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Geoinformatics Technology Application in North Karnataka for Water Resources Management

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Abstract:

Karnataka is in dearth of water resources, especially in its arid and semi-arid regions. So the management of water resources in these areas is very important. The annual average rainfall of 50 cm for the whole country and its totality area, it has been discovered that total water resources in India are of the order of 167 million hectare-meters. It has further been calculated that only 66 million hectare-meters of water resources in India can be employed for irrigation. The population of India as on 2011 stood at 1,210,193,422 (1.21 billion) persons. Thus, India supports about 1/6th of world population, 1/50th of world's land and 1/25th of world's water resources. India also has a livestock population of 500 million, which is about 20 percent of the world's total livestock population. More than half of these are cattle, forming the backbone of Indian agriculture. The total utilizable water resources of the country are assessed as 1086 km^3. Geoinformatics technology has its special advantage in this aspect. The paper introduces the applications of Geoinformatics, including remote sensing, geographical information system and global positioning system, in this field, such as surface water resources, groundwater exploration, dynamic monitoring of floods, water environment and drought monitoring, planning of water diversion project between basins and so on. It shows that Geoinformatics technology can play important role for North Karnataka development, especially in India. India is still an agricultural country; with the advent of powerful and high-speed personal computers, efficient techniques for water resource management have evolved, of which Geoinformatics technology includes RS (Remote Sensing), GIS (Geographic Information System) and GPS (Global Positioning System) are of great significance.

Keywords: Geoinformatics, remote sensing, semi-arid, water resources

1.0 Introduction:

Karnataka accounts for about six percent of the country's surface water resources of 17 lakh million cubic meters. With rapid growing population and improving living standards the pressure on the water resources is increasing and per capita availability of water resources is reducing day by day, it has become an important and dependable source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries (Todd and Mays, 2005). Of the 37Mkm^3 of freshwater estimated to be present on the earth, about 22% exists as groundwater, which constitutes about 97% of all liquid freshwater potentially available for human use (Foster, 1998). In India, more than 90% of the rural and nearly 30% of the urban population depend on groundwater for meeting their drinking and domestic requirements (Reddy *et al.,* 1996). The quality of surface water and groundwater resources is also deteriorating because of increasing pollutant loads from point and non-point sources. However, such an approach for water resource investigations is very costly, time-consuming and requires skilled manpower (Sander *et al.,* 1996). In contrast, Geoinformatics technology, with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within a short time, has emerged as a very useful tool for the assessment, monitoring and management of water resources (Jha *et al.,* 2007). The hydrogeologic interpretation of satellite data has been shown to be a valuable survey tool in areas of the world where little geologic and cartographic information exists or is not accurate, as well as in inaccessible regions of the world (Engman and Gurney, 1991). as remote sensors cannot detect groundwater directly, the presence of groundwater is inferred from different surface features derived from satellite imagery such as geology, landforms, soils, land use/ land cover, surface water bodies, etc., which act as indicators of groundwater existence (Todd, 1980; Jha and Peiffer, 2006). Moreover, Geoinformatics have emerged as powerful tools for handling spatial data and decision-making in several areas including engineering and environmental fields (Stafford, 1991; Goodchild, 1993). At present, India is still an agricultural country; the water consumed in agriculture is the most significant one.

In the past, several researchers (from India and abroad) have used Geoinformatics techniques for the clarification of water resource management with successful results (Krishnamurthy et al., 2000; Shahid et al., 2000; Khan and Moharana, 2002; Jaiswal et al., 2003; Rao and Jugran, 2003; Sikdar et al., 2004; Sener et al., 2005; Ravi Shankar and Mohan, 2006; Solomon and Quiel, 2006). On the other hand, some researchers have integrated Geoinformatics techniques to delineate water resources (Sreedevi et al., 2001; Shahid and Nath, 2002; Hadithi et al., 2003; Rao, 2003; Sreedevi et al., 2005; Israil et al., 2006; Srivastava and Bhattacharya, 2006). All the studies have been carried out in India; the majority of which focus on hard-rock terrains. The details about the applications of Geoinformatics technology in water resources, including groundwater prospecting, can be found in (Jha et al., 2007; Jha and Peiffer, 2006).

