Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2013, Volume 2, Issue 1, pp. 271-279, Article ID Tech-141
ISSN 2320 - 0243

Research Article | Open Access

Assessment of Meteorological Drought for Chittar Sub-basin Using Geographical Information System

M.C. Sashikkumar and O. Ganesh Babu

Department of Civil Engineering, University V.O.C College of Engineering, Anna University, Tirunelveli Region, Tuticorin, Tamil Nadu, India

Correspondence should be addressed to M.C. Sashikkumar, getsashi_kumar@yahoo.com, oganeshbabu@gmail.com

Publication Date: 25 September 2013

Article Link: http://technical.cloud-journals.com/index.php/IJARSG/article/view/Tech-141

Abstract Drought is a normal feature of the climate and its recurrence is inevitable. Droughts occur due to failure of monsoons over a region. Within a short period of time, the amount of moisture in soils begin to decrease which then leads to decrease in flow of rivers, water levels in lakes, reservoirs and wells after several weeks or months. As the economy of our country is often gripped with the gamble of monsoons, studies regarding drought become inevitable. Drought is caused due to deficiency of water that depends on rainfall, which falls in uneven pattern across the country. Hence, an attempt is made in the present study to analyse rainfall status and assess the drought severity of Chittar sub-basin in meteorological aspect using Geographical Information System (GIS). GIS provides tools to incorporate spatial and temporal variations of water resources data. The assessment of drought severity in the meteorological context was carried out by India Meteorological Department (IMD) method. Meteorological drought risk index for each rainfall station the sub-basin was calculated by frequency analysis. Spatial interpolation of meteorological drought risk index was mapped in Arc view GIS 3.2a software. The meteorological drought risk maps help the administrators and planners to plan various alternative measures to overcome the drought and its impacts.
Keywords *Drought, GIS, IMD, Sub-basin*

1. Introduction

Drought is a factor of uncertainty, which affects country's agriculture and economy. Periodic droughts pose serious limitations to nation's efforts towards agricultural self-efficiency. Drought is generally viewed as a sustained and regionally extensive occurrence of below average natural water availability, either in the form of rainfall, river runoff or ground water. All droughts originate from a significant reduction in precipitation extended over a season or longer and result in water deficit. It is to be realized that there is a need to develop a complete drought assessment procedure, which would consider all aspects of drought causing parameters. Drought continues to be a factor of uncertainty in Indian agriculture in spite of significant scientific and technological developments. Drought in India

has been considered mainly from meteorological point of view. As the basic factor for drought is deficiency of water, which depends on rainfall, it is aimed to analyse long-term rainfall data and to assess the drought severity of Chittar sub-basin of Thamiravaruni River basin, Tamil Nadu in meteorological aspect using GIS. Geographical Information System provides tools to incorporate spatial and temporal variations of water resources data.

2. Materials and Methods

2.1. Study Area

Chittar sub-basin of Thamiravaruni basin has been chosen for the present study since it has many dry regions within the perennial river basin. Thamiravaruni irrigation system is the one of the major systems in Tamil Nadu with a command about 77,500 ha irrigating Tirunelveli and Thoothukudi districts. Chittar River is the largest tributary of the Thamiravaruni River. It lies between $8^0$45’ N and $9^0$15’ N Latitudes and between $77^0$10’ E and $77^0$50’ E Longitudes. The eastern part of the sub-basin is generally plain with the lowest elevation of about 60 to 80 m above MSL and the slope ranging from is less than 1%, whereas in the west, the topography is undulating plains and the slope ranges from 1 to 3%. The high hills of the Western Ghats mark the western boundary of the sub-basin. The climate of the sub-basin is generally semi-arid. The maximum temperature ranges between 30°C to 37.5°C and the minimum temperature between 20°C to 27°C. The months of March, April, May and June are hottest depending on the location within the basin, and the cooler months are November, December and January. The index map of the Chittar sub-basin is shown in Figure 1.

