PC BASED LAND INFORMATION BASE FOR LOCAL ADMINISTRATION IN DROUGHT ANALYSIS AND MITIGATION A CASE STUDY FROM DECCAN PLATEAU, INDIA

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ABSTRACT

Orbital satellite borne multi channel and sensor generate enormous data on meteorology and land cover for analysis. It could be used in comparing the current situation with that of past and issue warning on the forthcoming drought. There is a need for an integrated information system having distributed database at local level. This base can also be used in export and import of real time information on situations with co-ordination units and guidance. This study highlights the land information base developed for this purpose and tested for a watershed in drought prone Deccan plateau in India.

1.0 INTRODUCTION

The worldwide computer net work leads to a revolution with regard to the amount of information available for exchange. Enormous amount of knowledge of and about data sets is communicated between organizations. The existing computer based tools have much strength over the traditional data exchange methods. The cost, in time and effort, of data collection, management and maintenance, form a substantial proportion of resources of individual organizations. Information necessary for decision making during natural hazards such as drought is diverse and is mostly spatial and temporal in nature. Drought is a temporary aberration, recurrent feature of climate and differs from aridity. It occurs virtually in all climat 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 section (heavy dependence on soil water), then people dependent on source of water and diminishes with agriculture sector, soil water and source of water. Its impacts on society result from the interplay between a natural event (less precipitation than expected resulting from climatic variability) and demand people place on water supply. The demand for economic goods is increases wit increase in population and per capita consumption.

Different subject perspective of drought, input data required and concept of land based information system is summarized in Figure1. **Meteorological drought** is defined on the basis of