Indian government always pays more attention to water resources utilization and development; this is why it can support 17.3% population of whole world. Although India occupies only 3.29 million km^2 geographical area, which forms 2.4% of the world's land area. The population of India as on 2011 stood at 1,210,193,422 (1.21 billion) persons. Thus, India supports about 1/6th of world population, 1/50th of world's land and 1/25th of world's water resources (Water Management Forum, 2003). India also has a livestock population of 500 million, which is about 20% of the world's total livestock population. More than half of these are cattle, forming the backbone of Indian agriculture. The total utilizable water resources of the country are assessed as 1086 km^3. But on the other side, the social-economic development of India would reach the middle level of developed countries in the world. Grain yield will increase 0.14 billion ton, while two third of the increase will be produced in the North India where is lack of water. At that time, the level of urbanization will be raised to 50% water consumed in cities will be increased greatly. So the situation of water shortage will be very serious. The shortage of water resources results from not only water resources itself but also water pollution. Besides, due to the non-uniform distribution of water resources both in space and time, the natural disasters related with water, such as drought, flood and water logging occurs frequently. With the development of society and economy, the loss resulting from these disasters becomes lager and larger. So the continuous and steady development of society and economy is closely related to the susceptible utilization of water resources. It is necessary to set up reliable and safest water supply system, to hold back the worsen tendency of water environment and establish effective system for water resources utilization, development and protection (Jiren and Musui, 2004).

2.0 Water Resources in Arid and Semi-Arid Regions:

The arid and semi-arid regions in Karnataka are mainly located in North Karnataka (Figure 1.), especially in Northeast Karnataka. North Karnataka includes the Krishna River Basin; with the total area of 258,948 kmÂ², which is nearly 8% of total geographical area of the country. The basin covers the states of Andhra Pradesh (113,271 kmÂ²), Maharashtra (69,425 kmÂ²) and Karnataka (76,252 kmÂ²). An average annual surface water potential of 78.1 kmÂ³ has been detected in this basin. Out of this, 58.0 kmÂ³ is utilizable water. Cultivable area in the basin is about 203,000 kmÂ², which is 10.4% of the total cultivable area of the nation. From natural conditions, it is true that arid regions are lack of water resources, but it is also related with human-being activities. The effectiveness of water utilization for agriculture is quite low, the phenomenon of wasting water exists, and the water consumption for unit industrial products is on the higher side, while the repeated-use coefficient on the lower side and the water pollution aggravates the shortage of water resources (Jiren and Musui, 2004). Because the increase of population and water consumption for economy development, the water for ecological environment is occupied, resulting in a series of ecological problems related to water, such as river withering, lake tail dead, lowering of groundwater table, secondary salinisation, quick expansion of desertification, increase of desert storm and so on.

The problem with water resources in the more inhabited semi-arid regions is a crucial question for overcoming obstacles to development. It is a fact that the governments of many semi-arid regions of the world are acting with the objective of implanting infra-structures capable of making available sufficient water to assure the supply for humans and animals and make irrigation viable. However, in a global sense this effort still is insufficient to resolve the problems originating from water scarcity, making regions continue to be vulnerable to dry periods, especially when speaking of the diffuse use of water in the rural environment. In any sense, the increase of and strengthening of the water infrastructure, with adequate management, constitute essential prerequisites for solution of the problem, serving as a basic element for the national development.

