Chapter: I

1. Introduction

1.1 An overview of Drought

Dry season is a natural disaster that varies from different hazards like Flood, avalanches, tornadoes and so on, since dry spell has a moderate beginning, develops over months or even years, influences a huge spatial extent, and cause minimal structural damage.

Its onset, end and severity are often difficult to determine (NDMA, 2010). 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.

As per Indian Meteorological Department (IMD), dry season is a circumstance when the aggregate precipitation is under 25 percent of its normal condition. India faced several drought years in last six decades. It is also a matter of concern related to changing climate with increased drought frequency as well as intensity. In India livelihoods of the more than 75% of the population are directly or indirectly dependent on agriculture sectors.

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 is a complex phenomenon with varying spatial extent and severity depending on the seasonal precipitation. It is one of the most recurrent and damaging natural hazards menacing the economic, social and political dimensions of our society (Chen et al., 2012; Riebsame et al., 1991; Wilhite, 2005; and Woodhouse and Overpeck, 1998). In other terms drought is a multi-causal and complex environmental issue which can have serious societal and economic consequences (Shamsipour et al., 2011). In recent years, many regions, including Asia, North America, Europe, and other continents, have suffered from environmental disasters caused by drought (Mishra and Singh 2010). In the last few decades, amongst all the natural hazards, droughts have had the greatest impacts (Bruce, 1994) affecting large areas and population on

different continents around the globe (Obasi, 1994; Hewitt, 2014; Wilhite, 2000). In the recent years, the overstress on regular assets, dreadful conditions of soil, decline in water assets and future extended environmental change situations have become significant zones of research (Kogan 2000).

Right quantification of drought impacts and monitoring efforts are the need of time for formulating preventive and mitigation plans. The impact of drought frequency, severity and persistence on the economy is increasing in the world (Wilhite et al., 2014). The varied characteristics and impacts of drought across different regions of the world make it difficult to monitor as compared to other natural hazards (Wilhite, 2000). Moreover, due to its complex nature, it is very difficult to understand comprehensive phenomenon as its dependency on moisture depletion from upper soil layer, evapotranspiration, and other climatic and atmospheric parameters etc. (Bravar and Kavvas, 1991). It always starts with the shortfall of precipitation, but may affect soil moisture, ground water, ecosystem and human beings. Therefore, it is critical to understand drought climatology and to establish a comprehensive and integrated drought information system that incorporates climate, soil and water supply factors (Wilhite 2000).

Agriculture sector is the foremost affected sector due to the drought. The recurring drought trend over the past few decades have attracted the attention of research communities other than agricultural scientists, including civil engineers, hydrologists, environmentalists, ecologists, meteorologists, geologists, economists, policy makers and managers. The ever-increasing needs of the growing population have put forward the threat of food security. With increasing vulnerability towards the changing climatic conditions and water demands together have raised the concern of worst drought conditions over the specific regions. Drought assessment and impact studies on different sector of the society are the need of the future. The impact of drought is non-structural and highly variable over space and time, making it difficult to monitor over large areas using conventional approaches. Generally, many drought indicators are used to monitor and assess drought, which vary depending on the region and season. Thus, there is a need to characterize large-area drought and its impacts periodically combining atmospheric, biophysical and water indicators.

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.

1.2 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 (Kogan, 1997). It is not usually a state wide phenomenon, with differing conditions in the state often making drought a regional issue. 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. A portion of the regularly acknowledged and utilized dry season definitions are: (i) The UN Convention to Combat Drought and Desertification (General, 1994) characterizes dry season as the normally happening wonder that exists when precipitation has been fundamentally underneath ordinary recorded levels, causing genuine hydrological uneven characters that antagonistically influence arrive asset creation frameworks; (ii) The World Meteorological Organization (WMO,1986) characterizes dry season as a managed, expanded insufficiency in precipitation; (iii) The Food and Agriculture Organization (Unger, 1984) of the United Nations characterizes a dry spell risk as the level of years when crops come up short from the absence of moisture; (iv) The reference book of atmosphere and climate (Schneider et al., 1996) characterizes a dry season as a broadened period a season, a year, or quite a long while of inadequate precipitation with respect to the factual multi-year mean for a spatial location; (v)

Palmer (1968) portrayed a dry spell as a huge deviation from the typical hydrologic states of a region. (vi) Tucker and Chaudhury (1987) characterizes "dry season" as a time of lessened plant development in connection to the authentic normal caused by decreased precipitation.

