Application of Water balance technique in the Drought analysis of Guntur District, Andhra Pradesh

Dr.N.Chandrayudu
Assistant Professor, Department of Geography, S. V. University, Thirupathi (India)
Email: ncrayudu@yahoo.com

G S Srinivasa Gopinath
Assistant Professor, VLITS, Dept.of BS& H, Vadlamudi 522213 India
Email: gopinathgarre@gmail.com

Abstract

Water balance is one of the important techniques used in the studies of climatology, hydrology and agro climatology. It is helpful in the evaluation of various hydrological elements like water storage, water surplus and water deficit, which in turn provide quantitative solutions to many hydrological questions, in a given region (Hemamalini, 1993). Drought is weather related hazard and cannot be visualized like any other weather hazard. Moreover, accurate prediction is also not possible. However, water balance technique enables to carry out drought analysis. It is a perfect tool to identify the years of drought, their frequencies, and intensities. To understand the vulnerability of each mandal of the district to droughts, drought analysis has been carried out. Index of aridity (i.e. the ratio between water deficit and water need of the area) is the key parameter used to identify the drought incidences. The analysis shows that all the representative stations of the district are prone to droughts. From the study, it is inferred that Guntur district has been prone to droughts/famines from time immemorial. The incidence of droughts is on the increase which was indicated through the analysis of decennial frequency. The overall drought proneness in all the mandals was above 40 percent. The Incidence of moderate droughts was high followed by severe and very severe and disaster type of droughts.

Keywords*: Disaster, Water balance, Environment, Physiographic conditions, Evapotranspiration, Crop-weather calendar, Drought- resistant crops.*

Introduction:

The term disaster is a French word ‘disastr’, ‘des’ means ‘bad’ and ‘astre’ means a ‘star’. It is a catastrophic situation in which normal conditions are disrupted and dislocated. Agriculture activity, to a large extent, depends on weather conditions and is vulnerable to various weather disasters during their growth period. Among all the weather hazards, drought is the single most significant weather-related natural disaster which occurs due to water scarcity conditions that have periodically been affecting one or other parts of the world.

Unlike other natural disasters, drought is different weather hazard. Its spatial extent is comparatively larger and difficult to identify the hazard in the initial stages as well as dissipating stage. Drought impacts social, economic and environmental factors. People from the drought-affected areas migrate in search of work which disturbs the normal life pattern. The Economic impact is mostly on agricultural and related sectors. While, drought is responsible for the decline in water resources, which lead to water scarcity conditions to the living beings and the environment. Further, drought also degrades the environment by salinization of soils, the decline in ground water, and increased pollution of freshwater ecosystems and the extinction of animal species (Mall et al., 2011). It is a complex phenomenon that may occur frequently in any area. It may occur in high as well as low rainfall areas. It also occurs in plains as well as in hilly areas. It is a condition of exceptionally dry weather which imbalance the hydrological conditions and causes crop loss and water shortages to people and livestock in a particular area (Alexander, 1993).

The perception of drought differs from the type of scientists to the other. According to Subrahmanyam (1980), drought is a comparatively shorter period of transient nature without adequate water supply mainly from precipitation.

Objectives: The following are the objectives for the present study:

1. To study is to study the drought conditions by their type, frequency, and severity.
2. To demarcate the drought-prone areas of the district.

Hypothesis:

1. The study area is under the domination of dry climate, and most vulnerable to drought conditions.
2. Water balance technique useful to analyze drought proneness.

Data sources:

For the present study two atmospheric elements viz., mean monthly air temperature and mean monthly rainfall are needed to do water balance. Thus, the data of twenty representative Mandals of the Guntur district were collected/gathered from the records of India Meteorological Department for a period of 30 years that is from 1986-2016.