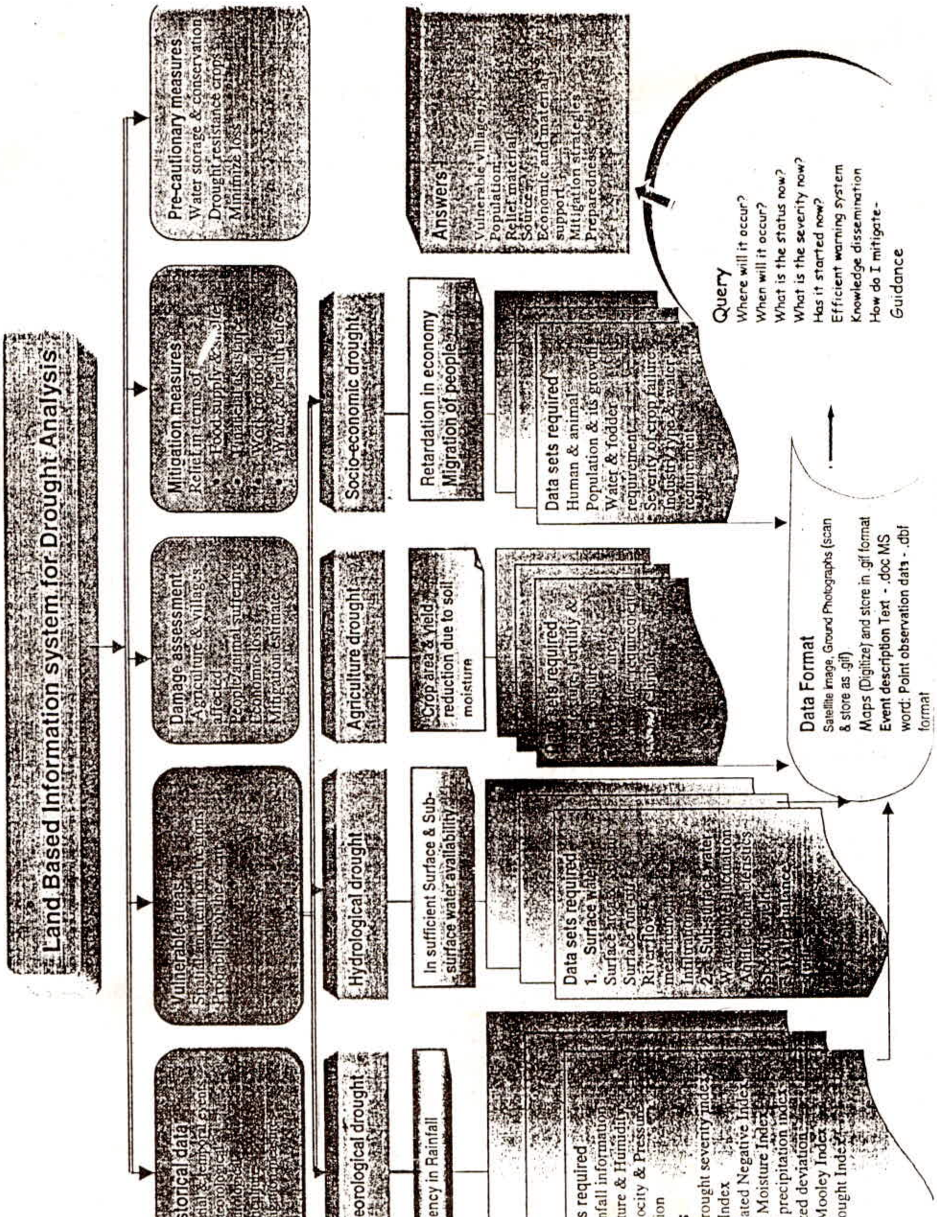

Fig. 1 : Land Based Information system for Drought Analysis

the degree of dryness and the duration of the dry period of a region. **Hydrological drought** is the effects of periods of precipitation shortfall on surface or subsurface water supply (stream flow, reservoir, Lake Level, groundwater) on a watershed or river basin scale. Changes in land use (deforestation), land degradation and the construction of dam affect the infiltration and runoff rates, resulting in variable stream flow and drought over downstream. **Agricultural drought** links various characteristics of meteorological/hydrological drought to agricultural impacts focusing on precipitation shortage, differences between actual and potential evapo-transpiration, soil water deficits, reduced ground water or reservoir level. **Socio-economic drought** associate with supply of water, forage, food grains, fish and hydroelectric power and demand of some economic good with elements of meteorological, hydrological and agriculture drought.

Advancement in technological observation and data collection and storage and retrieval systems provide decision makers vital information on: (1) a measurement of abnormality of recent weather (2) opportunity to place current status with the historical perspective and (3) spatial and temporal representation of historical droughts. Vulnerability analysis of drought is estimated based on, Biological (Agriculture), Meteorological (rainfall), Hydrological (water resources), Socio-economic (population, health) indicators. It is carried out assuming that it: (1) affects all areas and groups equally, (2)it is a process not event, (3) leave observable indicators and reflects severity and (4) select indicators are sufficient to warn and initiate mitigation activity. Hence, there is an immediate need for a system to store information collected at local level on a compatible format (for vertical integration and easy either way flow) which could be used in the integration of regional, country and global level analysis/forecast.

High resolution, resource satellite sensor data of Landsat, Indian Remote Sensing (IRS), SPOT and others are being used for surface cover monitoring and crop and surface water assessment. Near real time evaluation of in-situ and remote sensing data allows the physically based drought warnings in advance. Olsson (1985) estimated the bio-mass and albedo interpreted from satellite data and derived a relationship with population pressure. Change in Normalized Deviation in Vegetation Indices (NDVI) was correlated with crop moisture index (Rao et al. 1992). NDVI threshold of >0.5 throughout the crop season matches with crop yield (Jayaseelan et al. 1996). Meteorological data is collected by various agencies at local/regional on a dissipated manner. They are being used in estimating the meteorological drought indices such as Palmer drought severity index, Dryness Index, etc. Geo-stationary and polar orbiting satellite data are the potential source of information for meteorological data (precipitation intensity, amount and coverage, atmospheric moisture and winds, soil wetness etc.) evaluation, integration, validation and integration. Spatial distribution of Rainfall is achieved by integrate radar, rain gage and remote sensing techniques. Accumulated Negative Index, Negative Moisture Index, Standard precipitation index (SPI), Normalized deviation (ND), Bhalme Mooley aridity Index, Palmer drought severity index indicate the severity and onset of an even (Oladipoi, 1985). Land use, aided by slope and depth to water table fluctuation influence the severity of drought (Reed 1993). Indian Meteorological Department compares the average rainfall (70-100 years) and estimated deviation in rainfall and classify them in to normal (+19% to –19%), deficient (-20% to –50%) and scanty (>60%). Irrespective of data availability and their utility by several experts, a simple integrated information system for middle management level is not available at the regional/local level.

The main objective of this study is to develop a simple and low cost, land information base system, to store information of past and present events for comparison, using orbital temporal remotely sensed and ancillary data in understanding the situation and planning.

2.0 METHODOLOGY

The relevant and total data requirement for this study, could be classified in to spatial (maps, images), point observation (table) and text information (description of events). Multi date data collection would aid in comparison of historical events with that of the present and improvements of management techniques. Land use and land cover, water surface area (reservoir), area under cultivation and human settlement of the past and recent years were interpreted from orbital Indian Remote Sensing (IRS) satellite data. Area of individual theme unit was measured. Contour elevation, forest boundary, drainage network, spatial distribution of villages and communication network information was taken from topographic sheet. Site based information on, spatial distribution of wells and ground water data (aquifer characteristics), meteorological data (rainfall, temperature, wind speed etc.) and population of human/animal were collected during the field visits. Infiltration and evaporation characteristics were measured from representative natural surface. Ground condition, corresponding to the satellite date of pass was collected. A knowledge based information rule indicating the various parameters of drought was created from the historical data. Satellite images and photographs were scanned, spatial information – maps were digitized and point attribute data was tabled. The common query and desired reports, which would facilitate mitigation groups at the time of crisis, were created.

3.0 CREATION OF INFORMATION BASE

3.1 Data requirement and sharing

The information required to be stored in the system comprises of thematic components such as :- (a) source data processing capability, (b) data base, (c) interactive software tools and (d) application modules. Source data has wide range of spatial and point based climate, topographic, soil, cadastral, land use data etc. storage was relationally structured.