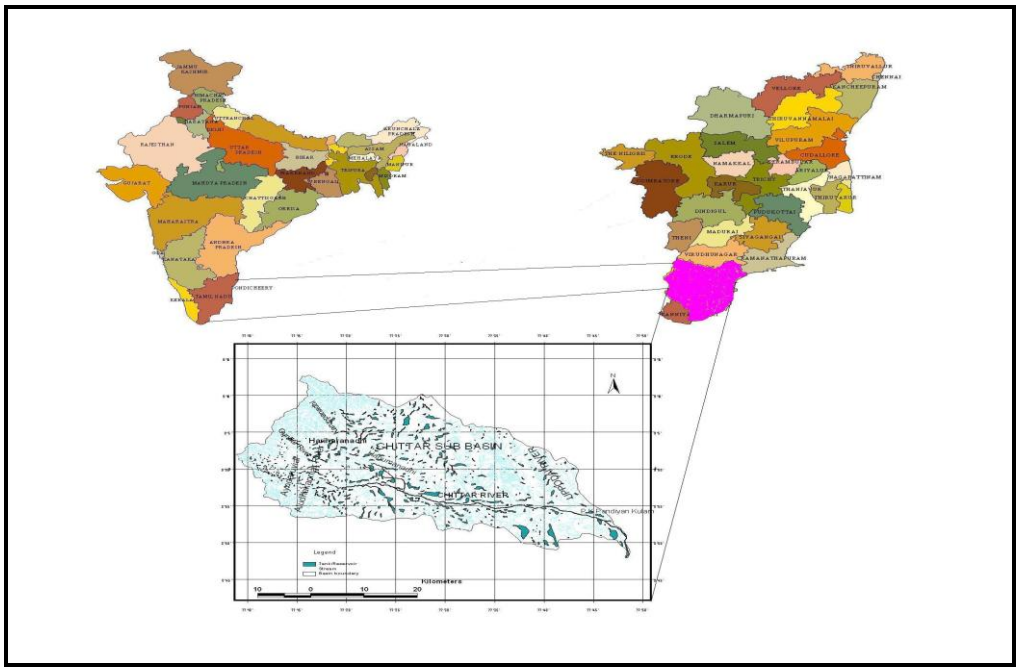

Figure 1: *Index Map of Chittar Sub-basin*

2.2. Rainfall Analysis

Rainfall is a main factor, which is responsible for vegetation, hydrology and it is particularly most important to agriculture. Thirty years of monthly rainfall data from 15 rain gauge stations in Chittar sub-basin were collected from Ground Water Division, PWD. The statistical parameters like mean, standard deviation, co-efficient of variation, skewness and kurtosis were identified. Rain gauge location map of Chittar sub-basin is shown in Figure 2.