Methodology:

Drought is an acute hydrological event that causes great economic and environmental damage. Numerous methods are used for the identification and quantification of drought. A clear understanding and better appreciation of the problem of droughts and aridity became possible after the subject of water balance analysis has been developed by Thornthwaite (1948) and Thornthwaite and Mather (1955), which is not only empirical but also analytical and realistic as it developed based on the rational concepts (Subrahmanyam and Sastry, 1968). The fundamental parameter of water balance that is used for drought analysis is water deficit which represents the amount by which rainfall fails to meet the demands of evapotranspiration after fulfilling the irrigation requirements of the area. Based on water deficit, technic namely Aridity Index (IA), i.e., the percentage ratio of water deficit to water

need is are used in this analysis. The graphical representation of the annual departure of aridity index at a station from the median against the successive years will enable to identify the drought years by their intensities. Subrahmanyam and Subramaniam (1965) have categorized the droughts according to their intensities by using standard deviation (σ) technique. For the present a paper the droughts occurred during the period 1986-2017 were analyzed using water balance procedures of Thornthwaite (1955).

Study Area:

Guntur district is located in central Andhra Pradesh, India, on the east coast of Bay of Bengal. It has a coastline of about 100 kilometers. The district is located between $15^0 18'$-$16^0 50'$ N latitude and 79^0 19'-80^0 55' East longitude. The total area of the district is 11400 sq.k.m with a population of 48.9 lakh (2011 census). The district's population density is 430 per sq.km. 33.81% of the District's population is living in urban areas and the remaining in rural areas. The district has 57 revenue mandals. the main agricultural products cultivated in the district are Cotton, Chillies, Paddy and Tobacco, It is a major transportation and textile hub in Andhra Pradesh as well as India. Guntur area has worldwide reputation for its exports of Chillies, Cotton andTtobacco.

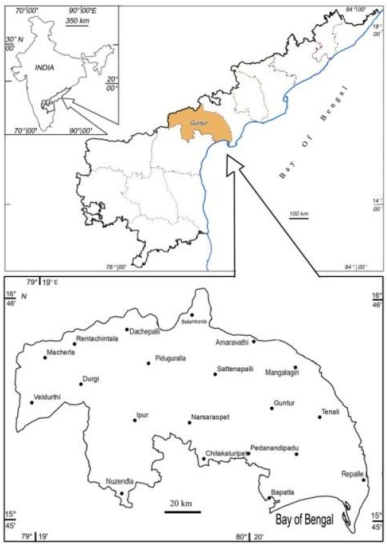

Fig. 1 Location and Administrative Divisions of Guntur District, Andhra Pradesh.

Historical incidence of famines/droughts in India

Historical knowledge of famines/droughts is essential in hydrological and agricultural studies for proper economic planning. A famine is a climatic phenomenon caused either by floods or droughts. Famines due to floods are rare phenomena. But famines due to droughts are more frequent, regional, and highly destructive in nature since the time immemorial. Drought is a most frequently occurring disaster in India and one- third of the nation comes under drought-prone (Thenkabali, 2004). Due to variable climatic and physiographic conditions, 35 percent of the area receives 750-1125 mm of rainfall and 33 percent of the area receives less than 750 mm of rainfall. About 68 percent of the agricultural area of the country is under the threat of droughts of varying intensities affecting 50 million people annually (National Centre for Disaster Management). All this water-scarce regions are drought-prone and experience

varying intensities of droughts (wrmin.nic.in/forms/list). If the drought conditions are neglected, they lead to a natural calamity in other words into famine conditions. Recorded evidence of famines/droughts prevailed over India indicate that India has experienced a number of famines since time immemorial.

Drought Analysis:

Water balance analysis is not only useful for the identification of drought spells, their duration, and intensity and spread but also to delineate climatic types and evaluation of crop suitability of a region. This type of analysis of climate is essential for the farmers and planners enabling them to select suitable crops, to develop a crop-weather calendar, to implement systematic and scientific irrigation scheduling in the drought- prone areas. The central objective of the study is to study the droughts episodes by their type, frequency and severity, apart from demarcating the drought-prone areas of the district.

Entire Guntur District is under the domination of dry climate, and most vulnerable to drought conditions. Keeping this in view, the incidence of droughts in Guntur District was analyzed. For that purpose, data pertaining on monthly average temperatures and rainfall recorded at weather stations representing 20 mandals of in Guntur District were collected from the records of India Meteorological Department, Hyderabad for a period of 31 years (i.e. from 1986 - 2017). These 20 mandals are taken as representative stations of the district to study droughts in the district.