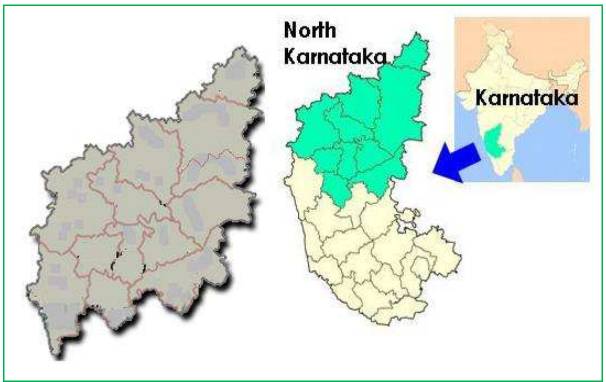

Figure 1. Index Map of the North Karnataka

3.0 Applications:

3.1 Water Resources Investigation:

Discharge in river channel can be accurately controlled by hydrological measurement, while the area of reservoir and lake can be determined by remote sensing. On the basis of that, water storage in lake and reservoir may be determined by means of stage -area-volume curve. This kind of curve can also be worked out on the basis of multi-temporal (flood, middle and dry periods) remote sensing images and corresponding simultaneous water levels in the lake or reservoir under investigation. This method is much economic than under-water topographic measurement. Key problem is obtaining enough multi-temporal remote sensing images.

Groundwater is the most important reproduced natural resources, especially for livelihood, animal husbandry and agriculture in arid regions. Remote sensing can provides the information about geology, hydrogeology geomorphology and urban environment analysis. They are helpful for searching groundwater, provides clue for field investigation and improve successful possibility. For finding groundwater, the penetration of radar is helpful to directly find shallow-layer groundwater in the places with ancient river channel and the plain area in front of mountains. Remote sensing has the ability for the observation in these aspects. With the advantage of high temporal resolution of meteorological satellites, it is possible to distinguish cloud and snow cover due to the movement of cloud.

3.2 Water Resource Management:

Water resources are the basis of suspendable development of society and economy in arid and semi-arid regions. It is recognized from the present situation that the key issue is the management. If powerful engineering and non-engineering measures are adopted, the problem in arid and semi-arid regions in North Karnataka (Figure 1) is really possible to be well solved. In fact, Remote Sensing, Geographic Information System (GIS) and Global Positioning System (GPS) can play important role to water resources management, such as surface water, groundwater, investigation, dynamic monitoring of ecology and estimation of water amount necessary for keeping and recovering ecological environment, existing irrigation area investigation and irrigation planning, soil moisture and drought monitoring, investigation of soil salinisation, planning, monitoring and effect evaluation of returning cultivated and to forest or grassland, dynamic monitoring of desertification and soil erosion, variation of river course and sedimentation in lakes and reservoirs, site selection of water project and its planning, design, construction and management. What follows is relatively detail introduction is several aspects.

3.3 Drought Management Monitoring:

Drought is always one of constrained factors for agriculture development; it is also one of natural disasters resulting in most considerable economic loss. Since an analysis of 100 years of rainfall data reveals that the frequency of 'below-normal rainfall' in arid, semi-arid and sub-humid regions is 54-57%, while severe and rare droughts occurred once every eight to nine years in arid and semi-arid zone (Country Report, 1999). In these zones, rare droughts of severe intensity occurred once in 32 years, with almost every third year being a drought year. Currently, over 10% of blocks classified by the Central Ground Water Board have been identified as 'overexploited'; blocks where the exploitation is beyond the critical level have been growing at a rate of 5.5% every year. It is estimated that 36% of blocks in the country will be on the critical list by the year 2017 (Poorest, 2008). From different considerations, there are agricultural drought, climatic drought and hydrological drought, also with different standard and grades.

Large covering is one of characteristics of drought; the soil moisture content measured in sampling point has certainly the problem of representative, namely, whether the soil moisture content at sampling point can reflect the drought situation over a large area and its spatial distribution. Remote sensing technology has the advantage of macro, objective, rapid and low cost. With its development, it opens a new way for drought monitoring, especially after the combination with GIS. On the basis of combination together with the conventional measurement of soil moisture content on ground and hydrological modeling, remote sensing becomes more practical and approaches the operational purpose for drought monitoring.