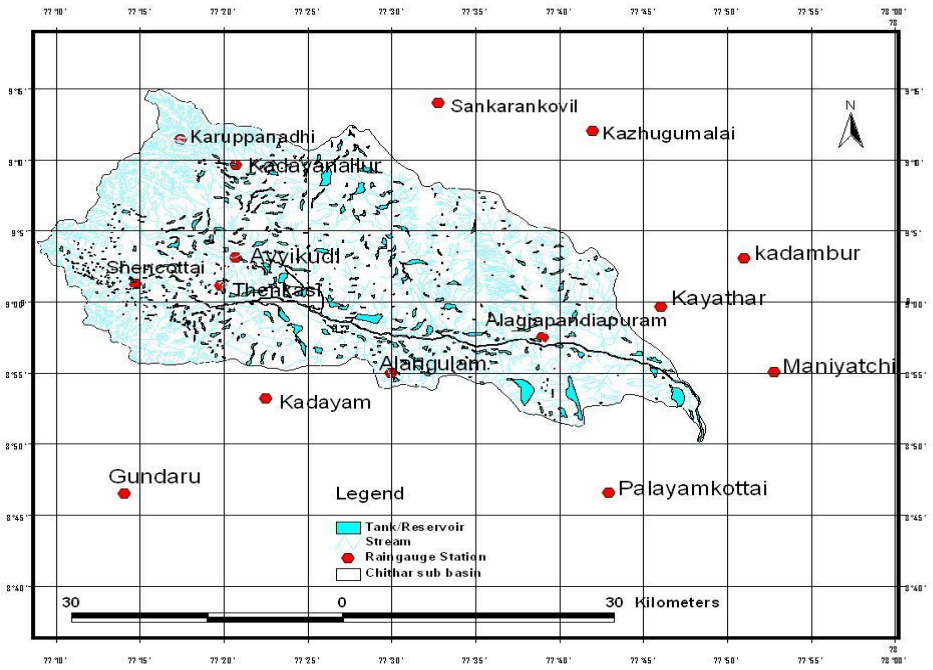

Figure 2: *Rain Gauge Location Map of Chittar Sub-basin*

2.3. Meteorological Drought Assessment

Meteorological drought is a situation when there is a significant decrease in precipitation from the normal over an area [1]. Among various methods, the IMD method is a simple and widely used one, which will give a preliminary idea about the drought condition of an area. In this method, drought is assessed on the basis of percentage deviation of rainfall from the long-term annual mean rainfall [2]. The percentage deviation (D_i) given by:

$$D_i = \frac{P_i - \overline{P}}{\overline{P}}$$

Where, P_i is the annual rainfall in the year i; and $\overline{P}$ is the long term annual mean rainfall.

IMD classification of drought is based on the deviation of rainfall which is given in Table 1.

Table 1: *IMD Classification of Drought*

Sl. No.	Range of D_i	Classification of Drought	Category
1	>0	M0	No drought
2	0 to –25	M1	Mild drought
3	-25 to –50	M2	Moderate drought
4	< -50	M3	Severe drought

The drought severity classes were found out for each rain gauge station on a yearly basis. The frequency of various classes of drought severity for each station was found out. The weight ages 0, 1, 2, and 3 are assigned to drought severity classes of no, mild, moderate and severe droughts respectively [3]. The meteorological drought risk index of each station is found out by multiplying the frequency of each class of drought severity by the corresponding weight age. The spatial distribution of drought risk was found out using the nearest neighborhood analysis in GIS [4].

3. Results and Discussion

The spatial pattern of drought risk of a basin can be analysed easily with the help of drought risk maps in GIS environment. This information will help the district authorities in prioritising areas for mitigating the effects of drought. The meteorological drought was quantified by taking into account the long-term drought severity or intensity and duration. Drought risk area mapping was then carried out in GIS environment. The results of this analysis are presented below.

3.1. Analysis of Rainfall Data

The statistical analysis was carried out for annual rainfall data to identify statistical parameters like mean, standard deviation, co-efficient of variation, skewness and kurtosis. The results obtained from this analysis are presented in Table 2. The average precipitation for the basin is 833 mm. The Kadambur Station has very low coefficient of variation of 23.95% and Kayathar has high variation of 52.82%. The coefficient of variation increases with increase in aridity. Also it indicates that many dry years and a few wet years in the study area leading to the identification of drought proneness. The parameters such as skewness and kurtosis were also estimated. The result indicates that all the rain gauge stations have positive skewness except Alagiapandiapuram and Kadayam which is negative skew. Most of the data have values above the mean. Negative skewness has huge influence on this parameter, which indicates the true homogeneity of drought condition. Usually annual precipitation data are highly skewed due to insufficient rainfall during non-monsoon periods. Analysis of rainfall data shows that there were many dry years and few wet years. The degree of skewness gradually increases as the climate becomes drier.

Table 2: *Statistical Parameters for Annual Rainfall Data in Chittar Sub-basin*

Sl. No.	Name of Rain Gauge Stations	Annual Average (mm)	Standard Deviation (mm)	Co-efficient of Variation (%)	Skewness	Kurtosis
1	Alagiyapandiapuram	626.03	282.80	45.17	-0.40	-0.19
2	Alangulam	743.6	219.70	29.55	0.55	0.3
3	Ayyakudi	674.0	227.97	33.82	0.27	-0.37
4	Gundaaru	1788.3	513.76	28.73	0.75	0.02
5	Kadambur	744.93	178.41	23.95	0.94	1.23
6	Kadayam	841.8	382.7	45.46	-0.01	-0.17
7	Kadanallur	737.10	277.29	37.62	1.29	3.5
8	Karuppanadhi	673.3	220.42	32.74	1.22	3.02
9	Kayathar	587.0	310.03	52.82	0.90	2.28
10	Kazhugumalai	742.13	200.13	26.97	0.34	-0.66
11	Maniyatchi	690.74	345.91	50.08	0.41	0.46
12	Palayamkottai	720.2	201.5	27.98	0.22	-0.46
13	Sankarankoil	674.9	242.93	35.99	0.63	-0.44
14	Shenkottai	1536.9	554.81	36.10	0.72	-0.37
15	Tenkasi	904.8	306.14	33.84	0.92	1.82