For the analysis of droughts, annual data of water deficit were derived from monthly water balance computations for 20 representative mandals of the district. Aridity indices (percentage ratio between water deficit and water need) were computed for all the representative mandals of the district, for all the years of their respective study period. The statistical technique namely standard deviation (σ) adopted to compute standard deviations of aridity indices for all the mandals to identify the years of droughts along with their intensities. Departures of yearly aridity indices from the median values were used as the base of reference. Yearly departures of aridity index at a station under consideration from the median when graphically plotted against the successive years provide not only the information of years of drought incidence but also the intensity of drought. Identification of drought years with their intensities at all the mandals in the Guntur District during their study period, Categorization of droughts made on annual basis was made using the scheme illustrated by Subrahmanyam and Subramanian (1965). Table 1. Provides the general scheme of drought categorization.

Table .1 General Scheme of Drought Categorization

Departure of Ia %from the Median	Drought category
Less than ½ σ	Moderate
Between ½ σ and σ	Severe
Between σ and 2σ	Very severe
More than 2σ	Disastrous

Based on the above scheme, the droughts that occurred in Guntur District in 20 mandals during the study period were categorized and presented in Table 2

Table. 2 Number of Drought years and their categories in Guntur District

Name of the Mandal	Drought Categories				Total Incidences
	Disastrous	Very Severe	Severe	Moderate	
Repalle	1	3	5	7	16
Tenali	1	3	3	8	15
Mangalagiri	2	2	6	4	14
Ponnur	0	4	5	7	16
Bapatla	1	3	4	9	17
Guntur	2	1	6	7	16
Amaravathi	1	3	3	6	13
Pedanandipadu	0	2	2	5	9
Chilakaluripet	0	7	2	5	14
Piduguralla	0	2	7	6	15
Bellamkonda	0	4	7	3	14
Sattenapalle	0	4	6	8	18
Ipur	0	13	7	6	26
Dachepalle	0	4	4	5	13
Nuzandla	1	4	3	4	12
Narasaraopet	1	4	1	12	17
Durgi	1	3	2	5	11
Rentachintala	1	3	0	12	16
Macharla	0	4	5	6	15
Veldurthy	1	4	2	9	16