Considering the advancement in networking technology, the local area information base was created using the minimum hardware and software (widely used) facilities. This would not only encourage the participation from the locals, but also avoid in degradation of data. The following resources were used: - **Hardware :** 486 Personal Computer with color monitor, Digitizer 48" x 24" size, Inkjet plotter/printer, Networking hardware. ***Software :*** PC-ARC-Info GIS version, MS access, Dbase IV, Visual Basics 5.0, Windows NT 4.0 operating system, Local area Networking Software, Norton, html, ftp and http for internet access etc. Figure 2 shows the data collection, storage, manipulation and reporting of the system.

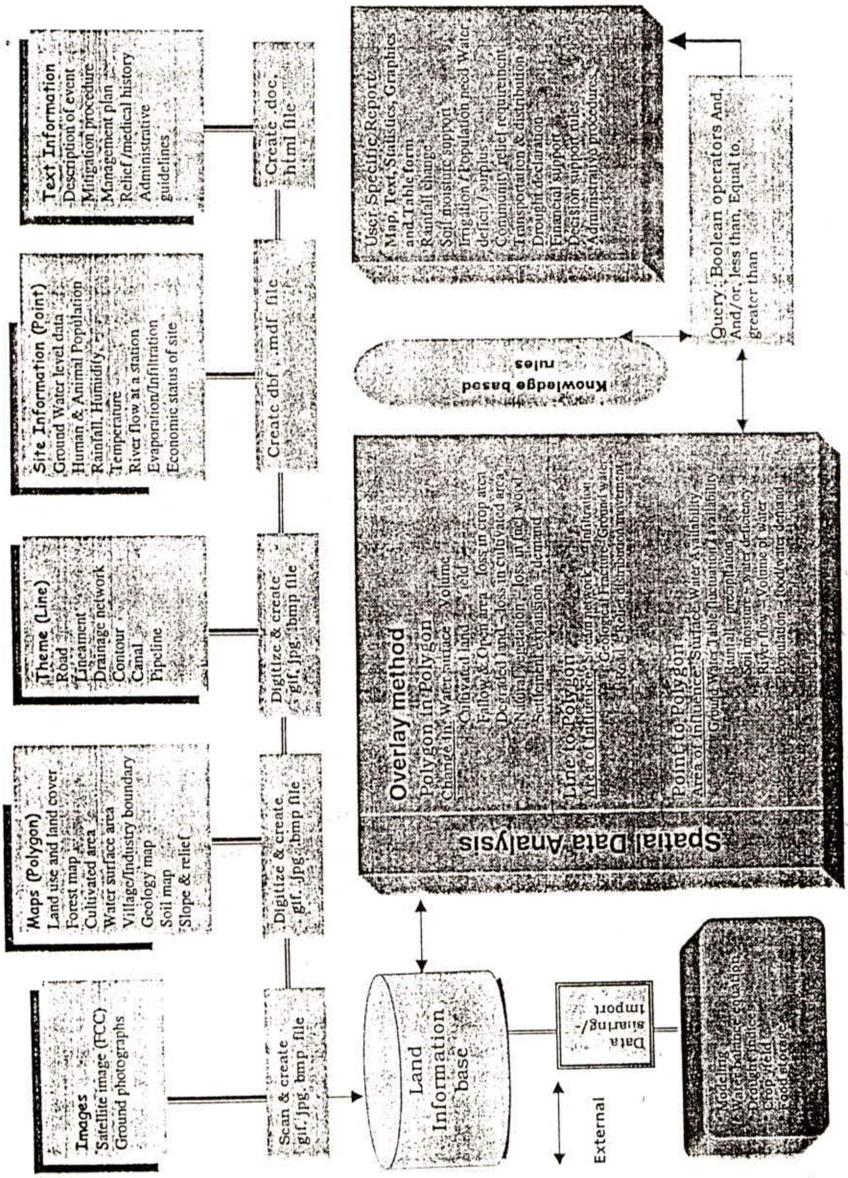

Fig. 2 : Flow chart showing the spatial data analysis and report generation

Data input from different sources such as thematic maps, photographs/satellite images, point based data were scanned /digitized and created digital files and stored with data security, onto the system. Various theme unit boundaries were represented by polygon and theme attributes by polygon identifier. The identification mark enables the link between the spatial and attribute database. Ground photographs and images were identified by their ID address. Attribute data were logically linked by relational data base concept through associate data items. They were matched by their identification.

Knowledge based and evidential reasoning methods have been tried and evaluated in a number of applications (Jankowski 1995 and Kraak et al. 1995). These methods use the ancillary data, heuristics and facts may be very simple or highly complex, Boolean operations are performed on a regular grid basis using either raster or vector data structures. It is also known as sieve mapping and has been applied successfully in many applications. A comprehensive knowledge on the prevalent parameters of the drought events of the past would aid in understanding the current event. Evidential reasoning is an approach which has become relatively popular for combining multiple pieces of evidence coming from different background knowledge and ancillary information. Table 1 shows the knowledge-based rules for drought assessment, derived from the past events. The present condition of a parameter is compared with the range observed during the past. Their probability of occurrence is classified as Very High, High, Moderate, Moderate to low and low. This decision aiding rules would ease the mitigation process. Retrieval of information is accomplished by Queries, relational operators such as union, difference, join, restriction etc.