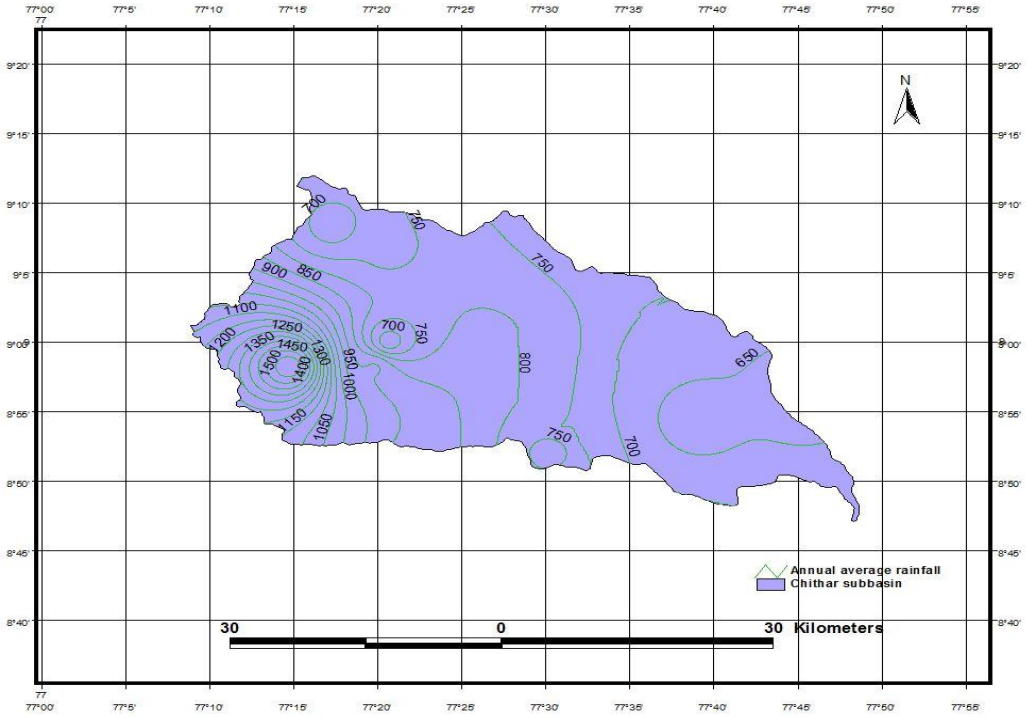

Figure 3: *Spatial Distribution of Annual Rainfall of Chittar Sub-basin*

3.2. Meteorological Drought Assessment

Drought assessment has been carried out for all the fifteen stations. The results shows that many blocks were affected by moderate and severe drought condition during the years 1982, 1986, 1989, 1999 and 2001. The drought severity values of all the stations were exported from MS Excel to Map/Info GIS to generate drought severity maps. Figures 4, 5 and 6 indicate the drought severity (block wise) for the years 1989, 1999 and 2001 respectively during which the basin had experienced severe drought conditions. From the Figure 4, it is observed that during the year 1989, all the blocks of the basin were affected by rainfall deficiency except Alangulam. Blocks such as Shenkottai, and part of Thenkasi, Ayyikudi are exposed to no drought. It can be seen from Figure 5, it is observed that during the year 1999, all the blocks of the basin were affected by rainfall deficiency except Karuppanadhi and some parts of Ayyikudi. Blocks such as Shenkottai, and part of Thenkasi are exposed to no drought. Moderate drought prevailed in Kayathar, Kadayanallur, Mannur, Alangulam of Chittar sub-basin. It can be seen from Figure 6 that during the year 2001, most of the blocks were affected by drought with severity class ranging from mild to severe. Parts of Mannur, Kayathar and some part of Ayyikudi, were severely affected.

