Drought Risk Assessment Using GIS and Remote Sensing

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Abstract Risk assessment is one of the key elements of a natural disaster management strategy as it allows for better mitigation and preparation. The non-structural characteristic of drought impacts has hindered the development of accurate, reliable and timely estimates of severity and planning in most of the cases. So drought risk assessment may help in the delineation of major areas facing drought, and thereby management plans can be formulated to cope with the disastrous effects of this hazard.

In recent years, geographic information system (GIS) and remote sensing (RS) have played a key role in studying different types of hazards. This study stresses upon the use of remote sensing and GIS in the field of drought risk evaluation. In the present study, an effort has been made to derive drought risk areas facing agricultural as well as meteorological drought in Bankura district of West Bengal by use of conventional data and available satellite images. The approach included creation of a spatial database and its integration in GIS environment by developing a suitable ranking and rating scheme for the generation of drought severity map. The results obtained provide information on severity of drought vulnerability, which has practical relevance to agricultural importance and for planning drought management and combating drought.

Keywords Risk assessment • Severity • Drought • Remote sensing • Geographical information system

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1 Introduction

Drought is one of the major disasters around the world leading to “severe water crisis”. Risk is defined as the expected losses, including lives, personal injuries, property damages and economic disruptions, due to a particular hazard for a given area and time period (WMO [6]). Droughts are recurring climatic events bringing significant water shortages, economic losses and adverse social consequences. Drought is considered by many to be the most complex but least understood of all natural hazards, affecting more people than any other hazard.

It is true that the main cause behind drought is precipitation and its variability, but there are more other factors contributing to the rise of waterless situation. Drought is a slowly creeping natural hazard that is a normal part of climate for virtually all regions of the world which results in serious economic, social and environmental impacts. Drought onset and end are difficult to determine as its severity. It is estimated that 4 billion people of the world’s population will live under conditions of water stress by 2025 with conditions severe in Africa and Asia.

Even though India has a long history of drought events in the past, it lacks proper drought management strategy at national level yet. The country needs the drought severity map for providing drought relief and management in time. There are strong links between poverty and proneness of an area to drought. Widespread crop failures leading to acute shortages of food and fodder adversely affecting human and livestock health and nutrition, scarcity of drinking water accentuated by deteriorating ground water quality and declining water tables leading to large-scale migration are the major manifestations of droughts.

Satellite data have been used frequently in the past for the study of disaster and land degradation. For qualitative assessment of drought, it is necessary to integrate and study the combined effects of terrain, meteorological and land characteristics of the area for which GIS is essentially required.

Kumar et al. [3] carried out micro-level drought vulnerability assessment utilising GIS in Addakal Mandal of Andhra Pradesh, India. The water requirement for all the 21 villages in Addakal Mandal was calculated, taking into consideration the requirements for human and livestock consumption and crop irrigation. As the groundwater condition in this region is critical, the water availability in irrigation tanks for meeting the requirements for each village was calculated for different rainfall scenarios. The percentage deficit or surplus for each village was calculated, and the drought vulnerability maps were generated. These maps were provided to the farmers along with the rainfall predictions of the season. An arrangement to monitor daily rainfall was set up and tested. This was useful in further refining the vulnerability assessment.

Chopra [1] carried out drought risk assessment using remote sensing and GIS in the State of Gujrat. Resultant risk map has been obtained by integrating agriculture, and meteorological drought risk map indicated that the area is facing a combined hazard. The map also represented the frequency of years a particular area faced the hazard.The study shows the results that can be used in taking corrective measures timely to minimise the reduction in agricultural production in drought-prone areas.

Prakash et al. [4] prepared drought severity map in Gubbi Taluk of Karnataka, India, by integrating 17 parameters which affect the drought. The approach included creation of a spatial database and its integration in GIS by developing a suitable rating and ranking scheme for the generation of drought severity map. The drought severity map was prepared using remote sensing data and other information. It was found that moderate drought was more predominant which accounts for 85% affecting about 300 villages.

In the present study, an attempt has been made to create an overall spatial database for drought risk assessment, and a drought severity map has been prepared for Bankura district of West Bengal.

2 Study Area

Bankura district is one of the seven districts of Burdwan Division in the Indian state of West Bengal. The district has been described as the connecting link between the plains of Bengal in the east and Chota Nagpur plateau on the west. The areas to the east and northeast are low-lying alluvial plains, and to the west, the surface gradually raises comprising rocky hillocks. Bankura is situated between 22°38′ and 23°38′ north latitude and between 86°36′ and 87°46′ east longitude, having the gross area about 6,882 sq km. On the north and northeast, it is bounded by Burdwan district, from which it is separated by Damodar River. On the southeast, it is bounded by Hooghly district, on the south by Paschim Midinipur district and on the west by Purulia district. The western part of the district has poor lateritic soil with scrubs and sal woods. In the eastern part, there are wide expanses of agricultural lands. About 46% of the net cropped area is under irrigation. Rice, wheat, oil seeds and vegetables are the principal crops that occupy the majority of the gross cropped area. Intermittent gaps of in precipitation and moisture stress during the monsoon give rise to serious setback in production during the Kharif, which is the mainstay of agriculture in the district.