Map overlay technique was used for change detection/assessment of crop/water surface area in estimating the crop water requirement or volume of water availability. A simple drought indices (a thumb rule type) that would indicate the status or onset of drought were calculated using the meteorological and other pertinent data sets.

This information base could be accessed through Internet and Intranets. The subject expert can download data/images, analyze it and share his opinion on the severity of event and relief operation with the relief managers. Further, financial and material assistance could be dispatched to the needy people. The probable opinions/relief of strategic importance can, be offered in the interest of the mankind. The html files could be exported or file-containing results may be downloaded (ftp). The status of the ground and aerial view can be of visualized. The information needed by user/mitigation/relief workers can be generated.

4.0 STUDY AREA

4.1 Drought in India

India is one among the region that is frequently affected by drought and famine. About Rs.200 crores is spent on drought prone area in India (Basu1985). The exchange of information between the site and the co-ordination unit on a traditional mode takes enormous time and right kind of

Table 1. Knowledge-based Rules for Drought Assessment

Parameter	Very High	High	Moderate	Moderate/Low	Low
Annual Rainfall	<400 mm	400-500mm	500-600mm	600-700 mm	>700 mm
Temperature °C (Average)	>38	38-35	35-30	30-28	<25
Normalized Deviation (ND)	<-0.60	-0.6 to –0.4	-0.4 to –0.2	-0.2 to +0.2	>+0.2
Standardized Precipitation (SPI)	<-2.0	-1.99 to –1.5	1.49 to 1.0	-0.99 to +0.99	>1.0
Palmer Index	<-4.0	-3.99 to –3.0	-2.99 to –2.0	-1.99 to –1.0	>-1.0
Aridity Index (Ia)	<21.2	21.3-37.2	37.3-42	42.1 –50.9	>51
Dryness Index(Id)	>53.1	39.4-53.0	39.3-35.0	35.0-26.0	<26.0
Pa	27.4	27.5-38.5	38.6-42.0	42.1-55.0	>55.0
Evaporation	>8.0	8.0-7.0	6.0-7.0	6.0-5.0	<5.0
Infiltration	>40	38-40	35-30	30-25	>25
Inflow to discharge	>3	3-2	2-1.5	1.5-1	<1.0
Water level fluctuation	>15	10-15	5-10	5-3	<3
Water Surface area change	>60%	60-50%	50-40%	40-35%	<35%
Crop area	>75%	60-75%	60-50	40-50	<40%
Irrigation intensive Crop area	>60%	60-50%	50-40%	40-30%	<30%
Decrease in crop yield	>80%	80-60%	60-50%	50-30%	<30%
Yearly Population growth	>50%	50-40%	40-30%	30-25%	<25%

information is not available at the time of decision making. Further, some of the relief measure options are not considered in the decision making process due to non-availability of total/complete data sets. Some of the reported events portray a very worst situation. A continuous famine for 12 years was reported during 310-298 BC and Jhelum river in Kashmir was completely dried up during 1917-18. From, the historical data, it is observed that this event occurs once in eighth or ninth year in arid and semi-arid regions. About 19 % of the total land and 39% of the cultivated land is often affected by drought. About 50% of the Deccan plateau are drought prone and faced severe drought during 1985, 86, 87 and 88. The gross domestic product of India has decreased by 7% due to loss of crops; 286 million people were affected and total loss of what, rice and coarse cereal crop production accounted for 36 million tonnes during severe drought of 1987-88. A reliable and timely information on the historical event and its damage control efforts is needed in developing an efficient and innovative strategy to combat drought.

4.2 Study area- Jhod nadi watershed

The system thus developed was used in creating an information base for a small watershed in Marathwada region, India, often classified as rainfall deficient zone. (Figure 3). Parbhani and Nanded districts of Mahsrashtra are one among the drought prone area in Deccan plateau in India. A portion of this region covering the Jhod nadi watershed of 190 km^2 has been taken up for this study. It has suffered severe drought and famine in the past.

Jhod nadi, tributary of Godavari River drains about 190 km^2 of area. It is a fourth order stream and is controlled by fractures. There are no minor irrigation facility is this watershed. However, canal irrigation system from the nearby scheme is being attempted.

4.3 Meteorological data

The climate is generally dry except during the southwest monsoon season (June-September). About 90% of the average rainfall of 890 mm are received during the monsoon and frequently it goes below 400 mm. Highest temperature of 44.4^{0}C (May) and lowest of 13^{0}C (January) was recorded at this place. The relative humidity is high (60-80%) during monsoon and decreases to less than 30% during May/June.(Table 2.a)

Table 2 a : Meteorological data

Month	1998				
	Temperature (Min & Max °C)	Humidity %	Wind velocity km/hr	Rainfall (mm)	Evaporation mm/day
January	12-33	34-56	4.6	7.5-3.2	4.3
February	14-35	28-46	6.4	5.0-0.0	5.3
March	18-40	26-42	7.8	11.6-0	6.9
April	23.43	27-42	9.2	8.8-9.6	8.6
May	25-44	27-46	12.7	19.9-18.7	9.0
June	27-40	47-70	16.3	154.5-62.7	5.5
July	22-40	65-81	14.6	218.7-0:0	2.1
August	22-35	63-81	11.9	190.9-0.0	1.9
September	22.33	64-81	10.4	197.7-0.0	2.9
October	17-30	46-67	6.5	59.9-11.0	3.5
November	11-32	38-59	5.2	23.0-0.0	3.7
December	10.5-31	35-58	4.5	9.6-0.0	3.8

