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Temporal orbital satellite images in the drought assessment and early warning decisions

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Abstract
The dependency on rainfall for agriculture and household purpose is very high in Deecan plateau. The crop failure not only leads to scarcity of food but also fodder. The water availability needs to be assessed immediately after monsoon and the demand and supply should be evaluated towards the crucial requirement during summer. Orbital satellite data were used in assessing the surface water availability and spatial distribution of crop area and their requirements. The possible water shortage during summer was evaluated for an area located at a rain shadow region in Maharashtra, India.

INTRODUCTION

Drought is one among the meteorological hazards that affect the people and their living conditions. It is a temporary aberration, recurrent feature of climate and differs from aridity, which is a permanent feature of climate. It occurs virtually in all climatic zones. It is defined as a deficiency of precipitation over an extended period of time results in water shortage and extensive damage to crops resulting in loss of yield. It begins with agriculture because of its heavy dependence on soil water. Drought management and planning of regional or local level requires information from monitoring, assessment, and vulnerability analysis in developing a warning / alert services. Advancements in technological observation, data collection and storage and retrieval systems provide vital support in decision making.

Drought hazard assessment
It requires information on the probability occurrence of an event from observation records and assessing their likely areal extent, duration and intensity. Vulnerability analysis includes mapping areas likely to be affected by drought and potential damage to lift and property. Effective early warning includes knowledge gained from hazard assessment and vulnerability analysis that is then incorporated into land use planning and structural design.

Space Technology
Earth observation satellites provide comprehensive, synoptic and temporal view of large areas in real time. Communication satellites aid in the dissemination of information. Stationary and mobile very small aperture terminals (VSAT) and ultra small aperture terminals (USAT) and array of antennae help in position, location and co-ordination of disaster relief operations, in addition to alert services (Rao 2000). Geo-stationary and Polar

orbiting satellites' (INSAT and NOAA) data provides information for long term rainfall prediction. Passive visible and thermal wavelength band information of the optical sensors is extensively used in the land cover (Torma 1997) monitoring and assessment. Active microwave sensors (Ijjas 1992) such Synthetic Aperture Radar (SAR) from ERS and RADARSAT provides terrain images in adverse weather conditions and also during day and night hours. High ground satellite imagery is increasingly applied in monitoring drought conditions through vegetation indices and other approaches. Tucker et al (1987) used band ratio techniques on AVHRR and Landsat MSS data in the generation of biomass and spectral vegetation mass and specific episodes of drought in Sahel. Rainfall and NDVI shows a positive correlation in diverse vegetation cover regions of east Africa (Davenport 1993). Pinder et al (1999) used Landsat TM band ratio (5/4) of before, during and after the severe drought and derived relationship with the tree growth. Venkataratnam et al (1993) used single frequency and polarization and look angle of SAR in determining the soil moisture in top 15cms of surface layer. Soleberg (1994) combined Landsat TM and SAR images (fusion technique) to improve the accuracy of specific inferences on the ground. Helen (1986) found that integrated ground observation, air-borne and satellite data in GIS system is most effective in monitoring Goja-Shewa area of Ethiopia.

Indian Scenario

India is one among the regions that is frequently affected by drought and famine. About 100 million US$ is spent for this purpose annually. About 19% of total Indian land and 39% of total cultivated land is frequently affected by this event. It is estimated that Indian Gross Domestic Production has decreased by 7% by crop loss and 36 million tons of food production was lost during the 1987-88 drought (Basu 1985). 50% of the drought area is located on Deccan plateau and 12% of Indian population lives here. Drought events occur every 5th year and it becomes severe on the 8th or 9th years. Marathwada region in the Deccan plateau is one among the rain shadow areas of Indian Peninsula. Monsoon rain fluctuation affects the surface and sub-surface water availability. Minor tanks and reservoirs were built to store water is not functioning efficiently. The water requirement during summer needs to be considered prior to utilization of the scarce resources prior to the crucial period of a monsoon region.

OBJECTIVES

The main objective of this study is to monitor the land use land cover features using IRS satellite data, evaluate the crop water and human demand and assess the probability of a (deficiency in water) drought event in a self sustainable region.

STUDY AREA

Location and Rainfall

About 12 km^2 area of sub watershed of Manas river in (about 700 km from Bombay) Nanded district of Maharashtra has been taken up for this study to demonstrate the usage of remote sensing data in the self-sufficiency of water resources management within the watershed (Figure.1). The run-off from the catchment water is stored in a minor irrigation-Maalgujari tank, built 400 years ago by Krishna Devaraya at Kandhar. The recorded yearly rainfall event for the years 1951-1999 varies between 453-1132 mm. About 90% of the annual rainfall are received during June-September (Figure.2). Water scarcity was reported during the year, that has recorded a total monsoon rainfall of 600mm or less. The maximum and minimum temperature ranges between 45^0C (April/May) and 15^0C (November/December) respectively. The evaporation from the water surface area and evapo-transpiration from the cultivated areas are high during April-May.