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 (NASA Earth Observatory). 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. If dry weather persists and water scarcity increases, the dry period is called as drought (Karunakaren, 2008) Drought is classified in a number of ways. A permanent drought is characterized by extremely dry climate when natural vegetation and crop growth are only possible through irrigation. An seasonal drought requires the synchronization of planting dates and cropping period with monsoon season and available soil moisture required for crop growth. While a contingent drought is of irregular occurrence, the invisible drought occurs even when there is frequent rainfall (Thornthwaite, 1948).

1.3 Types of Drought

Four major types of droughts are broadly defined and agreed upon in the scientific literature (WMO, 1975; Wilhite and Glantz, 1985; White and O'Meagher, 1995; McVicar and Jupp, 1998). According to the review of different literatures, four basic approaches to agreement with estimating drought conditions: 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 evapotranspiration. 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 (WMO, 2006).

As indicated by the Indian Meteorological Department (IMD), meteorological drought happens when the monsoon seasonal precipitation is fewer than 75% of its normal condition from long term mean. On the off chance that precipitation deficiency is between 26 to 50 percent is delegated 'moderate' drought condition. It is named 'extreme' if the deficiency surpasses 50 percent of long term normal. An all-India dry spell year is pronounced by IMD when the precipitation insufficiency for the south-west monsoon period of June to September surpasses 10% of its long term mean condition (IMD, 2012).

B. Agricultural Drought:

Agriculture is normally the principal monetary area to be influenced by agricultural drought. It occurs when there isn't sufficient soil moisture to address the need of a particular crop showing at a specific time and stage. Agricultural dry spell occurs after meteorological dry season however before hydrological dry season (College of Florida, 1998). In other term, agricultural drought happens when there is deficient soil wetness to address the issues of a specific crop growth. Deficiency of rainfall over India during crop growing stages can affect crops or lead to vulnerable crop conditions. Agricultural drought arises from wide variation in susceptibility of crops to soil moisture deficit during different stages of crop development in its growth cycle (Karunakaren, 2008). In India, Monsoon season considered from June to mid of October, the season is likewise called as South-West storm season where 90% precipitation happened in the season. Agrarian dry spell is gotten from serious meteorological dry season with a precipitation inadequacy of half from the drawn out normal at the duration of crop growing (Nagarajan, 2010).

C. Hydrological Drought:

Hydrological drought alludes to inadequacies in surface and subsurface water supplies. There is a delay between rainfall and less water in streams, waterways, and lakes, thus hydrological estimations are not the soonest pointers of drought. Hydrological dry season is related with the impacts of times of precipitation (counting snowfall) setbacks on surface or subsurface water elegantly (i.e., stream flow, reservoirs and lake levels, groundwater). In different terms, hydrological drought results from delayed meteorological dry spell bringing about depletion of surface and sub-surface water assets. The recurrence and seriousness of hydrological drought is frequently characterized on a watershed or stream scale. It is additionally

discovered that topography is one of the principle factors impacting hydrological dry seasons (Zecharias and Brutsaert, 1988; Vogel and Kroll, 1992).

D. Socio-economic Drought:

Socio-economic drought happens when actual water deficiencies begin to influence the wellbeing, prosperity, and quality of life of the individuals, or when the dry season begins to influence the market interest of a monetary item. Socio-economic drought, which is an extraordinary type of agricultural drought, addresses the damage brought about by all the previously mentioned types of drought (Majid Vazifedoust, 2007). Socio-economic drought varies from the other three as it reacts the connection between the market interest for some item and monetary merchandise, for example, food grains, water and animals scrounge and so on (Du et al., 2013). The economic effect of drought is difficult to measure and is commonly underestimated.