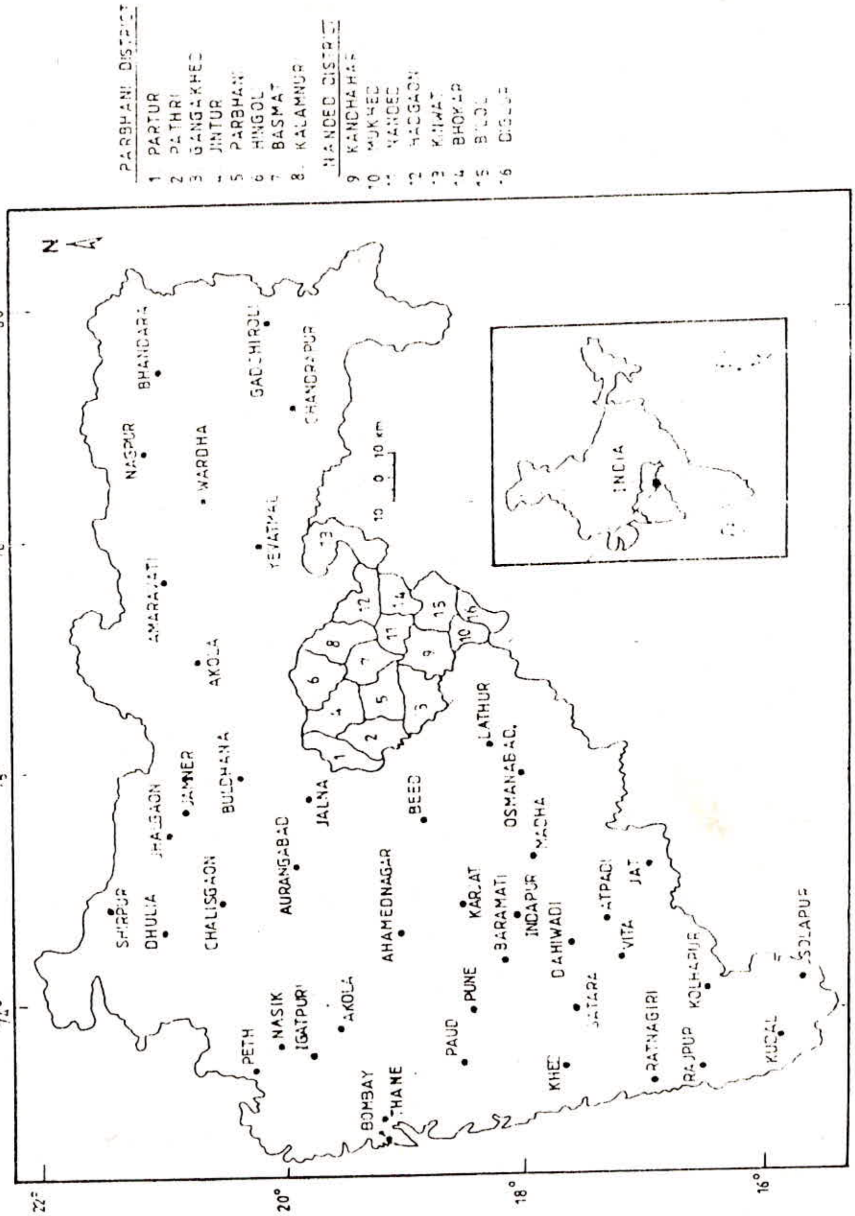

Fig. 3 : Location map of the study area

4.4 Soil and crop information

Soil map shows the presence of lateritic and sandy soil. The soil type/texture, water retaining capacity and permeability is important in ascertaining the favorable conditions of farm plots and yield. Majority of the soil is light to dark shades of gray brown in brown color. They are moderately high in soil reaction (pH 8.06-8.84) with total soluble salt content of 0.26-.0.94%. The percentage of clay content is high (70%) on top layers and low (less than 20%) in bottom layers. Select sections of the upstream watershed have soil cover having 70% of cobble and pebbles. The infiltration characteristics and evaporation rate of this region is shown in Table 2.b. Infiltration during rainfall through this layer of recharge onto the shallow aquifer important for soil moisture support of the plants.

Table 2 b : Soil Type and Infiltration Rate

Soil Type	Infiltration Rate (inches/hour)
Deep Sand, Loess	0.30-0.35
Sandy Loam	0.15-0.30
Clayey Loam, Shallow Sandy Loam, Low Organic Clay	0.05-0.15
Heavy Plastic Clay	0.0-0.05

In general, area is covered by natural vegetation (mostly in patches) is on the descent and fallow and open land on the ascent. Cultivated lands are adjacent to the drainage network. Degraded surface cover is on the rise. Rainfall determines the crop pattern and yield. Pulses Cereals; gram, paddy, groundnut, cotton etc. are some of the crops grown in this region. Crop yield is controlled by rainfall and soil moisture, in addition to water availability. Intense water demanding cash crop cultivation is on the increase. Irrigation water requirement of crops of this region is shown in Table 2.c. Crop irrigation requirement at the field level, is vital factor in estimating agriculture water demand, in addition to crop area and type.

