CHAPTER 1

INTRODUCTION

1.1 GENERAL

Water, a scarce resource, is the elixir of life. It is a natural resource, fundamental to life, livelihood, food security and sustainable development. It plays a vital role in every activities of human life. Drinking water, food production, removal of wastages and toxic elements etc., are some of the examples which clearly make us to recognize the importance of water. Even though the hydrosphere of our Earth includes \( \frac{3}{4} \) of its surface, it is well known fact that only around two percent of the water is fresh. That meager amount of water is erratically distributed spatially and temporally on the surface of the Earth. Unless if the meteorological system is well understood by proper analysis with modern technological tools and effectively managed to address the water needs of people, one can always expect some form of hydrological extremes like drought, flood, etc.,

Having understood the precursors of water crisis, United Nations has declared the decade 2005-2015 as International Decade for Action ‘Water for Life’. Water scarcity already affects every continent. Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage, where countries lack the necessary infrastructure to take water from rivers and aquifers (Report of United Nations, 2005). Water crisis is a silent emergency and cautions that water demand in the world’s two most
populous countries, India and China, will exceed supplies in less than two decades (Report of Inter Action Council, 2012).

According to National Water Policy (2012), India has more than 17 percent of the world’s population, but has only 4% of world’s renewable water resources with 2.6% of world’s land area. There are further limits on utilizable quantities of water owing to uneven distribution over time and space. In addition, there are challenges of frequent floods and droughts in one or the other part of the country. With a growing population and rising needs of a fast developing nation as well as the given indications of the impact of climate change, availability of utilizable water will be under further strain in future with the possibility of deepening water conflicts among different user groups. Low consciousness about the scarcity of water and its life sustaining and economic value results in its mismanagement, wastage and inefficient use, as also pollution and reduction of flows below minimum ecological needs. In addition, there are inequities in distribution and lack of a unified perspective in planning, management and use of water resources.

As per present estimate, India receives an average annual precipitation of about 4000 Billion Cubic Meter (BCM), which is its basic water resource. Out of this, after considering the natural evaporation-transpiration, only about 1869 Billion Cubic Meter (BCM) is average annual natural flow through rivers and aquifers. Of this, only about 1123 BCM is utilizable through the present strategies, if large inter-basin transfers are not considered. Thus, the availability of water is limited but the demand of water is increasing rapidly due to growing population, rapid urbanization, rapid industrialization and economic development. Therefore, besides augmenting the availability of water for utilization to meet increasing demands, assessment of drought like situation should also be carried out scientifically to tackle any future contingencies.
1.2 NATURAL DISASTERS

Natural Disasters are adverse events and disasters occurring due to natural processes which affect the Earth. The examples include flood, drought, tornado, hurricane, volcanic eruption, earthquakes, landslide etc., which affect in many ways million of lives around the world every year. Flood and drought, the hydrological extremes, are the two of such many disasters which are frequent and sometimes simultaneous in India. So, the need of assessing, forecasting and mitigating the disasters have become imperative and Government of India has established National Disaster Management Authority in 2005 to respond to any natural disasters in India. Planning and mitigation for all the hydrological extremes involve a thorough and deep understanding of them, proper assessment of their severity, forecasting and pre & post management practices.

1.3 DROUGHTS

Drought is an insidious hazard of nature. There is no universally applicable and acceptable definition for drought as yet. Numerous attempts to define drought have led to several definitions of drought (Nagarajan, 2003). Although it has scores of definitions, it originates from a deficiency of precipitation over an extended period of time, usually a season or more, that results in shortage of water. The direct impacts of drought are easily recognizable. Reduced crop, rangeland and forest productivity, increased fire hazard, reduced water levels, increased livestock and wildlife mortality and damage to fish and wildlife habitat are just a few. What the general public often overlooks are the indirect economic and social impacts of drought. For those who depend on water and other natural resources for their livelihood, drought can mean the loss of income and jobs.
Throughout human existence, drought has been a threat to the survival of society. It has often been a trigger for massive human migrations, famines and wars, altering the course of history itself. Despite massive developmental activities, drought continues to affect the global community in countless ways. It is not possible to avoid droughts. But drought preparedness can be developed and drought impacts can be mitigated. The success of both depends, amongst the others, on how well the drought characteristics are quantified. Drought has many facets in any single region and it always starts with the lack of precipitation and may (or may not, depending on how long and severe it is) affect soil moisture, streams, groundwater, ecosystems and human beings. This leads to the identification of different types of droughts (meteorological, hydrological, agricultural, socioeconomic), which reflect the perspectives of different sectors on water shortages. Meteorological drought is defined as the deficiency in rainfall. Hydrological drought is referred to as the deficiency in surface and ground water. Agricultural drought means the deficiency of available water in meeting crop water requirements. Socioeconomic drought correlates the supply and demand of goods and services with the above mentioned types of droughts.