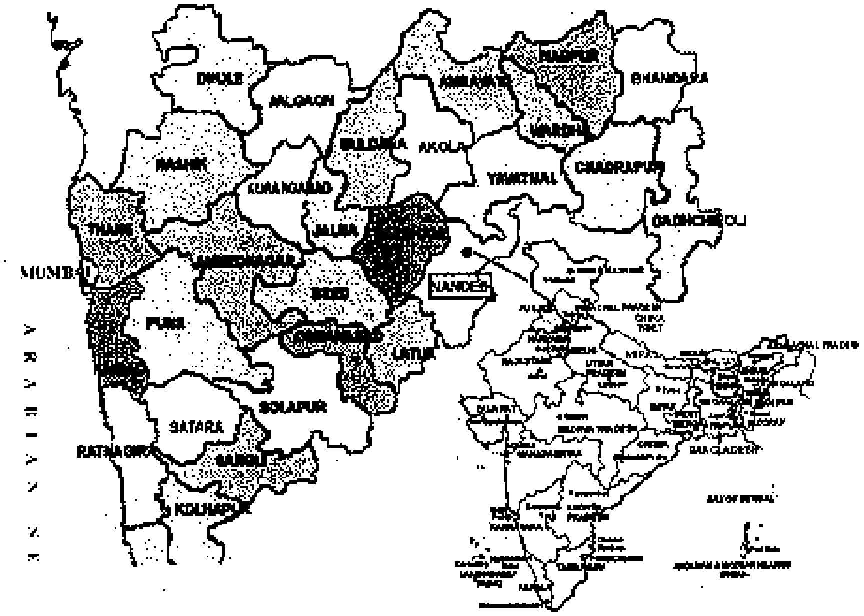


Figure 1. Map of the study area.

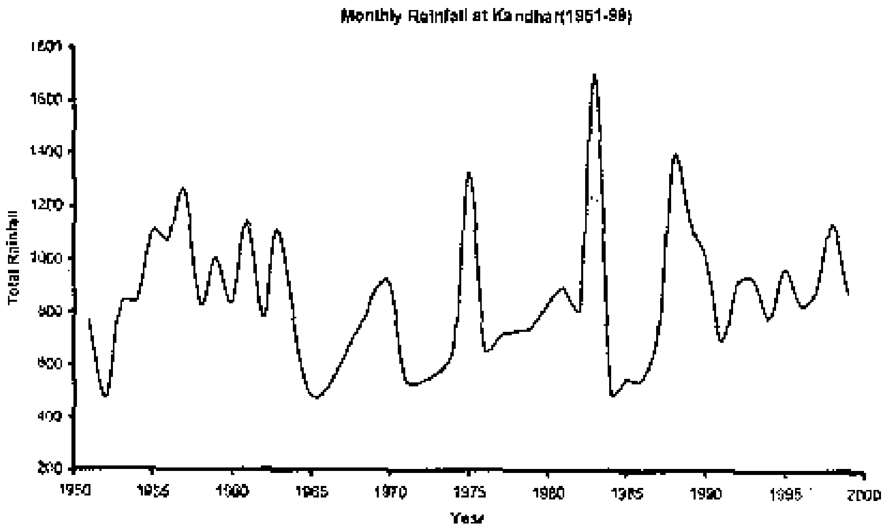
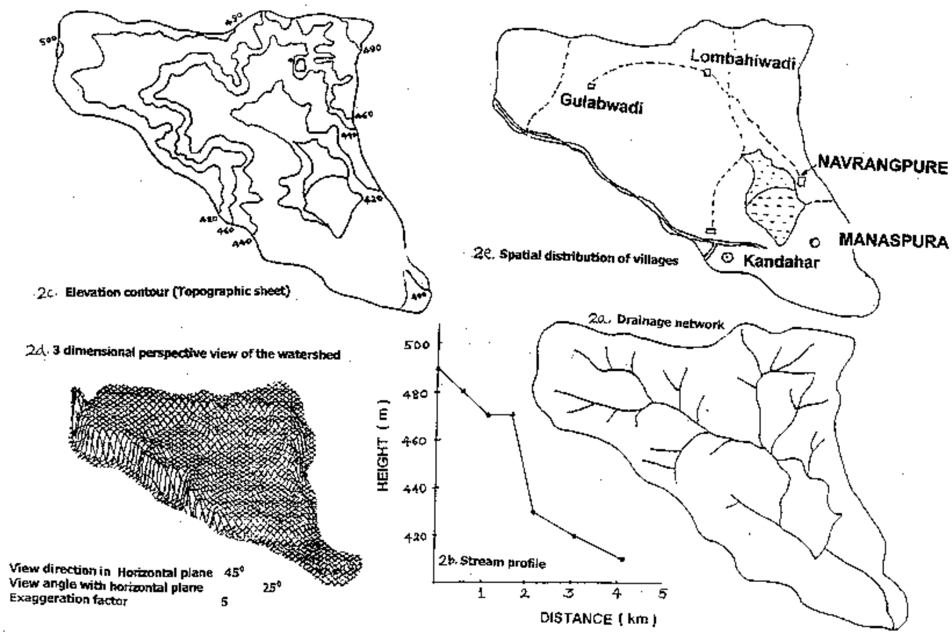


