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Vulnerability of climate and its impacts on regional drought over semiarid zone of India

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Abstract
The climate and its global changes may significantly affect the regional climate. The vulnerability of climate over a region is a function of the sensitivity of its natural resources. The sensitivity is expected to be intense over dry land zone and sharp when there is gradual increase in human population pressure. An attempt is made in this study to the vulnerability of the climate and water scarcity over a semiarid zone of west peninsula India. The water resource components are precipitation, river discharge, soil moisture stress and reservoir levels. A study on drought watch has been made using meteorological, hydrological and remote sensing data. The integrated impact of climate vulnerability, drought and manmade pressure has been assessed on water as well as vegetation.

INTRODUCTION

The climate of India except North East part is mainly dominated by two monsoons. More precisely the climatic zone of West Peninsula India is influenced by only southwest monsoon (Sing et al, 1996). The tele connection between southwest monsoon of India and global phenomenon is well established by several scientists. Eventually global changes may significantly affect SW monsoon of Indian regional climate. Here the studied region is a semi arid zone of Maharastra state (Figure 1) under climatic zone of West Peninsula India and receives 90% of annual rainfall during southwest monsoon. The weather systems mostly produce maximum precipitation at windward side of Western Ghats whereas the study area is situated at the leeward side of that mountain range. As a result the regional climate and its vulnerability get new dimension in microclimatic pockets of the study area due to orographic and other convectional factors. The vulnerability of climate over a region is very sensitive to water and agricultural resources. The sensitivity is expected to be intense over dry land zone and sharp when there is gradual increase in human and livestock population pressure.

METHODOLOGY

An attempt is made for the study of vulnerability of the climate using the criteria of India Meteorological Department (CWC, 1982). The tendency of precipitation based drought index which is directly related to climate vulnerability is evaluated over the area. Based on this study the most affected area, water and agricultural resources belt of Parbhani (Figure 1) is selected for assessment of impacts. Main attention is given on water resources components and rate of vegetation. The water resources components are pre-

cipitation as meteorological drought index, river discharge and reservoir levels as hydrological drought index, soil moisture stress as agricultural drought index. Human population pressure is incorporated as one of the socio-economic indicator of drought. Analysis of both land based and satellite data (IRS LISS-I) is incorporated to assess the rate of desiccation and degeneration of vegetation.

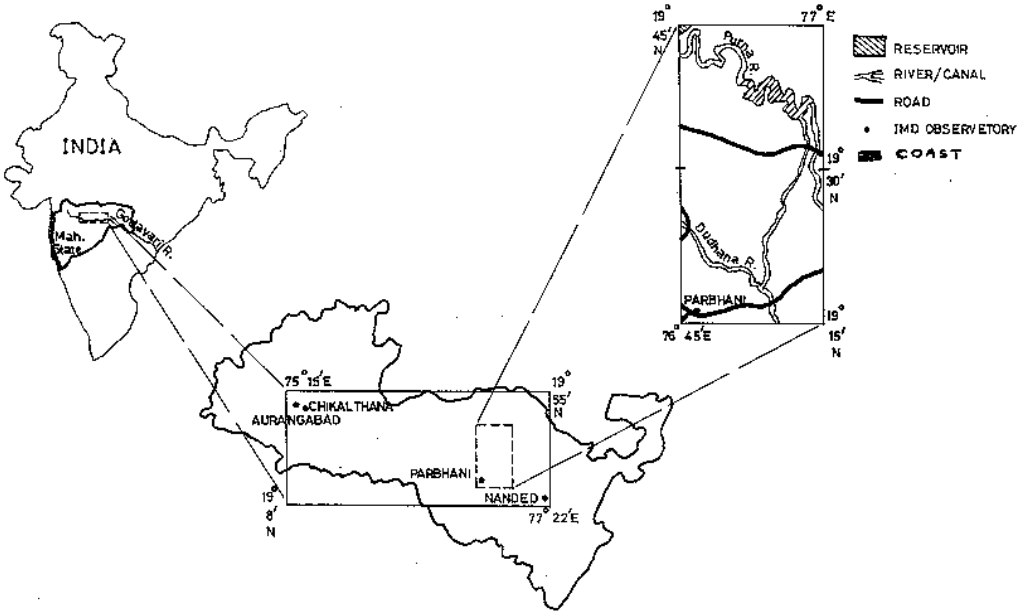

Figure1. Location map of the study area.