The climate especially to the upland tract in the west is much drier than eastern or southern Bengal. From the beginning of March to June, hot westerly winds prevail with maximum temperature around 45°C. The monsoon months (June to September) are comparatively pleasant with annual rainfall of about 1,400 mm. Winters are pleasant with temperature around 20°C.

3 Preparation of Thematic Layers

The data used for this study comprises of remotely sensed data and conventional data from different sources which includes the following:

1. Satellite image of Bankura district IRS-P6 LISS-III (acquired on Jan. 2006 from NRSA)
2. Annual rainfall and monthly rainfall data (5 years average) (acquired from National Atlas Thematic Mapping Organization (NATMO), Kolkata and IMD, Pune website)
3. Ground water yield data (NATMO, Kolkata)
4. Slope map (NATMO, Kolkata)
5. Soil map (NATMO, Kolkata)
6. Block boundary data (Bankura Zilla Parishad map)
7. Census data (Bankura govt. website)

Eight thematic layers have been generated from the above-mentioned data and used further to create a spatial database in GIS and risk assessment of drought.

3.1 Concept of Rankings and Ratings

Prior to integration of different thematic layers representing different information, individual class weights and map scores were assigned based on Saaty's Analytic Hierarchy Process. In this method, a pairwise comparison matrix was prepared for each layer using Saaty's nine-point importance scale, and this matrix was solved using eigenvector method.

Table 1 presents the details of various parameters and their relative ranking (weightage) and rating (4 having the highest and 1 having the lowest drought severity) that indicate the drought severity. The drought severity of a region depends on the cumulative effect of individual themes/classes. For this, the model is made to consider individual parameters to obtain a combined effect.

4 Development of GIS Model

The arithmetic overlay approach built into Arc View Model Builder of Spatial Analyst Module is used for the integration of the input data layers. The rating of each parameter is multiplied by its rank, and the sum of the cumulative values of all parameters is used for categorisation of drought into different classes to generate a drought severity map. Figure 1 represents the model for generation of drought severity map (Table 2).

The drought severity map generated by this model is shown in Fig. 2 which shows different drought classes which can be classified as not drought prone (0–1.6), mild

Table 1 Ranking and rating of various parameters

Sl. no.	Parameter	Ranking	Range of values	Rating
1.	Annual rainfall (mm)	0.25	>1,600	2
			1,400–1,500	3
			<1400	4
2	Monthly rainfall (mm)	0.22	240–295	2
			205–240	3
			120–205	4
3.	Soil	0.13	Gravelly soil	4
			Lateritic soil	2
			Older alluvial soil	1
			Red sandy soil	3
			Red yellow soil	3
			Younger alluvial soil	1
4.	Land use	0.11	Agriculture	1
			Dense sal	2
			Fallow land	4
			Open sal	3
			Reservoir	-
			Sand	4
			Shallow water	-
5	Ground slope	0.11	<10	1
			10–20	2
			20–80	3
			80–150	4
6	Ground water yield	0.1	>40	1
			25–40	2
			10–25	3
			1–5	4
7.	Cultivator density	0.05	116–141	1
			91–115	2
			65–90	3
			40–64	4
8.	Population density	0.03	244–358	1
			359–472	2
			473–586	3
			587–700	4

drought prone (1.6–2.4), moderate drought prone (2.4–3.2) and severe drought prone (3.2–4). The block boundary map was overlaid on drought severity map which is shown in Fig. 3. The statistics obtained from the map is presented in Table 3.

Fig. 1 Model for preparation of drought severity map

Table 2 Attributes of the drought severity map with grid code representing the severity level