3.3.1 Indian Remote Sensing Satellite:

Indian Remote sensing Satellite (IRS) series (IRS 1A, IRS 1B, IRS 1C, IRS 1D and IRS P3) have unique payloads to monitor and assess various natural resources available in the country and around globe at different spatial resolutions. Among the payloads available IRS 1C, IRS 1D and IRS P3 have WiFS (Wide Field Sensor) payload (Table 1). WiFS sensor collects data in two spectral bands 0.62-0.68 µm (red) and 0.77-0.86 µm (near infrared) with spatial resolution of 188 m and ground swath of 810 km with a revisit period of 5 days. The combined use of three satellites cover any part of the country once in 3-4 days. The Advanced WiFS (AWiFS) sensor onboard IRS P6 provides data in 56 metres resolution with a swath of about 700 km. Due to higher spatial resolution use of WiFS/AWiFS data enables detailed monitoring at district and sub-district level.

Table 1: Satellites/Sensors Being Used for Drought Monitoring

No.	Satellite/Sensor	Spectral Resolution (Microns)	Spatial Resolution (Metres)	Radiometric Resolution (Bits)	Temporal Resolution
1	NOAA-AVHRR (Swath= 2700 km)	0.58-0.68 0.725-1.10 3.55-3.93 10.3-11.3 11.5-12.5	1100	10	Twice a day
2	IRS 1C/1D-WiFS (Swath= 810 km)	0.62-0.68 0.77-0.86	188	7	5 days
3	IRS P3 WiFS (Swath = 810 km)	0.62-0.68 0.77-0.86 1.55-1.75	188	7	5 days
4	Resourcesat-1-AWiFS (Swath= 740 km)	0.53-0.59 0.62-.068 0.77-0.86 1.55-1.70	56	10	5 days

Future missions are planned to meet the requirements of the meteorology community. The INSAT-3D launched in the year 2010 will carry improved VHRR and vertical sounders for temperature/humidity profiles. The imager will have six channels and the sounder will have nineteen channels (Table 2). Radar Imaging Satellite (RISAT), launched in 2009, is expected to boost the utilization of microwave images in the fields of agriculture and disaster management. One of the major constraints of using optical data is persistent cloudy conditions during monsoon season resulting in non-availability of sufficient cloud free data. In this context, microwave remote sensing offers great potential for monitoring crop and soils especially during the monsoon season due to capability of radar systems to acquire data under all weather conditions. The multi mode, multi polarization SAR images of RISAT will be useful to study the crop sown area progression, crop condition and soil moisture during the monsoon season to strengthen the existing drought assessment methodology.

Geoinformatics constitute acquiring geospatial data i.e., mostly available from various satellite platforms and technology available for analysis of such data such as GIS, and other integrating tools like GPS. The ever increasing pressure on natural resources to meet the requirement of growing population calls for the development of plans that maintains equilibrium environment, ecology and human needs. The use of contemporary technology tools like Geoinformatics to find solutions for sustainable use of land and water resources has been found to be an indispensable management and decision making tool. Geoinformatics facilitate the cost effective, timely, customized and simplified solutions for resource use. Geoinformatics has become a new tool in the hands of modern cartographers and the technology has been proved beyond doubt for its efficiency to generate maps with accuracy and time effectively particularly to depict the physically devastated areas by disasters, impact assessment and quick dissemination of disaster information to people (Dutta, 2002). The application of Geoinformatics for resource management at micro level was successfully demonstrated by integrating both satellite imagery and ground data to generate action plans for land development (www.gisdevelopment.net/application/nrm/overview/ma03226pf.htm).