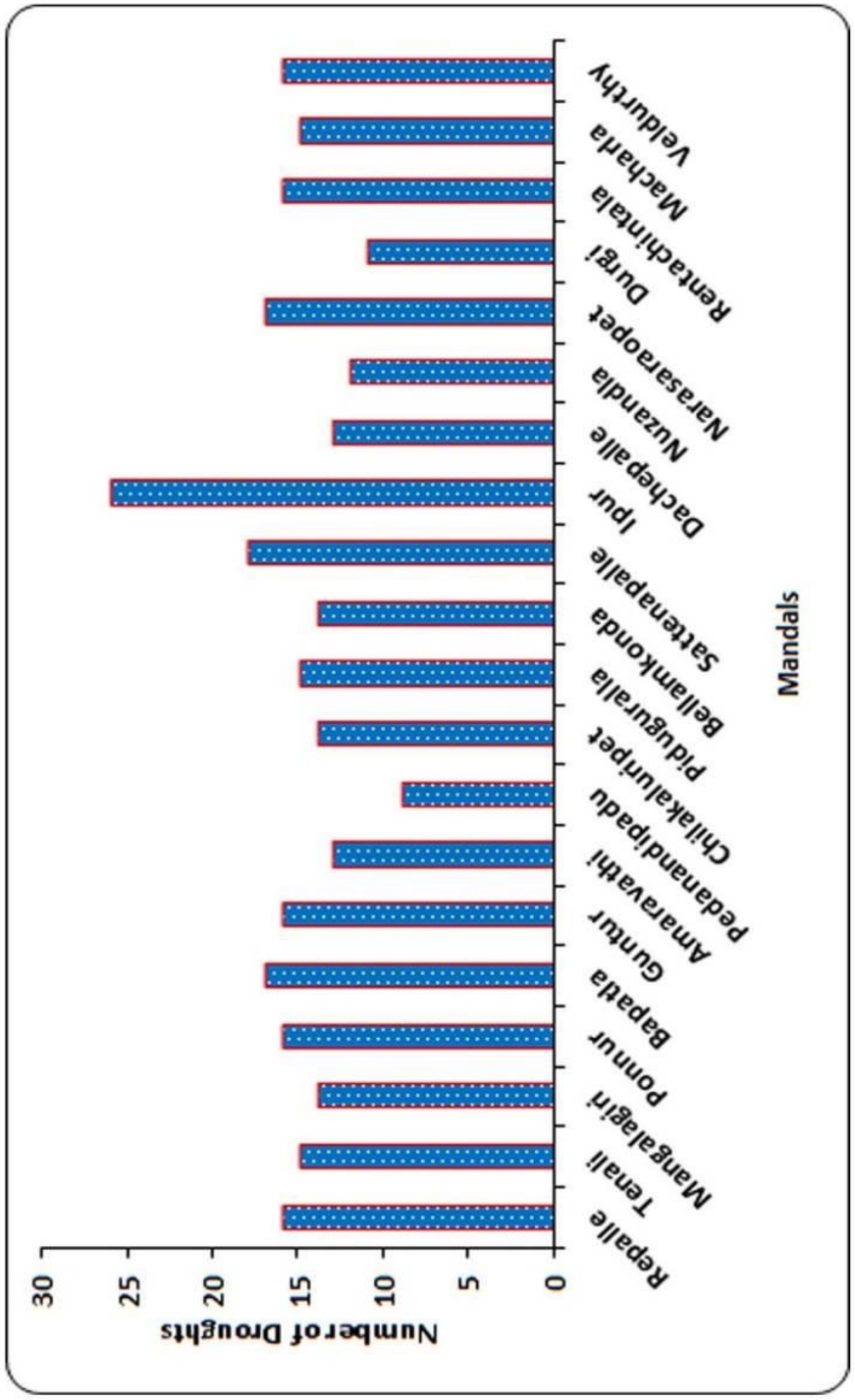

Fig.2 Mandal wise total number of drought incidence in Guntur District.

Table 2. and Fig.2 Illustrates that out of 31 years (1986-2016) Ipur Mandal has experienced drought in 26 years, Sattenapalli Mandal was under drought in 18 and Bapatla mandal, and Narasaraopet mandals were under 17. While, Repalle, Ponnuru, Veldurthy and Guntur mandals experienced 16 drought years each. Macharla, Tenali, Piduguralla mandals experienced 15 drought years each. Among the mandals, very less number of drought years was experienced by Pedanandipadu with10 years. The analysis reveals the fact that the entire Guntur District was under a drought impact during the study period.

In general, the number of drought years under the moderate category are more in Guntur District and the disastrous drought years the least. Among the mandals, Narasaraopet and Rentachintala recorded 12 years each, Bapatla and Veldurthy mandals 9 years each, Tenali,

Sattenapalle mandals recorded 8 years each, and Guntur, Repalle and Ponnur mandals 7 years each and rest of the mandals range from 3 to 6 years. The Least number of moderate years observed in Bellamkonda mandal i.e., 3 years.

The mandals which experienced a maximum number of severe drought years during the study period were Bellamkonda, Ipur and Piduguralla with 7 years each and Mangalagiri, Guntur, and Sattenapalli experienced 6 years each and in the remaining mandals the range of incidence varies between 0 and 5 years. However, there was no incidence of severe drought recorded in Rentachintala Mandal. The years with very severe intensity of droughts were identified in Ipur Mandal with 13 years of drought. Chilakaluripeta Mandal with 7 years. Nuzandla, Veldurthy, Ponnuru, Narasaraopet, Bellamkonda, Dachepalle, Sattenapalli and Macharla mandals experienced 4 year each of severe droughts, then remaining Mandals the incidence of very severe drought was 1 to 3 years. However, the incidence of Disastrous category of droughts were the least which was for one to two year in the entire study period

Drought Proneness

Knowledge of drought proneness of a particular region for a particular intensity of drought is also essential in agro-climatic studies. About 511300Km^2 area of India was identified as drought-prone. Among all the climatic types, the moist categories namely per humid, humid and moist sub-humid are drought tolerant to a large extent. While the dry climates namely dry sub-humid, semi-arid and arid are more prone to all types of drought. Permanent and contiguous drought conditions may lead to desertification (Subrahmanyam and Hemamalini, 1978). Hence, it is essential to identify drought-prone areas which are more frequently vulnerable to droughts.