Figure 2. Recorded yearly rainfall event for the years 1951-1999.

Drainage and Slope

Spatial distribution of drainage network of the area is shown Figure 2a. Twenty-five first order, eight, -second order and one third order streams drain the watershed onto the reservoir. Drainage density is less than 2 km/km^2. Slope profile of the 3rd order drainage was constructed and shown in Figure 2b. It shows a break in the slope on the upper reaches. This site could be used for development of water harvesting structures. 400 and 500m (above MSL) elevation contour was observed in the entire basin (Figure 2c). Areas having natural slope more than 10^0 are found only on the periphery of the watershed. 1-5^0 is predominant over the rest of the region. The elevation contours were digitized and created a 3 Dimensional perspective view of the catchment and reservoir (Figure 2d). This fly-wire image can be used in spatial water distribution planning.



Figures 2a-e. Terrain information of the study area.

Rock type and cultivated areas

Basalt of Cretaceous to Eocene age with massive and amygdaloidal variety along with red bole (marker bed) is exposed in the region. Ground water availability is confined to jointed/fissured and weathered rocks. Open dug wells exploit the shallow aquifer goes dry during April. The piped drinking water supply sources it from the reservoir. Rainfall and the availability of water in the tank govern the crop type and pattern. Rice, sugarcane and Banana cultivation is dominant (10% of the total cultivated area) in the reservoir and its surrounding in addition to downstream areas. Table 1 shows the crop area and type in this region Water intense cropping pattern is increasing every year. Dry land crops are sown in other parts occupies 30-61% of the cultivated land. The natural vegetation cover density is poor. Even the undergrowth/bushes were cut for wood fuel. The entire down stream of the lake is mostly black soil. Cash crop such, as sugarcane and banana plantations are grown here.

Table 1. Land use and land cover features of Kandhar area.

Land cover features	November 1991	November 1999
Dense vegetation	0.050	0.045
Moderate vegetation	0.1500	0.10
Low/Sparse vegetation	2.7200	2.730
Matured crop land	1.500	1.6
Standing crop	1.025	1.03
Fallow land	1.865	1.765
Open area	4.0625	4.1625
Rock outcrop	0.0725	0.0725
Reservoir/pond	0.5075	0.6025
Sediment laden area	0.0625	0.0425
Total	12.15	12.15

Surface cover and villages

The open area in the catchment is infested with cobbles and pebbles. Even though rain-fed pulses are grown this region, the soil moisture meets the optimal water demand during the crop period. The infiltration was determined (October/May) using double ring infiltrometer and open pit methods. The infiltration rates were 13/cm^3/ hr and 8 cm^3/hr respectively. It indicates the poor water retention capacity of the soil over the catchment and need for irrigation. Spatial distribution of the five villages is shown in Figure 2e and their population and crop area information of the revenue department is given in Table 2. The population density ranges between 1.26 and 28.0 persons/ha and the watershed average is 6.62 persons/ha. The growth rate is less than 1 owing to the drought events.

Table 2. Ground based data collection (Revenue department).