Attributes of Block_droughtfin.shp

Shape	Gridcode	Block_name	Area_Meters	Perimeter_Meters	Acres	Hectares
Polygon	4	saltora	7,505.355	399.319	1.855	0.751
Polygon	4	saltora	362.193	86.777	0.089	0.036
Polygon	4	sarenga	3,174.000	230.000	0.784	0.317
Polygon	4	saltora	17,064.740	648.244	4.217	1.706
Polygon	4	saltora	6,347.521	326.837	1.569	0.635
Polygon	4	saltora	3,833.043	288.877	0.947	0.383
Polygon	4	saltora	3,174.000	230.000	0.784	0.317
Polygon	4	sarenga	3,994.835	317.586	0.987	0.399
Polygon	4	sarenga	362.202	86.778	0.090	0.036
Polygon	4	sarenga	148,711.188	2,263.401	36.747	14.871
Polygon	4	sarenga	13,244.329	432.691	3.273	1.324
Polygon	4	sarenga	362.202	86.778	0.090	0.036
Polygon	4	sarenga	41,181.156	1,033.940	10.176	4.118
Polygon	4	saltora	3,106.744	224.529	0.768	0.311
Polygon	4	saltora	1,060.271	175.424	0.262	0.106
Polygon	4	sarenga	1,253.179	163.304	0.310	0.125
Polygon	4	sarenga	713.970	130.491	0.176	0.071
Polygon	4	sarenga	196,472.684	3,570.362	48.549	19.647
Polygon	4	saltora	362.196	86.777	0.090	0.036
Polygon	4	saltora	5,979.765	330.294	1.478	0.598
Polygon	4	saltora	714.073	130.496	0.176	0.071
Polygon	4	saltora	362.196	86.777	0.090	0.036
Polygon	4	sarenga	6,926.243	356.754	1.712	0.693
Polygon	4	sarenga	1,091.926	174.499	0.270	0.109
Polygon	4	saltora	289,477,739.309	89,991.770	71,531.221	28,947.774

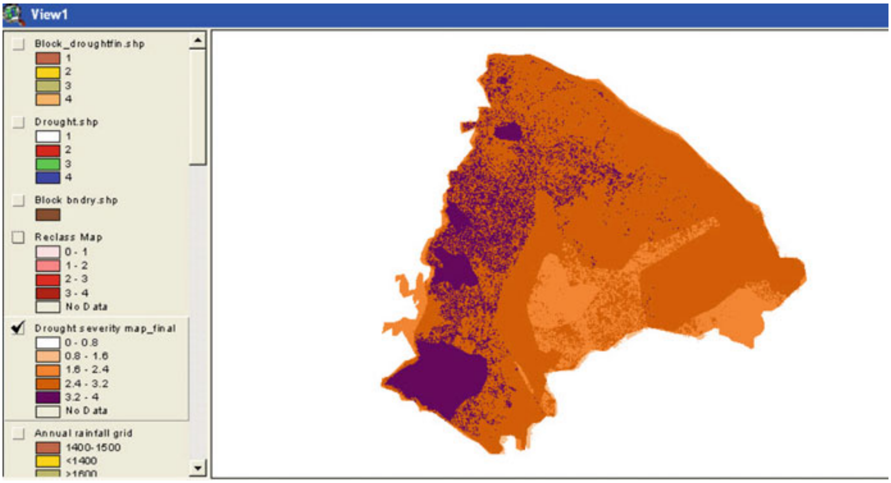

Fig. 2 Drought severity map of Bankura district

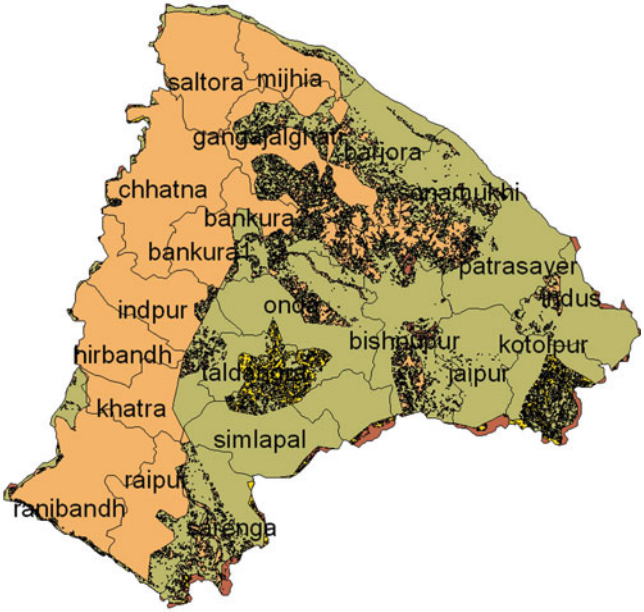

Fig. 3 Blockwise drought severity map

Table 3 Area statistics of drought severity level

SI. no.	Drought severity level	% of area
1	Not drought prone	17.5
2	Mild drought prone	2
3	Moderate drought prone	43.6
4	Severe drought prone	36.9

5 Conclusions

The main objective of the study was to prepare a drought severity map of Bankura district by integration of satellite, meteorological and other ancillary data and thus to obtain a spatial database for that.

1. It is found that about 20% area is not drought prone in Bankura, 43% of the area being moderately drought prone and 37% of area being largely susceptible to drought.
2. The drought severity map would help to point out the severity of drought vulnerability of different locations or places. This model thus provides an overall idea of drought risk associated with the district in block level.
3. This information is important for planners and administrators to take precautionary measures; moreover, the results can be used by local inhabitants to alleviate the continuation of drought phenomenon.
4. This model actually combines the meteorological data, collateral data and remote sensing data and integrates them in a GIS-based methodology to obtain the prevailing drought scenario and its management. The model thus can be used as a quick guide for identifying the extent of drought-hit locations.

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