The problems due to drought are compounded by the fact that drought invariably is handled as a ‘crisis situation’ and a short-term problem. At the household level, individuals perceive drought as a natural hazard, beyond human control. Both lead to different kinds of approaches and solutions. They also lead to many undesirable consequences.

1.4 DROUGHT SCENARIO IN INDIAN CONTEXT

In India, drought is a frequent hazard striking in one part or the other. Its impacts are not only confined to arid and semiarid regions but often in potentially good rainfall areas too, which are otherwise productive (i.e. humid and sub-humid rainfed agricultural areas). One third of the
geographical area of the country i.e. 107 million hectares spread over 99 districts in 13 states, was affected by droughts. The drought-prone areas of the country are confined to peninsular and western India – primarily arid, semi-arid and sub-humid regions (Report of National Commission of Agriculture, 1976).

An analysis of 100 years of rainfall data reveals that the frequency of 'below-normal rainfall' in arid, semi-arid and sub-humid regions is 54-57%, while severe and rare droughts occurred once in every eight to nine years in arid and semi-arid zones. In these zones, rare droughts of severe intensity occurred once in 32 years, with almost every third year being a drought year (Report of Poorest Areas Civil Society Programme, 2004). Historical details of drought intensities in India are shown in Table 1.1.


**Table 1.1 Drought Intensity – A Historical Perspective**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Period</th>
<th>Drought years</th>
<th>No. of years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1801-25</td>
<td>1801,04,06,12,19,25</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>1826-50</td>
<td>1832,33,37</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>1851-75</td>
<td>1853,60,62,66,68,73</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>1876-1900</td>
<td>1877,91,99</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>1901-25</td>
<td>1901,04,05,07,11, 13,15,18,20,25</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>1926-50</td>
<td>1939,41</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>1951-75</td>
<td>1951,65,66,68, 72,74</td>
<td>6</td>
</tr>
</tbody>
</table>
The problems of drought prone regions of India vary temporally and spatially in magnitude. During the drought year 2002 in India, it was estimated that the average loss in rainfed rice production was around Rs.2000 crore. According to India Meteorological Department, the country is said to experience a drought year when the overall rainfall deficiency is more than 10% of the Long Period Average (LPA) and more than 20% of its area is affected by drought conditions. IMD has categorized the year 2002 as ‘the first-ever all-India severe drought year’ since 1987. The rainfall deficiency of this order has only occurred thrice before in the last century in 1917, 1972 and 1987 (Report of IMD, 2004) noted that the aggregate rainfall received by the country as a whole during the year’s monsoon season from June to September, at 735.9mm (19.35% below the historical LPA of 912.5mm for this period). Further, 29% of the area in the country recorded drought conditions, with rainfall deficiency (relative to LPA) exceeding 25%. Of the 29% area affected by drought conditions, 10% was under ‘severe drought’ and the remaining under ‘moderate drought’.

Discussing region wise, the area under ‘severe drought’ (rainfall deficiency of more than 50%) covered two out the country’s 36 meteorological sub-divisions – West Rajasthan (-71%) and East Rajasthan (-60%). The area under ‘moderate drought’ (rainfall deficiency of 26-50% relative to LPA) covered 10 sub-divisions – Haryana, Chandigarh and Delhi (-36%), Punjab (-36%), Coastal Andhra Pradesh (-26%), Rayalaseema (-33%), North Interior Karnataka (-31%), South Interior Karnataka (-44%), Coastal Karnataka (-30%), Tamil Nadu (-45%), Kerala (-35%) and Lakshadweep (-45%). Besides, there were 9 other sub-divisions where rainfall deficiency exceeded 20% of the respective LPA. These included the Gujarat region (-24%), Saurashtra & Kutch (-25%), Telangana (-23%), East Uttar Pradesh (-24%), West Uttar Pradesh (-21%), West Madhya Pradesh (-22%),
Himachal Pradesh (-20%), Arunachal Pradesh (-22%) and Andaman & Nicobar (-24%).

Rainfall was ‘normal’ (deficiency below 20%) only in the remaining 15 sub-divisions. In terms of magnitude, year 2002 ranks fifth amongst the severest droughts India has faced in its meteorological history since 1875. IMD said that the situation was mainly caused by the dry spell in July with the rainfall deficiency of 49% during the month being ‘the worst in the history of recorded observations’. Only on two previous occasions in the past (1911 and 1918) did rainfall deficiency exceed 45% in July.

