of life of the people, or when the drought starts to affect the supply and demand of an economic product. Socio-economical drought, which is an extreme form of agricultural drought, addresses the damage caused by all the above-mentioned types of drought

Drought monitoring based on drought indicators used for the analyzing the drought events of the past, which would be calculated from satellite and climatic data. The different methods for assessment can be incorporated in SDSS-DM. An SDSS typically includes the following main components: (a) a database management system such as a GIS, (b) a set of potential analytical models and (c) a graphical user interface (GUI) which provides the user with a decision-making environment to interact with the computer. In addition, an SDSS will support the input of spatial data, the representation of spatial relations, the application of spatial and statistical analysis and a variety of outputs such as maps and reports.

Rationale:

Drought is considered a natural environmental hazard and has significant adverse impacts on agriculture and socioeconomic sector. Drought warning and characterization are important components of drought mitigation and risk management. Drought early warning comprises of both quantifying the impact and forecasting component. The early warning aims at providing accurate and timely information in advance or during the onset of drought to policy and decision makers, and managers to mitigate the impact of drought through contingency plans. The drought early warning and monitoring are dependent on single indicator (precipitation) for many decades. However, recent trends have shown the use of multiple, combined indicators for effective drought early warning. Ideally, an effective drought early-warning indicator must integrate precipitation and other climatic parameters and study its effect on the agricultural productivity, for a comprehensive assessment of current and future drought conditions. Drought is characterized on the other hand in terms of severity, location, duration and temporal variability. Several indicators/indices are used for drought characterization. The indices are derived from ground-based observations or model data and satellite based data.

Thus, aim is to understand the indicator affecting agriculture and factor which can be analysed to assess the drought situation over the study area. Drought monitoring based on drought indicators used for the analyzing the drought events of the past, which would be calculated from satellite and climatic data. To support the decision makers or planners and managers, a system that can generate different scenarios. The developed SDSS-DM would support the variety of Spatial and non-spatial dataset with the dynamic model to help decision makers in drought condition assessment and analysis in spatial and temporal scale.

Study Area:

Kachchh is a district of Gujarat state in western India. True and official spelling of Kachchh is Kachchh. This spelling is also correct to its pronunciation. Spelling Kutch was in use during British rule. Now official spelling is Kachchh. A large part of this district is covered with shallow wetland known as Rann of Kachchh. The Kachchh is famous for seasonal marshy wetlands surrounded by the Gulf of Kachchh and the Arabian Sea in south and west, while northern and eastern part are surrounded by the great and small Rann (seasonal wetland) of Kachchh. Kachchh district, is the largest district of Gujarat, the total area of the district is 45,652 sq. km, which is more than 23% of the total area of the state. The district is bounded on the north and northwest by the Sindh Province of Pakistan and on the northeast by Rajasthan state.

Administratively the Kachchh district is divided into ten Talukas, Bhuj is the districts headquarter. Nakhatrana and Lakhpat Taluka of Kuchchh district is selected for drought assessment and analysis based on various reports and literature review. Nakhatrana having a geographical extent 23.09 to 23.62 N, 68.93 to 69.62 E and population is around 14, 6367 spreads over an area of 19,8161 hectares (2011, Census). Nakhatrana is situated in the middle of Kachchh the tropic of cancer passing from Dhinodher hills, 20 km away from Nakhatrana town. Nakhatana is a town and a municipality in Kachchh district in the Indian state of Gujarat.

Lakhpat taluka having a geographical extent 23°.38'N to 23°.82'N, 68°.4'E to 69°.23'E, and population is around 62,552 and Area of Lakhpat taluka is around 2,18,864 hectares (2011, Census). Lakhpat is a city and a municipality in Kachchh district in the Indian state of Gujarat. Lakhpat is the taluka headquarter. There are 100 villages in Lakhpat taluk. The average literacy of Taluka is 49.76%. The main rivers of Taluka include Iron (Pitcher), Kharani (Punhro), Vaniyasar (Virani), Daman (Nog). Major Kharif crops are mung, millet, guava, sorghum, groundnut, and castor.