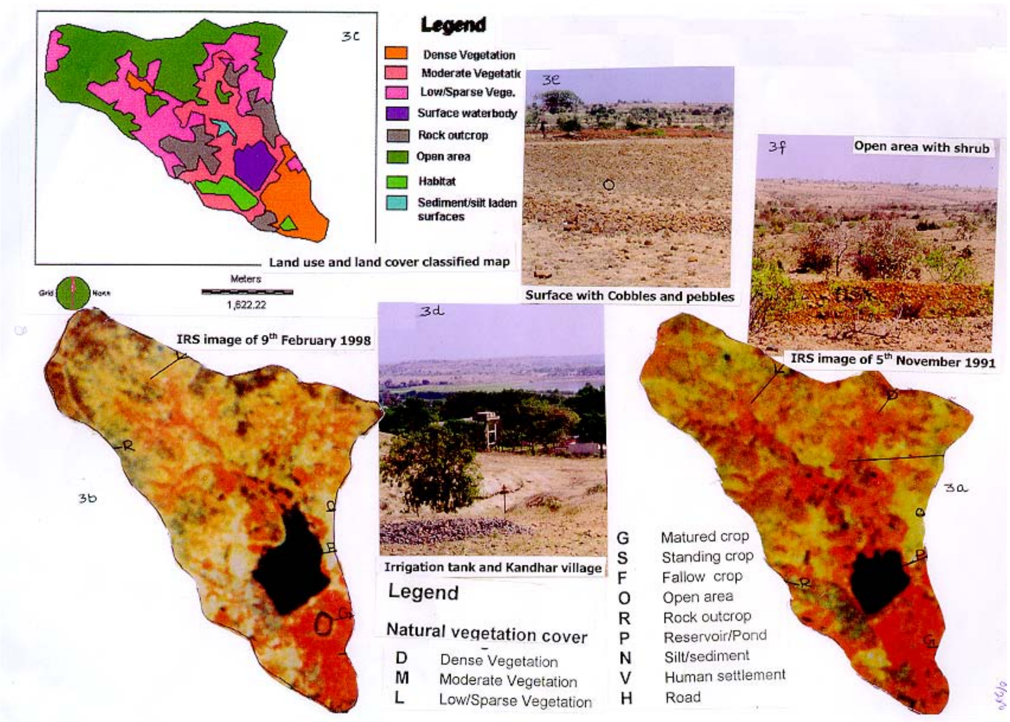
Village	Population		Total area (ha)	Cultivated area (ha)	Crop area (ha)			
	1991	2000			Rice	Sugarcane	Cotton	Rest
Gulabwadi	402	450	355	215	3	-	85	127
Lumbajiwadi	120	180	100	80	6	-	50	24
Navrangpura	792	862	401	253	3	-	109	141
Kandhar	14065	15065	537	295	15	16	105	516
Manaspura	1751	1901	1334	690	14	4	275	397
Total	17144	18058	2727	1533	41	20	624	1205

Crop water requirement of Rice 0.010 mcuft/ha; Sugarcane: 0.060 mcuft/ha
Dry land crop (Rest) 0.010 mcuft/ha. (Source Michael 1998)
Rest: Jowar, Moong Tal, Udit dal, Teel oil, Haldi, Mirchi, Ambadi etc
Human requirement: 200 lt./day Cattle: 100 lt./day

SATELLITE DATA ANALYSIS

Orbital satellite images (optical range) were used in the estimation of land use and land cover areas in the watershed. False Color Composite of Indian Remote Sensing data of May 1989, November 1991 February, 1998 November1999 and May 2000 were used in this study and Figure 3a and 3b show the data corresponding to November 1991 and February 1998 respectively. Land cover features interpreted and mapped include: - Natural

Vegetation Cover Density -dense (D), moderate (M), sparse/low (L); cultivated land - fallow (F), standing crop (S) and matured (G) crop; non-cultivated areas- open area (O), rock outcrop (R); water bodies - lake/pond /reservoir (P); human activities- settlements (H); and Road (A). Table 2 shows the land cover features and its variation. The place and its surrounding water storage are clearly identifiable from the LISS III data. Ground based data collection was carried out during October and April to verify the surface cover. Land use and land cover patterns were digitized and shown Figure 3c. Maalgujari tank and the Kandhar village, cobble and pebble infested surface area and open areas with shrubs are observed during the field visits are shown in Figure 3d, 3e and 3f respectively. Natural vegetation cover in patches in the catchment covers the area and fallow and open area is increasing. Trees are being cut for fuel wood. Cash crop cultivation is on the increase. Assessment of field irrigation requirement is vital in flow regulation.



Figures 3a-f. land cover features as seen by orbital remote sensing data, ground observations and classified map.

SUMMARY AND CONCLUSION

Dry land farming activities begin in May and sowing is completed before July every year over the catchment. Flowering of crops during November-December requirement uninterrupted water for crop production. Total water requirement from the rain-harnessed water is the critical in planning. The crop area was determined from the satellite data. Due to ground resolution of individual farms and homogenous cropping pattern, the crop type could not be ascertained. However, the percentage of crop type recorded by the revenue department was considered. Individual crop and human and animal requirements suggested by Michael (1998) was used in the estimation of water demand.