Table 2 c : Crop Water Demand

Crop	Crop Water Requirement Acre inch	Crop yield kg/acre
Wheat/Barley		
Maize	30	
Jowar	24	
Bajra	20	
Ragi	24	
Ground nut	20	
Cotton	50	
Total		

4.5 Geology and sub-surface water

Horizontally bedded, Deccan basalt of Cretaceous to Eocene age with massive and amygdaloidal variety with red bole marker bed is exposed in this region. Spheroidal weathering is predominant. Transported recent deposits are confined to the valley. Gravel bed consists of sub-rounded gravel of basalt, chert and chalcedony. Table land and low flat country underlain by Deccan trap are covered by black cotton soil. At places laterite covers the surface. Ground water potential is confined to jointed and fissured rocks and weathered and soil mantle. Table 2.c shows the specific yield of different formations observed in this region. Open dug well of unto 5 m are found to tap the water from percolation. The well begins to dry from February onwards and supply of water through water tankers from the adjacent areas would begin every year. 6m (dia) open dug well with a depth of 12.15m yields about 4-6 lt/sec on an average. (Saha 1998). The annual ground water net recharge of 1174,54 & 14675 hect.m and net ground water withdrawal was 17030 and 24162 hect.m. for Nanded and Parbhani districts respectively.

4.6 Human settlement and population

There are about 26 villages spread out in this watershed. Revenue department maintains a record on the land use type prevalent in its jurisdiction (Table 2.e). Census records maintain village as unit for its survey. Table 2.e shows the sample of the record. The average human population of village ranges between 200-300 and animal population of about 300 when compared with 1951cens data, the population growth rate has gone unto 32.26% during 1991. Further the population density has increased from 89 (1951) to 219 / km^2 (1991). Human water demand is estimated from the consumption and distribution water loss and industry type and water demand. There is no major water consuming industry in this watershed. Relief measures were estimated on the revenue village basis. Table 2.e shows the number of village affected by drought over the Taluka (group of revenue villages) in the past.

4.7 Remote sensing data & temporal land cover assessment

IRS false color composites of November 1988, 1991 and February 1998, were visually interpreted in demarcating the spatial distribution of agriculture, vegetation cover, settlement etc. and its change. Image characteristics such as tone, texture size; shape, pattern, location and association were used in identifying a theme unit. Figure 4. Shows the satellite image of Jhod Nadi of November 1991. Natural vegetation has been grouped into Dense (>40% crown density), Moderate (40-10%) and Low/sparse vegetation (<10%) based on the crown density. Cultivated lands identified by their size and shape and they were grouped into fallow, crop initial and matured stage depending on the growth, phonological conditions. Open are and rock out crop areas by their texture, shape and association and spectral characteristics; Hydrological features such as water spread of a lake/reservoir, canal and river course by their shape and size; Human settlements by their shape and tone and Transportation network by their linear feature. Table 3 shows the land use and land cover and its change between the drought (1988) and normal years (1998).

Table 2 d : Rock and Aquifer Characteristics

Rock Type	Specific Capacity Lpm/m	Transmissivity M^2/day	Specific yield %
Weathered basalt	50-300	30-190	4
Vesicular basalt		36-503	2.7
Fractured basalt	60-100	31-450	2.70

Table 2 e : Human and animal population

Year	Human	Animal	Industry (lts)
1999	20,000	10,000	10,000
1998	17,000	11,000	8,000

Table 2 f : Revenue Information

Village Id	Name	Cultivated land in acres	Non-agriculture	Forest land (km^2)	Incidence of drought
V100	Ajri	40	60		1971, 1988, 92
V200	Maja	38	20	8	1988, 92

Table 2 g : Drought Affected Villages

Taluk & Total Villages	1970/71	1972/73	1981/82	1987/88	1991/92
Nanded (200)	200	97	200	197	168
Kandahar (201)	201	95	201	201	120
Mukhet (124)	124	106	106	124	106

5.0 DROUGHT ASSESSMENT

Mitigation measures require assessment of vulnerable regions and their probability, rapid water and food availability and status of on-going mitigation methods. Assessment of meteorological, hydrological, agricultural and socio-economic drought and the spatial distribution demarcated, based on the scientific methods. They are estimated on the following lines:

5.1 Meteorological Indicator

Continuous meteorological data is collected by agencies are used in the estimation of meteorological indices (ref. Olaedipo 1985). They measure the % of rainfall deviation from

Fig. 4 : Plate 1 IRS image showing Jhod nadi water shed (Nanded district)

Table 3 : Land use and Land Cover of Watershed (IRS data 1998)