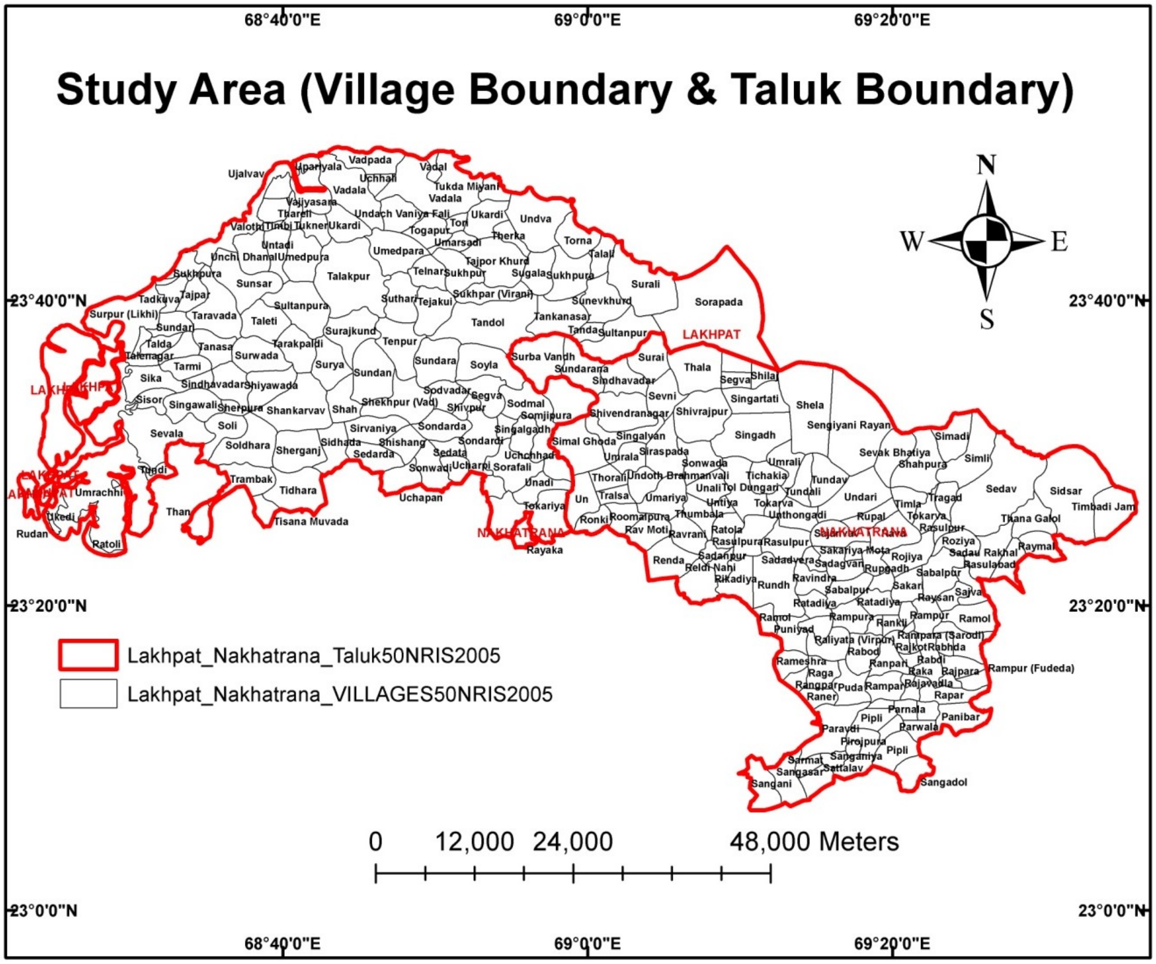

Figure 1: Study Area Map

Objective:

The present study has been designed to develop a Decision Support System for obtaining Drought information in the Lakhpat and Nakhatrana Taluk of Kachchh district, Gujarat, India.

1. To formulate and evaluate satellite-based indicators for drought characterization
2. To develop spatial models for drought Assessment and analysis.
3. To develop a geo-spatial technique to quantify seasonal drought assessment.
4. To develop a Spatial Decision Support System for Drought Management (SDSS-DM) to monitor crop growth, precipitation condition and temperature conditions in study area.

Dataset:

- **Remote Sensing Data:**

Various remotely sensed dataset has been used in the study to identify the drought classes and supporting dataset over the study area. The present study uses the ten years (2002-2016) Sixteen-day composite NDVI product (MOD13A1), daily rainfall (CHIRPS V2.0), MODIS 8-day LST (MODIS), and Sixteen day NDWI product (MODIS); these data were acquired for entire year from various websites. In-situ dataset from IMD has been used for validation and generation of climatology. A brief account of the various satellite products are given below

- **Vector Data:**

1. Vector dataset related to the political boundaries, Soil maps, Geomorphologic maps, Transport network, drainage networks and Land use maps etc. are archived from NNRMS portal (www.nnrms.gov.in).

- **In-Situ and Demographic Data:**

IMD New High Spatial Resolution (0.25X0.25 degree) Long Period (1901-2013) Daily Gridded Rainfall Data Set over India This data product is a very high spatial resolution daily gridded rainfall data (0.25 x 0.25 degree). The unit of rainfall is in millimetre (mm).

IMD High resolution 1-degree By 1-degree gridded daily temperature data (1969-2009) was archived from National Climatic Centre (NCC-IMD, Pune).

Demographic Information was archived from Census Book of India-2011.