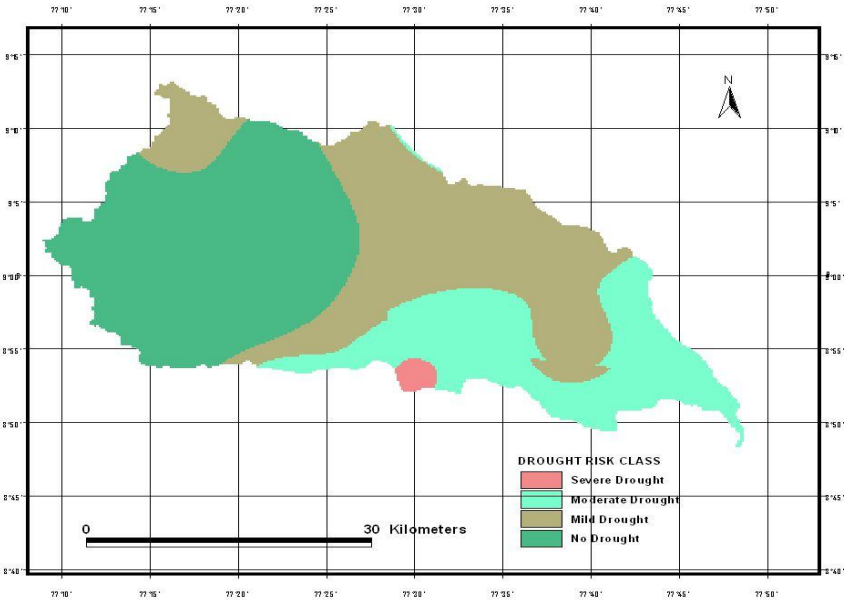

Figure 4: *Drought Severity of Chittar Sub-basin During 1989*

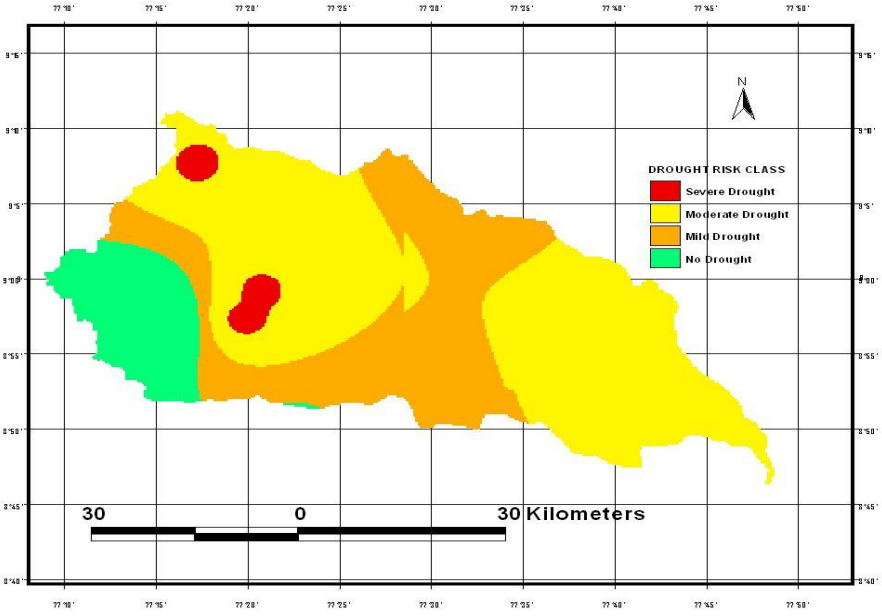

Figure 5: *Drought Severity of Chittar Sub-basin During 1999*

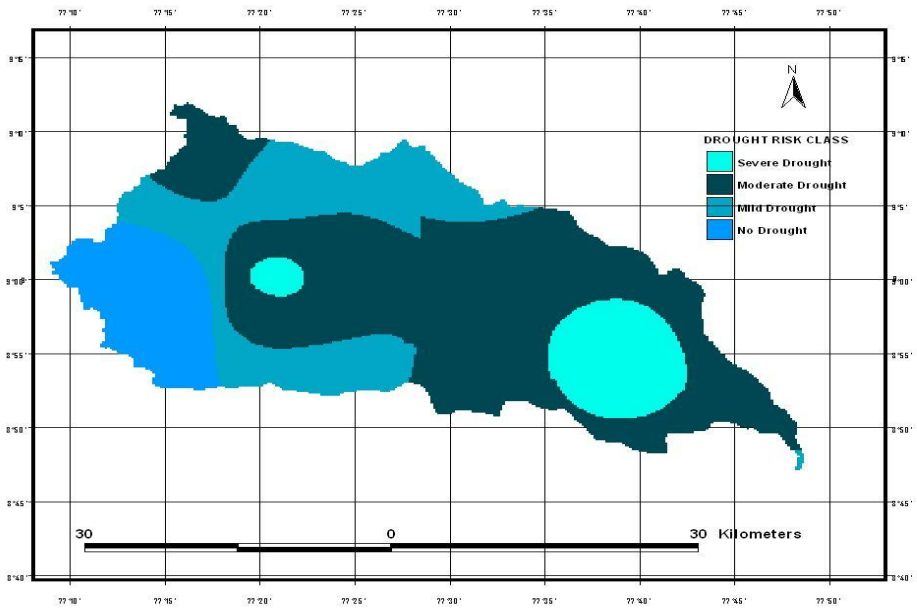

Figure 6: *Drought Severity of Chittar Sub-basin During 2001*

3.3. Meteorological Drought Risk Mapping

Meteorological drought risk index was developed by frequency analysis based on thirty years rainfall data and the results are shown in Table 3. The drought risk index ranges from 1.00 at Gundaru to 2.84 at Kayathar. Four drought risk classes were delineated based on the range of drought risk index. The spatial interpolation of meteorological drought risk index was carried out using Arc view GIS 3.2a. The meteorological drought risk map for Chittar sub-basin is shown in Figure 7. In general, as the blocks surrounding the Western Ghats receive very good rainfall, they are very less prone to meteorological drought risk than other regions. As the distance of blocks from Western Ghats increases, the rainfall decreases. As a result, the drought proneness gradually increases towards East, which can be clearly noticed in the risk map. As Tenkasi and Senkottai are shielded by Western Ghats, they are very less prone to meteorological drought risk. Part of Kadaiyanallur, Kilpavur, Alangulam, Kurivikulam, Shenkottai