Table 2: Payload characteristics of and applications of future Indian satellites

Satellite	Payload	Bands/Resolution	Resolution(km)	Applications
INSAT-3D	6 Channel IMAGER	Spectral bands (µm) Visible : 0.55-0.75 Short wave IR:1.55-1.70 Mid wave IR: 3.70-3.95 6.50-7.10 Thermal IR: 10.30-11.30 11.30-12.50	1km 1km 4km 4km 4km 8km	Cloud characterization Mesoscale processes
	19 Channel Vertical SOUNDER	Spectral bands (µm) Short wave infra red : six bands Mid wave infra red: five bands Long wave infra red: seven bands Visible :one band	10×10 for all bands	Atmospheric water vapour/temperature
Megha Tropiques	SAPHIR SCARAB MADRAS GPSROS	Six bands around 183 GHz 4 Channels: Sc-1 (Visible), Sc-2 (Solar), Sc-3 (Total) Sc-4 (IR window) Radiation instrument in short& long wave 89&157GHz radiometer 10,18&37GHz radiometer	10 km Horizontal Resolution 25 km at nadir 40km Horizontal Resolution 10 km Horizontal Resolution	Water vapour profile Six atmospheric layers upto 12 km height Radiation budget Ice particles in cloud tops cloud liquid water and precipitation; sea surface wind speed 23 GHz : integrated water vapour Vertical profile of temperature and humidity

With development of remote sensing sensor, several approaches have been developed. They can directly or indirectly reflect drought regime on the basis of the data obtained from these sensors. The approaches which are relatively practical at present in Karnataka are thermal inertia method, crop water shortage index method, deviation from mean normalized difference vegetation index method, water supply vegetation index method and the method of soil moisture measurement by microwave remote sensing. Karnataka considers regions which received rainfall less than 400 mm during *kharif* and less than 30 per cent during the cropping season and 20 per cent deficiency of rainfall during critical stage of crop growth as drought affected areas. The criteria followed is production above 75% of normal – no drought, 50 to 75% normal – moderate drought, 25-50 % - severe drought, <25 per cent – disastrous drought. Karnataka state has recently revised its norms for drought declaration in the light of four consecutive years of chronic drought. It was felt that the current norms to define drought affected areas were inadequate and inappropriate. The taluks of the state are divided in to four categories based on annual rainfall. The threshold values for rainfall deviations and number of dry weeks for drought declaration vary across the four groups of taluks. The criteria also differ for year to year, for the taluks experiencing consecutive years of drought.
Details are available in the annual report (2005-06) of Revenue Department of Government of Karnataka.

There is lot of confusion still existing between science and policy communities about the characteristics of drought as a result of which drought management practices all over the world is progressing slow. Governments respond to drought through ad hoc or crisis management approach rather than through coordinated or strategies. There are two types of management measures namely (short term measures and long term measures). Short term measures include adoption of contingent crop plans, cultivation of drought tolerant crops, mulching, cultivation practices like optimal spacing, rationing, nutrient management and rainwater management. Long term management includes land and water management practices to enhance the productivity in a sustainable manner.

Drought management requires a joint efforts of individuals/institutions originating from multidisciplinary aspects and together should evolve a mechanism to understand the inter relations of various aspects and generate the action plan. For example meteorologists foresee the availability of water through rainfall; natural resource managers or environmental specialists focus on the analysis of the impact of different water availability situations on various interests like agriculture, live stock and people. The major challenge lies in bringing these groups together with inter connectivity and synergy to evolve group actions. The different institutions in the drought management plan should include water institution, meteorology, agriculture, ground water, environment and socio-economic. These groups collectively should address various issues such as identification of human, biological, financial and legal constraints, identification of research needs, integration of science and policy, formulation of drought plan, creation of public awareness, implementation of planned activities either short term or long term etc. A model for institutional participation is shown in Figure 2.

4.0 Presently Used Methodologies:

4.1 Thermal Inertia Method:

National Oceanic and Atmospheric Administration (Advanced Very High Resolution Radiometer) is the usual data source for drought monitoring. In thermal inertia method, after atmospheric correction, the fires step is to calculate ground surface temperature, reflectivity, reflectance through atmosphere on the basis of data from CH1, CH2, CH4 and CH5 (spectrum reflectance from various channels), then calculate thermal inertia value. The second step is to establish the correlation between moisture content and thermal inertia value of soil. It is usually a one-dimensional linear equation with two parameters. The thermal inertia values are different for various types of soil. It is affected directly by the soil pattern and property. The spatial structure of soil has also effect on thermal inertia, but it is quite difficult to actually determine this effect.