Approach and Methodology:

The methodology dealt with following aspects to achieve defined objectives in the research thesis.

- **Phase-1:** This phase deals with the collection of the data from various sources, its geometric correction for the accuracy and validation. Phase-1 also includes the agro-meteorological indices generation, with the help of remotely sensed dataset. Development of various drought indices using vegetation and climatic parameters has been performed in phase-1.
- **Phase-2:** This phase deals with the design and development of the Spatial Decision Support System from drought Management. Where architecture of the dataset has been finalised in PostgreSQL, and Geoserver as web GIS server has been used for the data distribution over the internet. An interactive Web GIS portal has been developed using various programming platforms for the visualization and data distribution with GIS functionalities.

Outcome:

The study is aimed to quantify the drought characteristics and quantification. In order to analyse the drought situation over the study area, various layers of information has been processed and multiple outputs generated to achieve the desired aims. To ease the user interaction and to help the non-technical user to efficiently ingest data and generate appropriate outputs, the entire tool was packaged into an Information and management System. The developed system has a Graphical User Interface (GUI). The present GUI provides facilities to the user to conveniently select and visualise data for the required week/month/season (as the case may be) and display the generated outputs.

With the help of various Agri - meteorological indices year 2011 and 2015 experienced normal conditions whereas, the year 2012, 2013, 2014, and 2016 experienced normal to severe drought conditions. In addition to the utility of ISDI for seasonal agricultural drought characterization, it can be used to quantify in advance the impact of drought on reduction the agricultural yield. Some more years' data and some station validation need to be incorporated to arrive at a more accurate model.

The developed ISDI model-generated results illustrates the year 2015 and year 2016 experienced moderate to severe drought condition over the majority of the villages in the study area.

The approach, conceptualized and implemented in the present study, could be a step forward for the existing conventional approaches in providing a new pathway that is feasible and can be operationally implementable with current and future satellite data for growth stage-wise, and seasonal agricultural drought assessment in the study area or district level for disaster management planning.

Thesis organization

The study has been organized into seven chapters. All chapters highlight relevant literature.

- **Chapter 1: Introduction**

The first chapter is an overview of the research work undertaken. It deals with the introduction to the subject, rationale and relevance of research topic in present context and study area, research objectives, over view of data base and methodology.

- **Chapter 2: Literature Review**

Chapter-2 illustrates an overview of remote sensing and Geospatial technologies applications in the field of Drought management and analysis with related research by international and national research community. This chapter also discussed about the application domains or disciplines in which SDSS have been most commonly applied. In addition, detailed case studies were provided from a variety of disciplines, which highlighted important application domains, technological approaches, modelling techniques, software integration methods, and the role of stakeholders.

- **Chapter 3: Physical and socio-economic characterisation**

In the third Chapter the brief characteristics of physical and socio-economic setup of the study area is outlined. Chapter describes about the geomorphology of the study area, drainage network, rail network, road network, land use and soil type etc. along with demographic information.

- **Chapter 4: Data Used and Methodology**

Chapter 4 provides detailed information about spatial data used in this study and methodologies adopted for the research work. The chapter includes the methodology to develop various indices for drought assessment using various agricultural and meteorological parameters. It includes the methodology for Vegetation Condition Index (VCI) generation, Standardised Precipitation Index (SPI) generation, Precipitation Condition Index (PCI) generation and finally development of Integrated Spatial Drought Index (ISDI). Finally, a seasonal agricultural drought index is developed for the seasonal agricultural drought monitoring.

- **Chapter 5: Development of SDSS-DM**

Chapter 5 discusses about tools and technology adopted for development SDSS-DM and methodology used in the system development. Detailed discussion about the database design, programming approach, and Web-GIS server architecture has been covered in this chapter. The Graphical interface with integrated dataset pertaining to the Drought indices, vegetation indices, study area, and other physical parameters are described in this chapter.

- **Chapter 6: Results and Discussion**

Chapter 6 discussed about the results obtained and discussions during research work. Detailed analysis of the various vegetation indices, Meteorological indices, and Integrated Spatial Drought Index (ISDI) has been discussed in this chapter. The spatial and temporal variation of the drought classes over the study area based on various indices has been illustrated in the chapter-6

- **Chapter 7: Summary and Conclusion**

Summary of the research has been concluded in the chapter-7. This chapter describes findings based on the spatial and temporal variation of the drought classes derived from various Agri - meteorological indices, where year 2011 and 2015 experienced normal conditions whereas, the year 2012, 2013, 2014, and 2016 experienced normal to severe drought conditions. In addition to the utility of ISDI for seasonal agricultural drought characterization, it can be used to quantify in advance the impact of drought on reduction the agricultural yield. Some more years' data and some station validation need to be incorporated to arrive at a more accurate model.

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Through proper channel

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