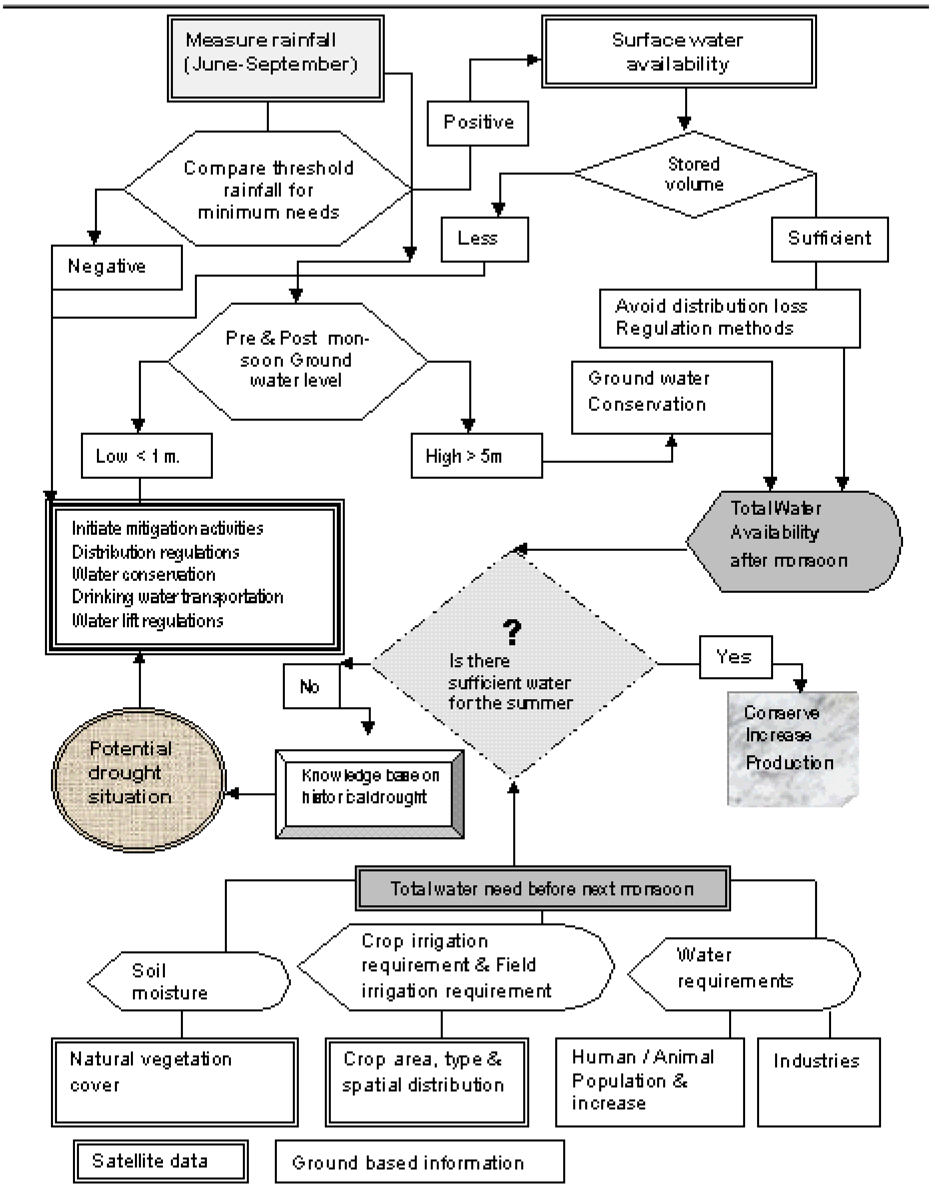


Figure 4. Flow chart showing the methodology for drought susceptibility assessment immediately after monsoon.

There is no water consuming industry in this area. Crop requirement is estimated to be 15.25 mcuft and the human and animal requirement is 19674.27 cuft. /day. It is assumed that 50% of the rainfall is available for surface storage. It is estimated that the area need

700mm of rain every year to meet the current trend of cultivation practices (growth of sugarcane/rice/banana). The year receiving rainfall lesser than the threshold would be beginning of drought event. Figure 4 summarizes the methodology adopted in this study, which could be used effectively.

It may be concluded that synergistic use of optical and radar satellite could be effectively used in monitoring the water demand and supply of areas susceptible to drought event. Based on the situation assessment immediately after monsoon, water conservation measures for summer and impending disaster (severity) could be effectively communicated to people. Conservation measures could effectively tackled with their effective co-operation.

Acknowledgement
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