CLIMATE VARIABILITY

The general trend on mean ambient temperature of semiarid zone of West Peninsula India has been increased by 0.07-0.81^{0}C climatically. In the study area the maximum trend in temperature has been increased 0.49^{0}C over Parbhani. Both mean maximum and minimum temperature have been raised in all stations except Nanded. The peculiarity in climatic behavior over Nanded may be due to poor availability of time series data. But in same time domain ambient temperature has been increased by 0.19^{0}C over Parbhani and 0.05^{0}C over Chikalthana. Though the accumulated precipitation is increased in recent climatic period the coefficient of variation(CV%) has been increased over Chikalthana and Parbhani but decreased over Aurangabad and Nanded. the climatic hazards was maximum over Nanded in earlier phase rather than the recent phase (Table 1). The climatic variation of recent micro climatic phase over Chikalthana and Parbhani is also evaluated and rainfall variability is increased in recent years over Parbhani even in micro phase(Table 2). The value of CV% and probability of occurrence of rainfall (CWC 1982, NIH 1991) indicate the tendency of climate vulnerability over Parbhani in the study area (Table 1,2).

Table 1. Statistical analysis of phase wise rainfall data.

Station	Duration for Phase I & Phase II	Long-term annual average rainfall in mm	CV% (Coefficient of variation)	75% non-exceedance probability of annual rainfall (mm)	Probability of occurrence of rainfall > 75% of long-term annual average(in %)
* West Peninsula India(WPI)	1901-1947	1149	14.9	> 1000	89
	1948-1994	1055	16.7	> 1100	96
• Aurangabad (AGB)	1902-1941	711	29.45	> 600	85
	1940-1982	772	19.36	> 700	85
• Chikalthana (CKT)	1952-1974	680	22.75	> 600	83
	1975-1997	773	32.03	>600	83
• Nanded (NND)	1963-1977	844.26	35.35	> 800	66
	1973-1992	1058	33.69	> 900	80
• Parbhani (PBN)	1944-1970	928	26.03	> 800	81
	1971-1997	938	30.41	> 800	78

*Data Resource IITM, Pune, • Data resource IMD, Pune

Table 2. Statistical analysis of micro phase rainfall data.

Station	Duration	Long-term annual average rainfall in mm	CV% (Coefficient of variation)	75% non-exceedance probability of annual rainfall (mm)	Probability of occurrence of rainfall > 75% of long-term annual average(in %)
Chikalthana (CKT)	1980-1988	714	36.64	> 600	70
	1989-1997	914	27.03	>600	100
Parbhani (PBN)	1980-1988	994	28.18	> 800	90
	1989-1997	1015	31.31	> 800	80

ANALYSIS OF DROUGHT

The main characteristics of a drought are associated with the decrease in water availability over an area for a particular period. In fact the water scarcity over a regional pocket may be evaluated through several drought indices. In this study the drought analysis is initiated by precipitation based drought as it is most responsive to climate vulnerability. Moreover the spatial and temporal data availability of rainfall is maximum over Indian region rather than actual evapo(transpi)ration, soil moisture and run off data. The area averaged normalized deviation of annual rainfall with respect to climatic zone of West