Jameson (1932) coined the term ‘index of liability’ which indicates the ratio of the number of drought days to the total number of days examined. Drought proneness can be calculated by taking the number of droughts that occurred in each drought category under consideration. The percentage ratio of the number of drought years to the total number of years examined provides the overall drought proneness of the area. Similarly, percentage ratio of a number of years of the drought of each category to the total number of drought years will give proneness to each category of drought. The overall as well as category-wise drought proneness of the 20 mandals of Guntur district was computed and presented in Table.3

Table. 3. Drought vulnerability in Guntur District in percent.

S.No.	Mandals	Drought Proneness (%)				
		Overall	Disastrous	Very Severe	Severe	Moderate
1	Repalle	51.6	3.2	9.7	16.1	22.6
2	Tenali	48.4	3.2	9.7	9.7	25.8
3	Mangalagiri	45.2	6.5	6.5	19.4	13.0
4	Ponnuru	51.6	0.0	16.1	12.9	22.6
5	Bapatla	54.8	3.2	9.7	13.0	29.0
6	Guntur	48.3	3.2	9.7	16.1	19.4
7	Amaravathi	42.9	0.0	10.7	10.7	21.4
8	Pedanandipadu	55.0	0.0	15.0	15.0	25.0
9	Chilakaluripet	45.2	0.0	12.9	16.1	16.1
10	Piduguralla	54.8	0.0	9.7	22.6	22.6
11	Bellamkonda	44.0	0.0	12.0	24.0	8.0
12	Sattenapalli	51.6	0.0	3.2	25.8	22.6
13	Ipur	80.6	0.0	16.1	41.9	22.6
14	Dachepalli	42.6	0.0	14.3	10.7	17.9
15	Nuzendla	46.2	3.8	15.4	11.5	15.4
16	Narsaraopet	58.1	3.2	12.9	3.2	38.7
17	Durgi	47.6	0.0	14.3	9.5	23.8
18	Rentachintala	53.6	0.0	10.7	0.0	42.9
19	Macherla	48.4	0.0	12.9	16.1	19.4
20	Veldurthi	53.6	3.6	14.3	7.1	32.1

The analysis shows that all the representative stations of the district are prone to droughts. Ipur mandal is comparatively highly vulnerable to droughts with 80.6 percent of overall drought proneness followed by Narasaraopet with 58.1% and Pedanandipadu overall drought proneness 55%, Piduguralla and Bapatla 54.8% each, Veldurthy and Rentachintala 53.6%, Ponnuru, Repalle and Sattenapalle 51.6%. While the rest of the mandals overall drought proneness lies between 42.6% and 48.4%.