1.4 Impacts of Drought

Drought produces wide-ranging impacts that span many sectors of the national economy. These impacts are felt much beyond the area experiencing physical drought. The complexity of these impacts arises, since water is basic to our capacity to deliver products and give administrations. Drought produces both direct and indirect impacts. Direct effects or essential effects are generally physical/material and incorporate decreased food production, expanded fire danger, drained water levels, higher animals and untamed life death rates, and harm to natural life etc. When direct impacts have multiplier effects through the economy and society, they are referred to as indirect impacts. These include a reduction in agricultural production that may result in reduced income for formers and agribusiness, increased prices for food and timber, unemployment, reduced purchasing capacity and demand for consumption, default on agricultural loans, rural unrest, and reduction in agricultural employment leading to migration and drought relief programs.

A. Economic Impacts:

Many economic Impacts occur in agriculture and related sectors, including forestry and fisheries, because of the reliance of these sectors on surface and subsurface water supplies. In addition to obvious losses in yields in crop and livestock production, drought is associated with increases in insect, infestations, plant disease, and soil erosion reducing the soil fertility.

Drought also bring increased problem with insects and diseases to forest and reduced growth. The incidence of forest and range fires increase substantially during extended droughts, which in turn places both human and wildlife populations at higher levels of risk.

B. Environmental Impacts:

Drought impacts on environment results as degradation of water quality, severity of air quality, forest fires, and loss of biodiversity etc. Some of the effects are short term and conditions quickly return to normal following the end of the drought. Other environmental effects linger for longer time or many even become permanent. Wildlife habitat may be degraded through the loss of wetlands, lakes, and vegetation. Species migration will increases affecting the carrying capacity and niche conflicts will increase. However, many species will eventually recover from this temporary irregularity. Although environmental losses are difficult to quantify, growing public awareness and concern for environmental quality has forced public officials to focus greater attention and resources on these affects.

C. Social Impacts:

Social impacts involve public safety, health, conflicts between water users, reduced quality of life, and inequities in the distribution of impacts and disaster relief. Many of the impacts identified as economic and environmental have social components as well. Population migration is a significant problem in many countries, often stimulated by a greater supply of food and water elsewhere. Migration is usually to urban areas within the stressed area, or to regions outside the drought area. Migration may even be to adjacent countries. When the drought has abated, the migrants seldom return home, depriving rural areas of valuable human resources. The drought migrants place increasing pressure on the social infrastructure of the urban areas, leading to increased poverty and social unrest.

1.5 Drought Warning and Characterization

Drought warning and characterization are important components of drought mitigation and risk management (Wilhite and Glantz, 1985). 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 (Svoboda et al., 2002). Drought is characterized on the other hand in terms of severity, location, duration and temporal variability. Several indicators/indices are used for drought characterization. These indices are numeric values that help to define the duration, intensity and spatial extent for each drought episode (Tsakiris et al., 2007). The indices are derived from ground-based observations or model data and satellite based data. The severity is determined by the magnitude of the variable used to characterize drought conditions. The spatial and temporal characterization of drought determines spatial coverage of drought over a region for specified time scale.

1.6 Study Area

The Study area of the research is Nakhatrana and Lakhpat Taluk of Kachchh. Kachchh is a district of Gujarat state in western India.. Am major part of the Kachchh is coverd by the 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 (http://www.diet-kutch.org/). 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. There are several small ports all along the coast, which are mainly used as fishing ports. Kandla and Mundra are the two-important port in the district and support the industrial and commercial activities in the state. Figure 1.1 illustrates the complete geographical location of study area.