Peninsula India (Sing et al 1996) is used here as precipitation based drought index (Rao 1986). Annual rainfall below 20% deviation (>-0.2) from normal indicates no drought condition. Thedrought severity increases from –0.2 (20% deficit) to –1 (100% deficit) as –1 indicates no rainfall condition. The total available time series data over a station is equally phased by past (Phase I) and present (Phase II) trend to see the tendency of occurrence of drought along with its severity. The study indicates that the occurrence of drought and its severity is increased most over Parbhani and it is decreased over Aurangabad, Chikalthana and Nanded (Table 3). The qualitative study indicates that the periodicity of precipitation based drought over the area is 0-6 years. The average tendency is consecutive three mild to moderate drought years. Hence the feedback of climate vulnerability is a danger of Parbhani. In addition the human population pressure, a primary parameter of socioeconomic drought certainly enhances the possibility of desiccation and/or desertification process over the area. The impact of climate vulnerability as well as population pressure over Parbhani has been assessed using available river discharge, evapotranspiration, human population and remote sensing data.

Table 3.Occurrence of meteorological drought with severity over the area.

(Area Averaged Normalized Deviation of Rainfall)

	Phase	Duration	Drought severity				
			No (<20% deficit)	Mild (20-39% deficit)	Moderate (40-59% deficit)	Severe (60-79% deficit)	Extreme (80-100% deficit)
Aurangabad	I	1902-1941	9	16	10	5	0
	II	1940-1982	10	23	7	0	0
Chikalthana	I	1952-1974	2	13	6	1	0
	II	1975-1997	8	6	6	1	0
Nanded	I	1963-1977	4	7	2	1	1
	II	1978-1992	9	4	1	0	0
Parbhani	I	1944-1970	15	9	3	0	0
	II	1971-1997	13	10	04	0	0

Annual river discharge and soil moisture stress (actual evapotranspiration/potential evapotranspiration, Saha 1993) have shown decreasing trend temporally and it indicates the interactive water scarcity for the growth of flora and fauna. The phase wise mean normalized deviation of annual river discharge as drought index (ARDI), soil moisture deficit as drought index(SMDI), normalized deviation of human population pressure index (PPI) are presented in Table 4. The periodicity of river discharge based drought is also 0-6 years. The correlation between precipitation based drought index and ARDI is quite significant (Correlation Coefficient = 0.7, P=0.012). The correlation with SMDI is not well established. The normalized deviation of vegetation index (NDVI) (Owe et al,1988) is evaluated using IRS 1A LISS-I May 30,1989 and 1B LISS-I May 28,1998 remote sensing data. The drought watch matrix over Parbhani has shown tendency of water scarcity (Table 4).

IMPACT ASSESSMENT

The integrated impact of climate vulnerability, drought severity along with periodicity and population pressure has been assessed on water degradation and degeneration of vegetation. The available IRS 1A and 1B LISS-I digital data of closest Julian day has been used in 10 year domain under clear sky condition (Figure 2,3). The time difference is maximized considering availability of remote sensing data of same generation. The thematic layer is evaluated from difference image for each land cover degradation. The hazards zone has been detected in a part of Yeldari and Siddheshwar reservoirs. Many small water bodies are degraded (Figure 4). The tendency of shift cropping has been observed along Purna river bank (Figure 2 and 3). The vegetation is significantly degenerated in Basmath crop belt which is a main local resource of agriculture (Figure 5).

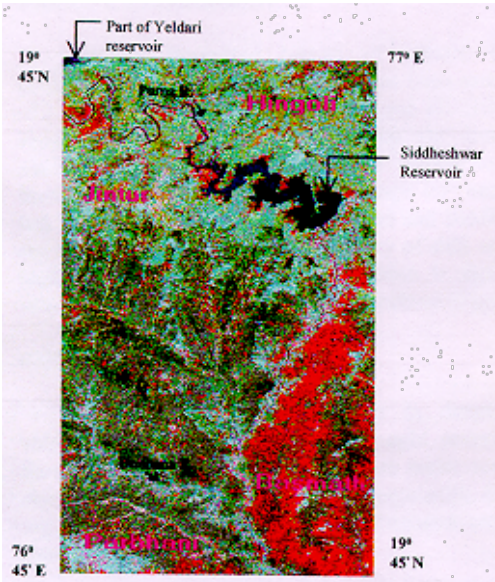

Figure 2. FCC (IRS 1A LISS-I) of band 234 of a part of P027R54 dated 30 May, 1989