The thermal inertia method is suitable for drought monitoring (Figure 3) in winter and early spring, namely, under the case of bare soil. In case of land covered with vegetal cover, this method is not so suitable because vegetation may change the thermal conductivity of soil.

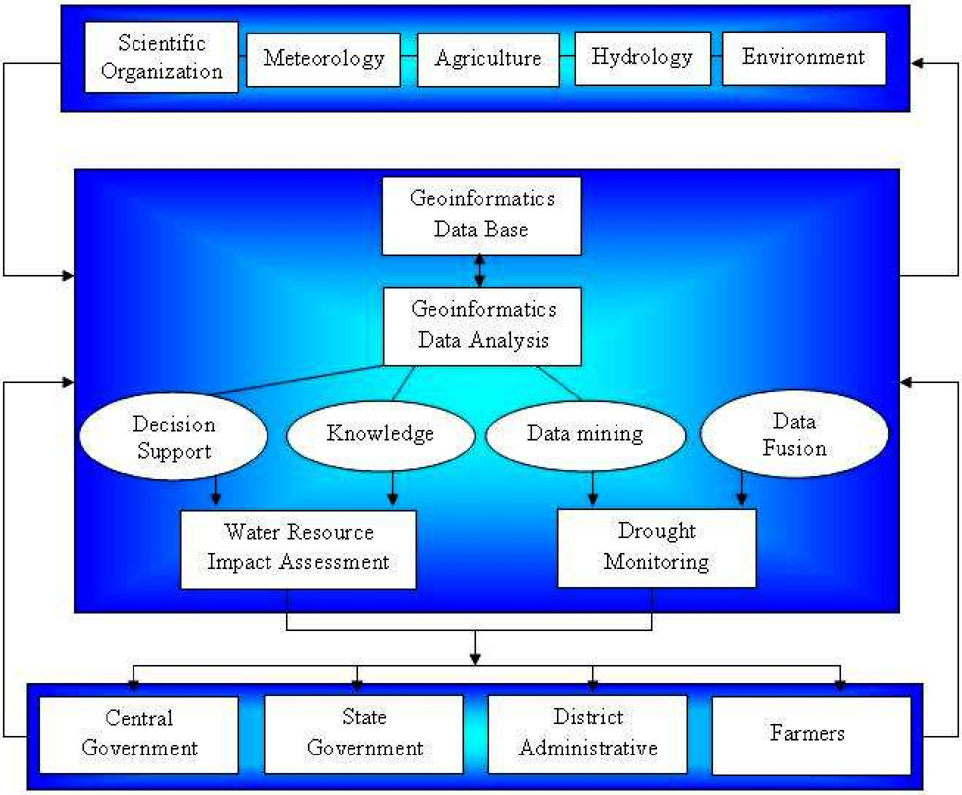

Figure 2. Data flow applications of Geoinformatics for water resources and Drought management