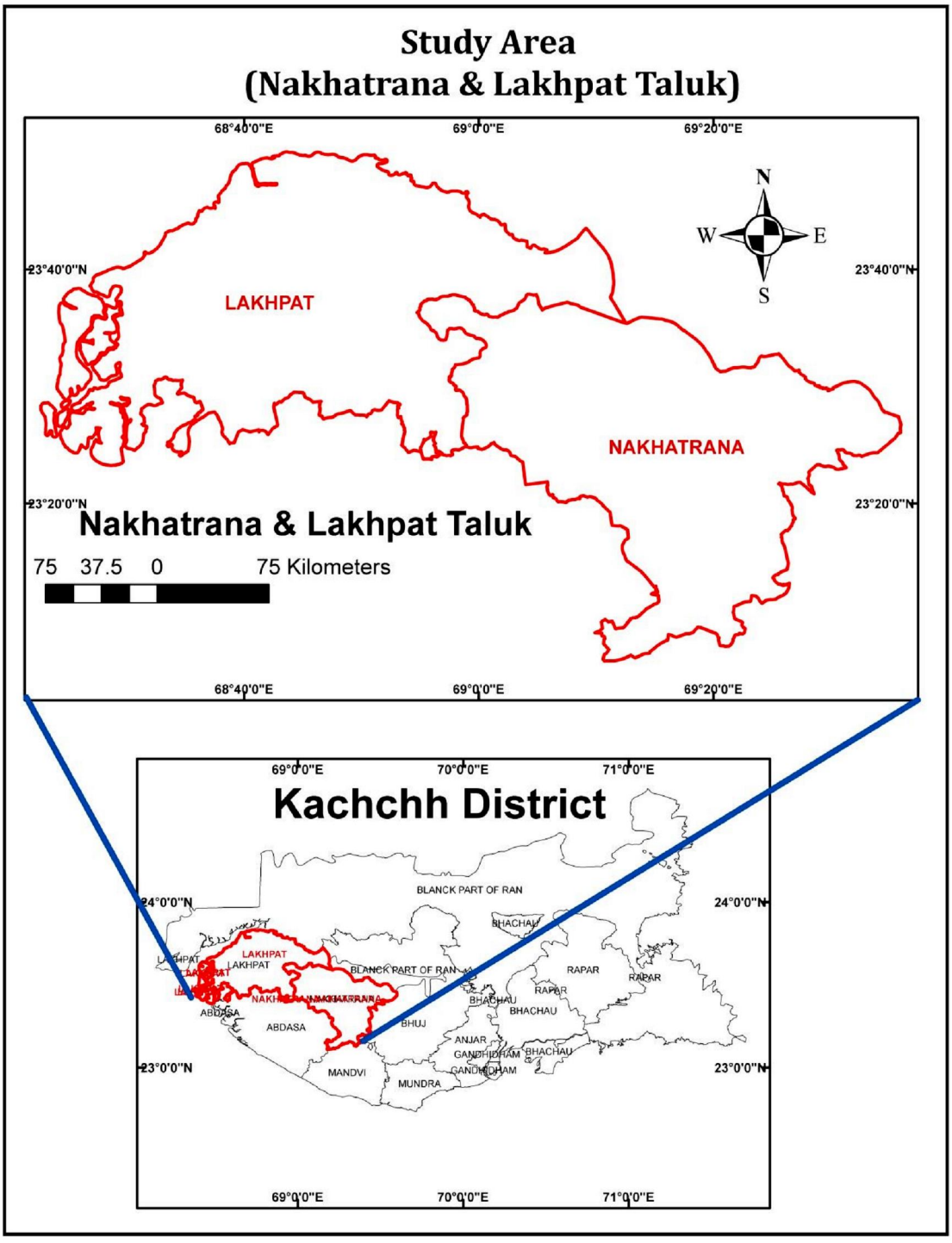

Figure 1.1 Study Area

1.7 Development of a Spatial Decision Support System for Drought Management:

Decision Support System is a management tool for non-expert users that started in the 1980s (Abbot et al. 1991; Boboşatu, 2008). There has been a growing interest in integrating GIS for