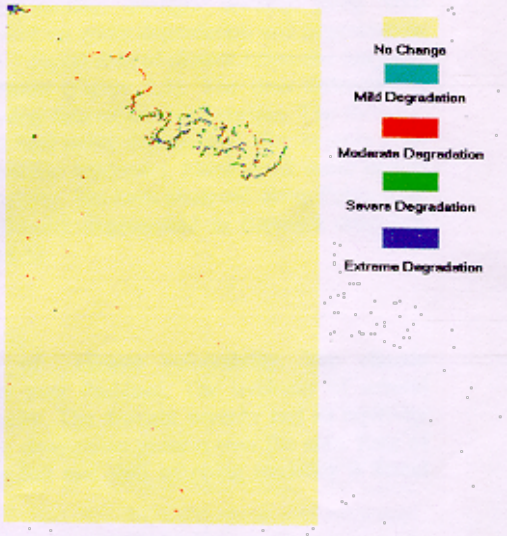

Figure 4. Water degradation, 1989 - 1998

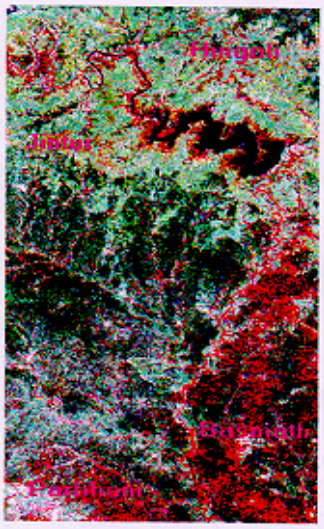

Figure 3. FCC(IRS 1B LISS-I) of band 234 of a part of P027R54 dated 28 May,1998

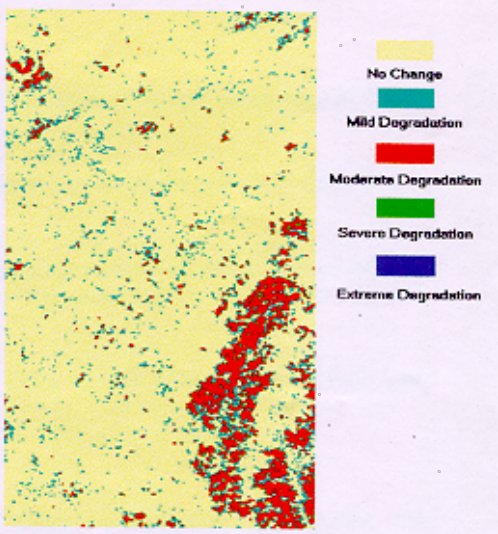

Figure 5. Degradation in Vegetation, 1989 - 1998

Table 4. Drought watch over Parbhani.

Year	Drought Index	PARBHANI	Remarks
1989	ARDI SMDI PPI NDVI	-.11 0.741 0.29 -0.013	-1≤AND<0, -1≤ARDI<0, 0≤SMDI<1

1998	ARDI SMDI PPI NDVI	-.214 0.593 0.65 -0.033	& PPI>0 indicate deficit values
Difference (1998 - 1989)	ARDI SMDI PPI NDVI	-0.104 -0.148 -0.36 -0.02	Drought intensity has been increased with time

CONCLUSION

The zone of Parbhani is in danger of climate vulnerability. The climate vulnerability has great role on drought severity over Parbhani. The tendency of several drought indices over Parbhani indicate water scarcity. The drought severity and its repitivity along with population pressure are responsible for desiccation process over the area. Rate of vegetation is decreased recently in Basmath crop belt and shift cropping tendency is found along the river bank of Purna.

More time series satellite data is required to delineate quantitative rate of desiccation and degeneration process.

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