The traditional approach to drought as a phenomenon of arid and semi-arid areas is changing in India too. Now, even regions with high rainfall, often face severe water scarcities. Cherrapunji in Meghalaya, one of the world’s highest rainfall areas, with over 11,000 mm of rainfall, now faces drought for almost nine months of the year. On the other hand, the western part of Jaisalmer district of Rajasthan, one of the driest parts of the country, is recording around 9 cm of rainfall in a year. Total rainfall increases generally eastwards and with height. Increase in precipitation is high at an elevation of around 1,500 meters in the Himalaya Mountains. With average annual rainfall ranging between 20 cm to over 1000 cm, the primary challenge is to store this precious water for the dry season that may follow. The droughts in Odisha State, which has an average rainfall of 1100 mm, remain a matter for continuing concern. Conditions of water scarcity in the Himalayan region are also not uncommon.

1.5 SIGNIFICANCE OF THE PRESENT STUDY

Drought is a naturally recurring feature of climate which occurs in all climatic zones. The characteristics of drought vary significantly from region to region, and it is different from aridity, which is a permanent feature
of climate and is restricted to low rainfall regions. The term drought refers to a constant reduction of water availability with respect to normal (mean) values. This reduction affects a wide region, and spans a significant period of time. There is no universal and all-compassing definition of drought, as it cannot be viewed as a purely physical phenomenon, but must also be considered in relation to its impacts on society. Each type of drought has specific characteristics and affects different aspects of society. Drought causes huge losses in agriculture, damages natural ecosystems and forestry. It leads to degradation of soils, desertification, social alarm, famine and impoverishment. India also has the history of some severe droughts in the last 200 years.

Drought is just not the scarcity or lack of rainfall, but an issue related to water resource management. The requirement of over 80-90% of the drinking water and over 50% for irrigation is met from groundwater in India. The control of this resource is with the owner of land. Without effective and large scale rainwater harvesting, only limited recharge can take place. An earlier analysis of incidence of droughts over the last two centuries in India does not show any increase in the frequency of drought in the recent years. However, the severity appears to have increased. In the context of increasing awareness about disaster preparedness to handle any future contingencies related to droughts, the country needs a systematic drought mitigation plan, which requires identification of areal distributions of drought affected/prone areas.

Government of India has started a programme called ‘Drought Prone Areas Program (DPAP)’ to address problems of frequent droughts in India. Areas which are affected by droughts are being included to DPAP program based on the report provided by revenue officials, which usually do not include a local level comprehensive scientific assessment. Till now, the
inclusion of the end users of water (farmers) in preparing drought mitigation plan has never been given a thought which means that all stakeholders are not part of fighting against droughts. Those water users are main elements of experiencing the droughts. The present study explores the possibilities of bringing the water users to the mainstream of combating the droughts and preparing the mitigation plan along with policy makers.

Identification of parameters affecting drought is very crucial since the phenomenon of drought itself is not fully understood. The difficulty involved in understanding the drought phenomenon is the identification of the right parameters that initiate drought. The parameters triggering drought condition in a region are primarily its climatic, geological, topographical and geographical variations. In addition, it is accelerated with the human intervention with nature. Comprehensive drought severity assessment approaches are proposed by the present study using Conventional Demand-Supply method and Remote Sensing technology. Drought mitigation measures are proposed to be suggested by the study that can be implemented through existing Water Users Associations (WUAs) for the benefit of people who suffer from the droughts.

1.5.1 Water Users Association (WUA)

It is an element of Participatory approach towards the management of irrigation system. Traditionally, the irrigation systems are functioning below the designed potential due to various factors. One among the factors is ignoring the inclusion of the farmers (Water Users) into the operation of irrigation systems. Many governments across the world realized the importance of inclusion of farmers in management of irrigation systems and encouraged the formation of water user associations by framing legislation. The main idea behind forming WUA is to cut down operational expenditure and to ensure equitable distribution of water. Also, WUAs are empowered to
mobilize resources needed to the operation, maintenance and improvement of the irrigation systems. Any violation of the rules framed by WUA by its members is looked into it and fines are charged on them. Philippines is one of the best examples for running WUA successfully to effectively maintain and manage irrigation systems. This can be used as a platform to resolve conflict among farmers in field level.

Distribution of quality fertilizers, seeds and pesticides, adoption of better agricultural practices and usage of modern technology are some advantages of existence of WUAs. Indirectly, yields of crops can be improved. It is proposed to explore the possibilities of extending the functioning of WUAs in drought mitigation programs during the rainfall deficit years.