and Kayattar blocks are under moderate drought risk status. Northern and tail end blocks such as Sankarankovil, Ottappidaram, Karuppanadhi, Karunkulam, part of Manur, and Kayattar are liable to severe drought risks. During heavy rainfall periods, considerable runoff flows to sea, which may be conserved by recharging; to feed the drought affected tail end blocks in this basin.

Table 3: *Meteorological Drought Risk Assessment in Chittar Sub-basin*

Sl. No.	Name of Raingauge Station	Annual Average Rainfall (mm)	No Drought	Mild	Moderate	Severe	Drought Risk Index	Drought Risk Class
1	Alagiyapandiapuram	626.03	0.2	0.4	0.2	0.2	2.4	Moderate
2	Alangulam	743.6	0.25	0.35	0.35	0.05	2.2	Moderate
3	Ayyakudi	674.0	0.16	0.39	0.29	0.16	2.45	Moderate
4	Gundaaru	1788.3	1.00	0.00	0.00	0.00	1.00	Very Mild
5	Kadambur	744.93	0.30	0.48	0.22	0.00	1.92	Mild
6	Kadayam	841.8	0.52	0.23	0.13	0.13	1.89	Mild
7	Kadayanallur	737.10	0.28	0.28	0.36	0.08	2.24	Moderate
8	Karuppanadhi	673.3	0.10	0.38	0.35	0.17	2.59	Severe

9	Kayathar	587.0	0.16	0.13	0.42	0.29	2.84	Severe
10	Kazhugumalai	742.13	0.36	0.48	0.16	0.00	1.8	Mild
11	Maniyatchi	690.74	0.32	0.45	0.16	0.07	1.98	Mild
12	Palayamkottai	720.2	0.29	0.36	0.23	0.13	2.22	Moderate
13	Sankarankoil	674.9	0.16	0.32	0.39	0.13	2.49	Moderate
14	Shenkottai	1536.9	0.94	0.06	0.00	0.00	1.06	Very Mild
15	Tenkasi	904.8	0.55	0.26	0.16	0.03	1.67	Mild