Categories	1988 in Sq.km.	1998 in Sq.km.
Dense Vegetation	9.51	66.512
Moderate Vegetation	5.513	9.451
Low/Sparse Vegetation	8.133	9.884
Cultivated land-Early	56.000	4.195
Cultivated-Mature	1.05	3.213
Fallow Land	71.652	62.662
Open area	32.101	5.177
Rock outcrop	1.835	1.835
Reservoir/lake	-	-
Road net work	0.65	0.67
Settlement	1.65	1.6

historical data and similarity to the past events. **Palmer Drought Index** is a soil moisture algorithm widely used over areas of uniform topography. It is calculated based on precipitation and temperature data as the local. Available Water Content (AWC). Further, the input data is the basic terms of water balance equation such as evapo-transpiration, soil recharge, run off, moisture loss from surface layer. It is calculated monthly. **Normalized deviation (ND)** of rainfall is calculated by :- $[P_{[o]}-P/P]$, where $P_{[o][o]}$ is the total annual rainfall of a year and P is the average rainfall. It ranges between –1 to +1.

Standard Precipitation Index (SPI) quantifies the precipitation deficit for multiple time scales. Normalized deviation of Rainfall (ND) indicates the rainfall deviation from the mean. It is calculated as ND=(Tot-P)/P; where P is the average annual rainfall of that area and T_{of} is total annual precipitation in mm for a particular year. Figure 4 shows the ND for the study area. It has experienced below normal conditions during 1904-7, 1911-13, 1918-21, 1923-30, 1976-78 and 1984-87. De Martonne's aridity Index $(I_A) = P/(T-10)$ and if the index is <5, it is compared to True desert and 20-30 as semi-arid zone.

Bhalme and Mooley Index is expressed as accumulated negative moisture index (NMI). It classified the condition between normal and extreme drought. It is estimated as: $NMI=(100(P_{m[o]}-P_{mean})/e$, where $P_{m[o]}$ is monthly mean over N years of observation, P_{mean} total monthly rainfall M = month under consideration and e is the standard NMI demarcates the boundary conditions between monthly moisture conditions. Meteorological data and the estimated indices of 1988 and previous drought indices were taken as example in creating knowledge based rule for decision making.

5.2 Hydrological Indicator

Analysis of precipitation data enables in quantifying the moisture status and the trend of rainfall of a region. The estimation of rate and duration of water flow in a river system is important for