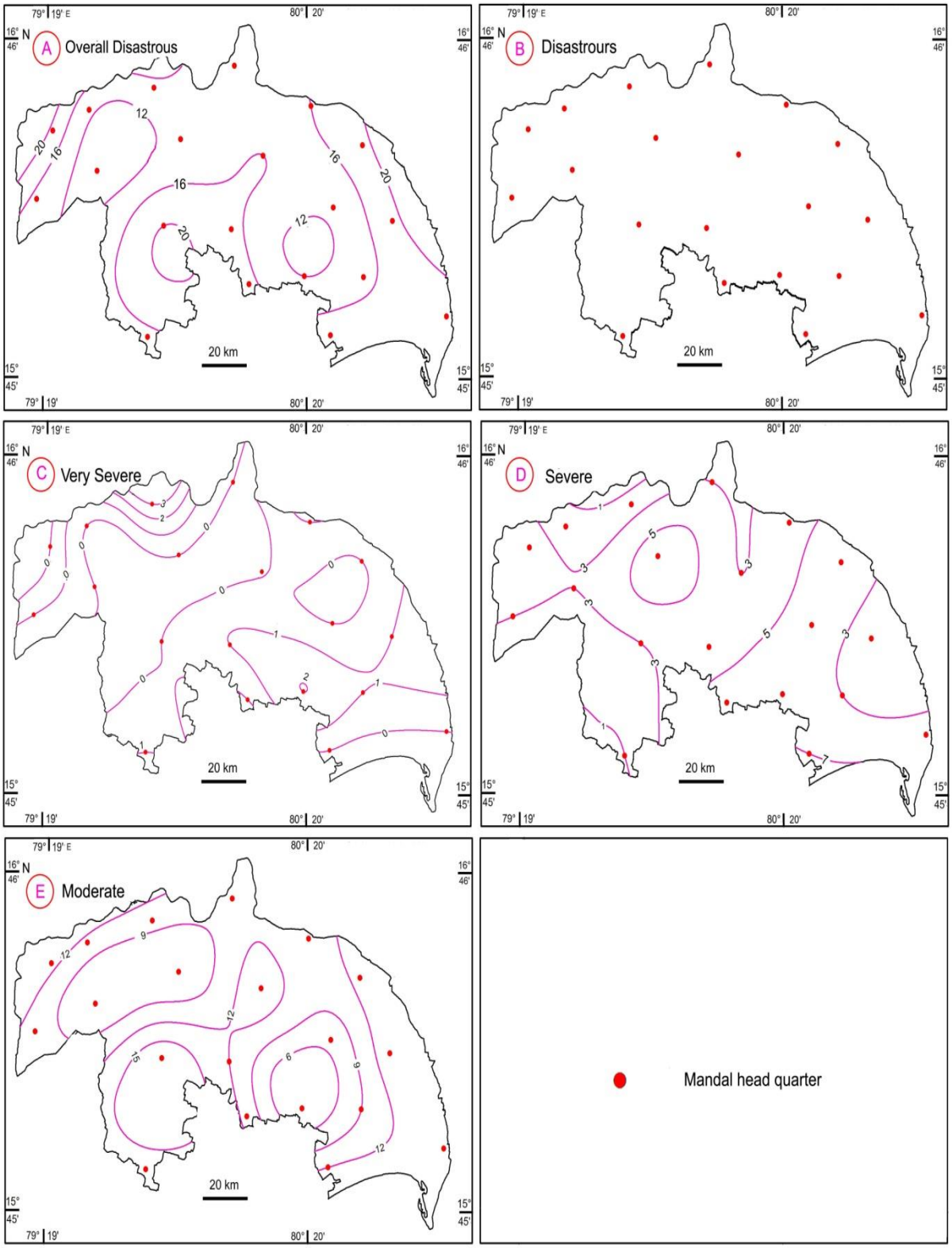

Fig.3 Overall and category-wise drought proneness of the 20 mandals of Guntur district

Drought proneness in a disastrous category is highest in Mangalagiri with 6.5%, followed by Nuzandla mandal with 3.8%, Veldurthy 3.6% and the rest of the mandals have values either 0% or 3.2%. Very severe category is highest in Ponnuru, Ipur, with 16.1% each, Nuzandla 15.4%, Pedanandipadu with 15%, Dachepalle, Veldurthy, and Durgi 14.3% each. Ipur, highest among severe drought category with 41.9% drought proneness, similarly Rentachintala is top among moderate drought proneness with 42.9%.

Conclusions:

From the above study, it is inferred that, Guntur District has been prone to droughts/famines from time immemorial. The incidence of droughts is on the increase which was indicated through the analysis of decennial frequency. The overall drought proneness in all the mandals was above 40 percent. Incidence of moderate droughts was high followed by severe and very severe and disaster type of droughts. Drought has long term socio-economic impacts on the men and the environment. Identification of the beginning of a drought spell and its intensity in time helps to prevent damage to the growing crops due to drought through supplemental irrigation. Thus, it is essential to assess the nature, duration, and proneness of droughts of a particular region. Then the drought management practices such as assessing crop suitability, growing drought-resistant crops, preparation of crop weather calendar and proper irrigation scheduling can be carried out in order to save the crop from adverse effects of the droughts.

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