various applications, such as for water movement within the drainage basin, surface water pollution control and groundwater contamination, Clinical Decision Support System, Soil Erosion, Geospatial Decision Support for Drought Risk management, (Abbot and Refsgaard 1996; Jamieson and Fedra 1996; Olsson and Pilesjo 2002; Moore and Loper 2011; Dragan et al 2003, Goddard et al. 2003) and building decision-support systems (DSS) for analysis and assessment. Following the recent trend of modelling effort, the DSS to be constructed here is intended to be a decision-support system for the management of drought for expert and non-expert users. Thus, Spatial Decision Support System (SDSS) is to support the decision maker that is a prescribed system which can generate different scenarios is usually required for planners and managers. The DSSs were traditionally developed for single users, which involve data management, model management, and the user interface component to reside on the same machine. This requires platform specific development, a costly, and a non-extensible alternative. Now rapid growth of the internet technology over the past decade has opened up new methods to supply and share data, models, tools and other information to potential users (Wallace et al., 2001). According to Black and Stockton (2009), a generic Decision Support System architecture must include a knowledge base, analysis tools, and inference engine. In the advancement of technologies, the spatial decision support systems are developed for various applications as Crop Growth Monitoring and Food Security Strategies (Wang, and Chen, 2010). The application of decision support System (DSS) in the fields of agriculture provides a new and efficient method for improving the management of regional food production mode and decision-making on the management of food security (Cao Weixing, et al. 2007). A DSS is developed for accessibility analysis using open source technologies which shows the strength and application of the web- GIS (Burdziej, J., 2011). The space technologies such as RS and GIS are now increasingly influential tools, to develop decision support system for monitoring and analysis of drought.

For long term drought mitigation plans involves two major requirements: (i) to have an accurate drought risk assessment giving the degree of hazard or vulnerability in the geographical area. (ii) Real-time information regarding the drought condition and ability to forecast the situation variation. Due to the diffuse spatial and temporal variation of drought vulnerability it is very complex to drought management. The geospatial technology enables us to incorporate several databases (historical and real-time) to analyze, querying and updating with geographical area. Analysis of drought is a multi-scalar and multi-factor so, to

develop a methodology to integrate all modules for different drought types in a single system is a critical task. Thus, it is necessary to develop a quantitative evaluation tool which can analyses the situation on a given scale for drought assessment; equips the decision makers and administrators to timely predict and monitor the 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 used to simulate future scenarios 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 should 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.

1.8 Research problem identification

1. Identification of indicators useful for characterization of drought throughout crop season?

2. Is there a need of different drought indicators at different stages of agricultural drought?

3. How can a comprehensive system of real-time monitoring and management of drought be developed for the study area using satellite remote sensing data and GIS technology?

4. How spatial technologies and a decision support system do help policy makers in decision making processes?

5. What is the substantial gain we can envisage in terms of newer concept, indicators, Drought index and development of a Spatial Decision Support System for Drought Management (SDSS-DM)

1.9 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 and validate spatial models for drought Assessment.
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.

1.10 Scope of Study

A better knowledge of agricultural drought and drought indices is needed to characterize them and to develop drought indices to analyse agricultural drought that may be useful to reduce the effect of the drought in study area. Soon, data available from earth observation satellites will play a major role in the assessment and monitoring of drought with spatial consistency in observations at Taluka scale. Remote sensing data can provide multi-disciplinary set of input indicators that constantly monitor the various environmental components potentially affected by drought (soil, vegetation etc.) in order to obtain comprehensive and updated picture of the agricultural situation. The present study has been undertaken to develop methodologies and demonstrate them for early warning and characterization of agricultural drought using agricultural, meteorological and hydrological parameters, derived from earth observation satellite data and to develop an application of SDSS-DM, for planning especially as it relates to agricultural drought as more flexible, dynamic and responsive for timely decision forming on geographic space.

1.11 Framework of the Thesis:

The thesis is composed of 7 chapters starting with the introduction of drought and especially agricultural drought with reference to Lakhpat and Nakhtrana taluk of kachchh, Gujarat, based on the available information. The Chapter 2 provides a detailed review of the previous work done in the field of drought especially using remote sensing and GIS techniques and existing SDSS. Chapter 3 presents Physical and social characteristics of the study area. This

chapter provides detailed information on Kachchh districts. 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 discusses about tools and technology adopted for development SDSS-DM and methodology used in the system development. Chapter 6 discussed about the results obtained and discussions during research work. Finally, Chapter 7 provides a summary of major findings and significant conclusions. The chapter also deals with the practical relevance of the study and the perspectives for further development.