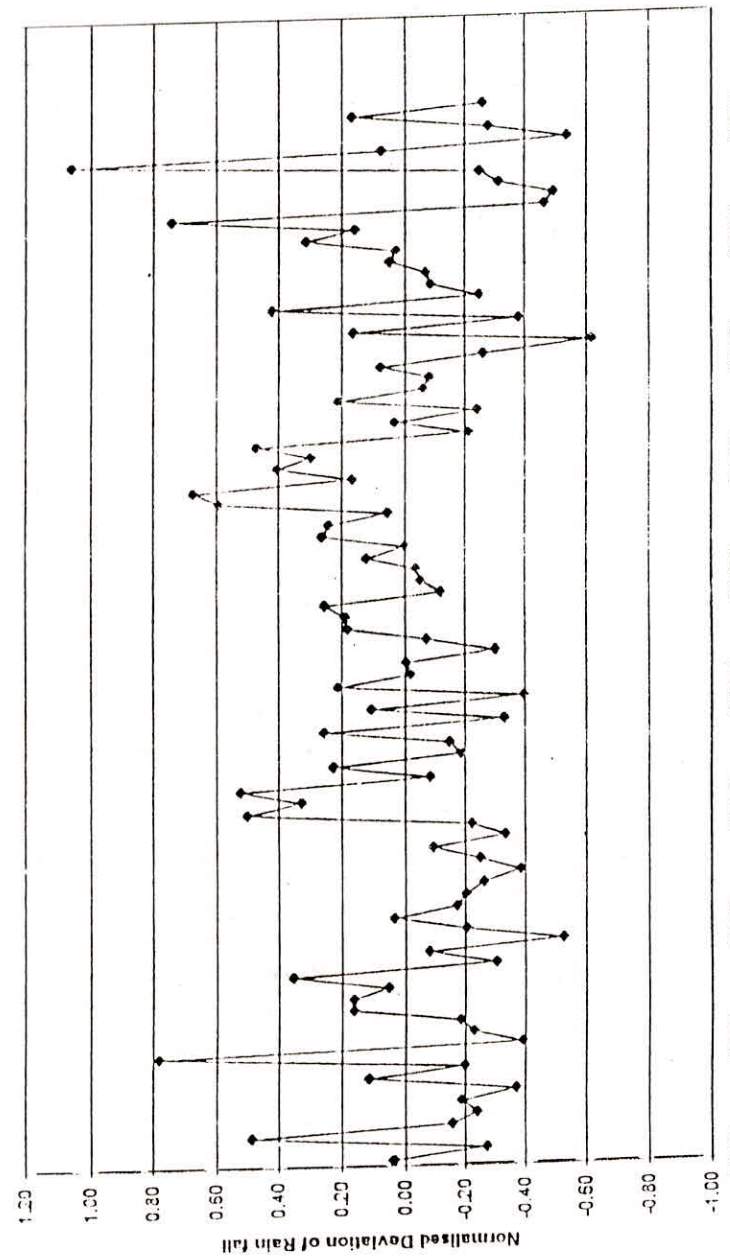

Fig. 5 : Time Series Plot of ND values of rainfall at Nanded

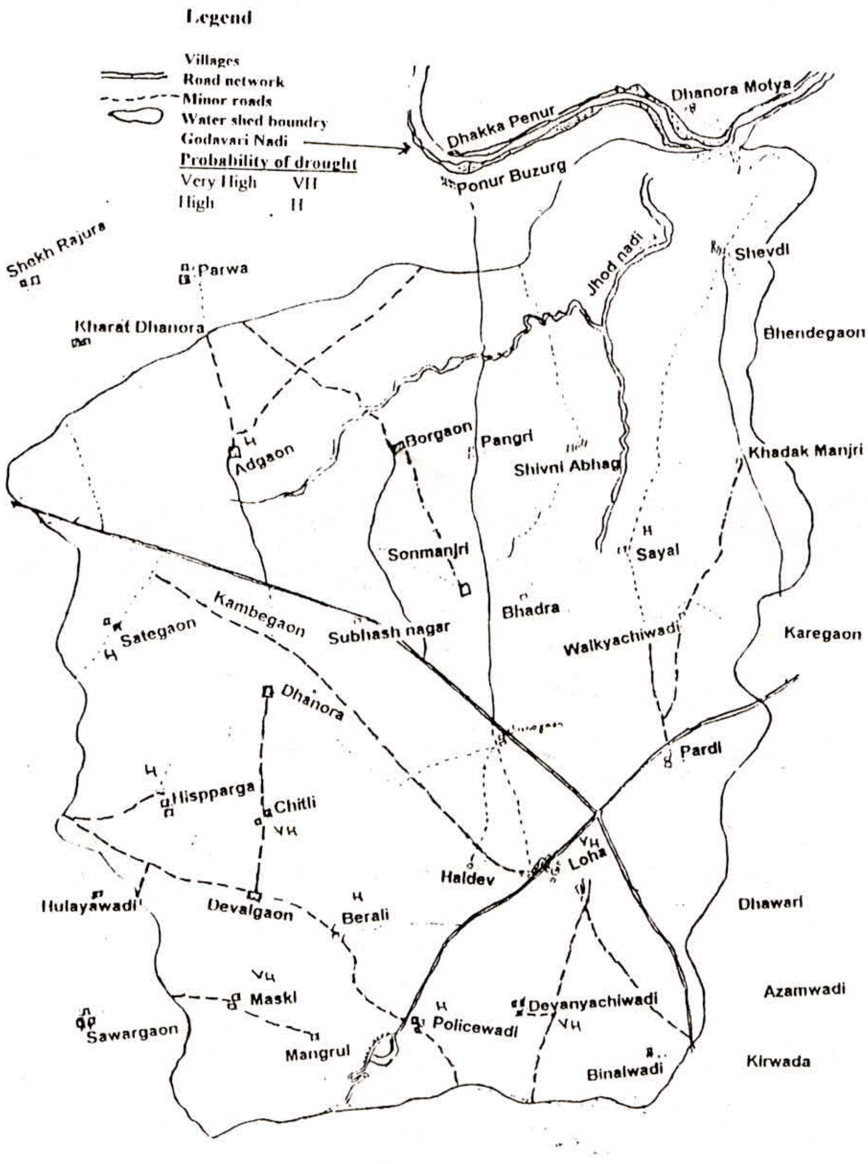

Fig. 6 : Spatial distribution of villages in Jhod nadi watershed

water supply and waste disposal. The percentage of deficit of rainfall in drought prone is comparatively low with rest of the area. The amount of surface water in a major stream indicate the water availability for a particular period. About 10% and 15-21% of total rainfall infiltrates into hard rocks (basalt) and river alluvium respectively and the rest goes as run-off.

Water use for agriculture, mean weighted over the territory depends mainly on climatic conditions and distribution system. Total irrigation water use is assessed by irrigated land dynamics estimated based on the crop demand and water availability. Domestic and public water use is in the range of 10-50 lts./day. It increases during summer. Livestock also need more water in warmer climate in order to reduce the risk of dehydration.

Water requirement = {Crop Irrigation requirement x Crop area + distribution loss} +
{Human requirement (Population x water need) + Industrial need

5.3 Biological Indicators

Deviation in the vegetation cover indicates the soil moisture and growth factors. Area covered by the natural vegetation including forest growth and cultivated lands can be ascertained by satellite data supported by select field visits. The in-situ availability food, fodder and fuel wood for consumption can be estimated prior to import.

5.4 Socio-economic Indicators

Water, food and fodder demand depends on the human and animal population. Increase in the population would lead to additional production. Decrease in cultivated land leads to loss of work and revenue and migration to adjoining areas. Increase in demand for food (proportional to the rate of population growth) is the principal driving force in the demand for water. The shortfall of food is expected to be 35 million by year 2025. The food demand is assumed as 250 kh/person/year/ (GOI 1992).

6.0 SUMMARY AND CONCLUSION

The land information base described above was tested over part of a watershed in drought prone Deccan plateau in India. It provides information for operational and strategic management planning and execution. It is easy to use at field level by administrative and relief workers. This approach could be applied in similar climatic zone.

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