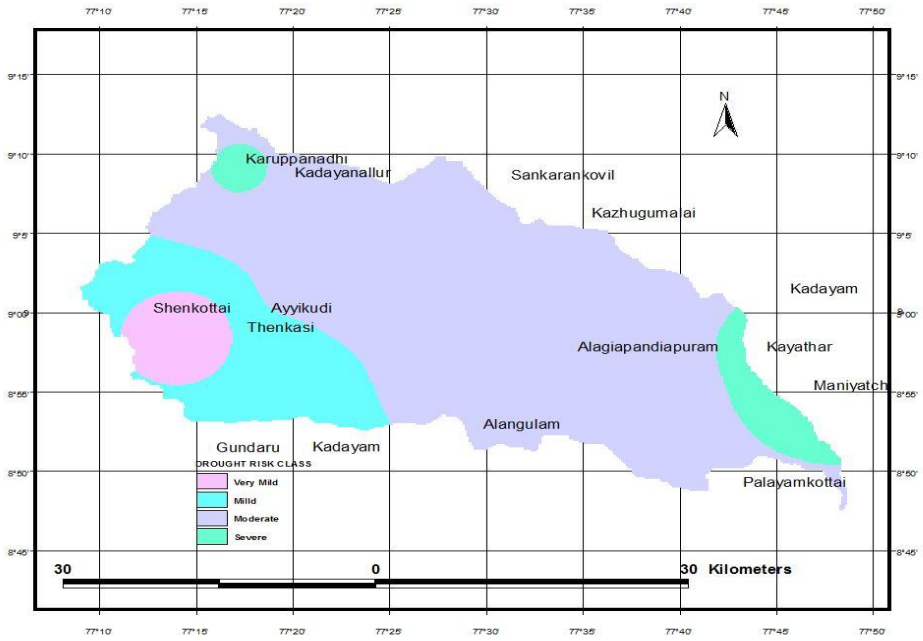

Figure 7: *Meteorological Drought Risk Map of Chittar Sub-basin*

4. Conclusion

Drought is a period of drier than normal conditions that results in deficient water related problems. The consequences of drought range from water supply shortages and crop losses to famine and human abandonment of geographic regions. Drought risk area evaluation is inevitable for taking up the proactive approach of mitigating the drought. The historical occurrence of droughts and their intensity, duration and spatial extent are of great concern for evaluating the risk. In the present study, an attempt is made to quantify meteorological drought risk index. Geographical Information System provides tools to incorporate spatial and temporal variations of water resources data. Rainfall analysis was carried out to find out the variation in space and time for Chittar sub-basin. The assessment of drought severity in the meteorological context was carried out by India Meteorological Department method. IMD is a simple methodology to assess meteorological drought severity of a region. A meteorological drought risk index was developed using the frequency of different classes of drought severity ascertained by this method. Meteorological drought has occurred in the basin once in every 3 to 5 years. Meteorological drought risk area map indicates that except the western blocks of the basin, almost all the other blocks of the basin need urgent drought proofing measures. Evaluations of droughts would help the water resources managers to plan and execute the drought mitigation measures. This will also be very useful to take effective long-term drought proofing measures for the regions that are constantly affected by drought.

References

[1] Dracup J.A., Lee K.S., and Paulson E.G. *On the Definition of Droughts*. Water Resource Research. 1980. 16 (2) 297-302.

[2] Herbst P.H., Bredenkamp D.B., and Barker H.M.G. *A Technique for the Evaluation of Drought from Rainfall Data*. Journal of Hydrology. 1966. 4; 264-272.

[3] T. Murali Krishna, G. Ravikumar and M. Krishnaveni. *Remote Sensing Based Agricultural Drought Assessment in Palar Basin of Tamil Nadu State, India*. Journal of Indian Society of Remote Sensing. 2009. 37; 9-20.

[4] Sharma T.C. *A Drought Frequency Formula*. Journal of Hydrological Sciences. 1997. (6) 803-814.