1.5.2 Remote Sensing and GIS

Remote sensing techniques make use of electromagnetic radiation in the visible, infrared and microwave regions to collect measurements of reflectance of plants, soils, water and other materials. The Earth Observation satellites which include both geostationary and polar orbiting satellites provide comprehensive, synoptic and multi temporal coverage of large areas in real time and at frequent intervals and ‘thus’ - have become valuable for continuous monitoring of atmospheric as well as surface parameters related to droughts (Jayaseelan 2002).

The visible and near infrared bands on the satellite multispectral sensors allow monitoring of the greenness or vigor of vegetation (Deekshatulu, 1998). Agriculture is highly dynamic in nature because of the changing phenomenon of crops, which is further complicated by the interaction of the crops with the environment. Continuous monitoring of the agriculture is necessary for taking up necessary actions of developmental activities. The earth observation satellites provide comprehensive, synoptic
and multi temporal coverage of large areas in real time and at frequent intervals. They can be used to detect the early stages of drought events as anomalies in a time series. Through high resolution Remote sensing images, the crop related data can be collected faster and accurately, compared to conventional field based methods. It may become easier to carry out drought preparedness operations efficiently through reliable drought mapping due to scientific advances in remote sensing.

Geographic Information System (GIS), is a software tool for managing large quantum of spatial data where the spatial data base management is very much required. These systems are designed to bring together spatial data from diverse sources into a unified database employing a variety of digital data structures and representing spatially varying phenomena as a series of data layers all of which are in a spatial register (Common Coordinate System). Drought severity assessment involves processing a voluminous spatial data which if processed manually is costly and time consuming. GIS provides complex analysis between different layers has become possible and hence used in this study to create the database for data analysis, mapping and for creating drought severity maps.

Advancements in the remote sensing technology and the Geographic Information Systems help in real time monitoring, early warning and quick damage assessment of drought.

1.6 OBJECTIVES

Drought can be assessed in meteorological, hydrological and agricultural aspects. Of these, rainfed agriculture is controlled by meteorological drought and the other cropped areas by agricultural drought. Comprehensive scientific analysis and usage of advanced technologies like Remote Sensing and GIS have not been effectively exploited in making drought mitigation plans. This makes India to lag behind other developed
countries in proper management of irrigation systems to avert any drought kind of situation. The present study aims to assess agricultural drought and prepare a plan to mitigate droughts. The specific objectives of the study are:

(i) to determine the agricultural drought severity of a command area using conventional demand-supply gap;
(ii) to assess the remote sensing based agricultural drought severity of the command area; and
(iii) to analyse the drought vulnerability of irrigated agriculture in GIS environment.

1.7 SCOPE OF THE STUDY

India is the seventh largest country in the world. Its population exceeds 1.2 billion according to the provisional census conducted in 2011. The rate in which our population increases is far more that the rate at which the water resources potential increases. This is a worrying fact among the policy makers. Even the available water resources are not managed to fulfill the domestic water needs of our people. So, the need has arisen to effectively manage the existing water resources and augment them further extent.

DPAP (Drought Prone Area Program) considers four parameters to assess the agricultural droughts in our country. The parameters may not address the non-uniformity present water resources distribution in an irrigation system. An attempt has been made in this study to understand drought severity distribution by Demand-Supply Gap analysis and satellite images using Remote Sensing Technique.

Pennar delta, located in Nellore district in southern part of Andhra Pradesh, has been considered for the present study. The study area is not included in DPAP program as there were no frequent meteorological droughts.
in its history. But, prevalence of agricultural drought has to be studied as farmers suffer frequently due to failure of crops in different parts of the delta.

1.8 ORGANIZATION OF THE THESIS

This thesis has been organized and presented in seven chapters. A brief description of the problem, objectives and scope of the study are presented in this Chapter. Chapter 2 discusses the drought literature in respect of drought definitions and drought assessment methodologies. Chapter 3 describes the study area and data collection from Nellore district in Andhra Pradesh State in India. A preliminary rainfall analysis of hydrologic data is included in the same chapter. Chapter 4 elaborates about the methodology, results and discussions in respect of determination of agricultural drought using conventional demand-supply gap analysis. Chapter 5 deals with the methodology, results and discussions in respect of assessment of remote sensing based agricultural drought severity. The results of drought analysis by conventional and Remote Sensing methods are compared with implementation of Drought Prone areas programme and final vulnerability map of the study area are prepared and presented in Chapter 6. Chapter 7 provides the summary and conclusions of the study.