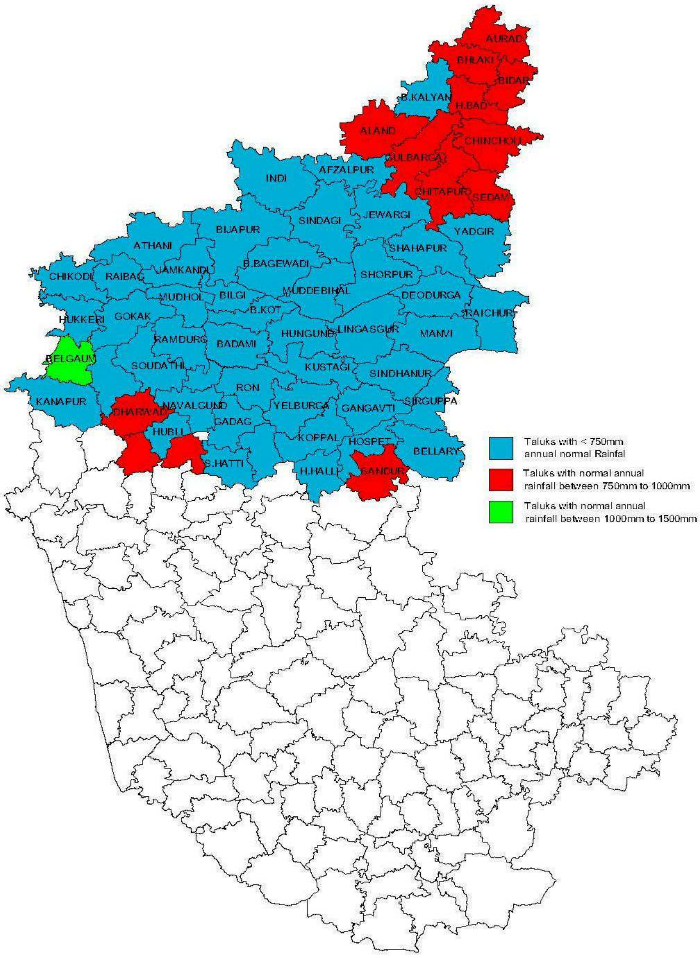

Figure 3. Drought Affected Taluks in North Karnataka

4.2 Crop Water Shortage Index Method:

The definition of **C**rop **W**ater **S**hortage **I**ndex is as follows:

CWSI = 1 – Ea / Ep (1)

Where Ea is actual evapotranspiration, while Ep evapotranspiration capacity. The smaller the value of Ea, the higher the value of CWSI, indicating less water supply ability, namely land is arid. Because evapotranspiration has close relation with soil moisture content, namely water supply ability, so CWSI also has close relation with soil moisture content. Both CWSI and soil moisture content indicate the degree of soil drought. The analysis for experiment shows (Tian Guoliang, 1992); that the relation between them is better to be expressed by the following logarithmic equation:

CWSI = A + B * Ln W (2)

Where W is soil moisture content expressed in percentage. The correlation coefficient between CWSI and the soil moisture content in the soil profile from ground surface to the depth of 50 cm is higher than those for other soil layers. The norm of drought according to CWSI is: heavy drought when CWSI>0.913, middle drought when CWSI is from 0.912 to 0.765, slight drought when CWSI is from 0.764 to 0.617, normal when CWSI is from 0.616 to 0.322, humid when CWSI<0.321. The infrared temperature Te can be obtained from NOAA meteorological satellite. It has simple linear relation with daily evapotranspiration. Besides, infrared temperature can be used to calculate daily average temperature and then Ep. So CWSI can be calculated from infrared temperature from NOAA meteorological satellite and level of drought can be classified.

4.3 Deviation from Mean Normalized Vegetation Index Method:

Normalized Difference Vegetation Index (NDVI) is expressed as:

NDVI = (CH2-CH1) / (CH2+CH1) (3)

Where CH1 and CH2 are spectrum reflectance's from first and second channels of NOAA (AVHRR) separately. The vegetation index calculated from remote sensing data can reflect the growth situation of plants, while the normalized one can reduce, to a certain degree, the error from sun elevation, atmosphere and observation for the place not beneath the satellite. Water supply may affect growth regime, so normalized vegetation index can reflect indirectly drought situation, although there is a lag in time. On the basis of calculated NDVI from NOAA (AVHRR) for many years, the average value of NDVI for each place and each time can be obtained. This average value may indicate the mean situation of water supply from soil. The longer the time series is, the better the representative of these mean values is. The deviation or relative deviation of concurrent NDVI from mean value shows the degree of drought or humidity. The level of drought for different regions can be determined in this way. This method is simple and easy to be used, also quite objective, but it is necessary to notice what period is the data accumulation term in long time series, namely, normal period, dry period or humid period.

4.4 Water Supply Vegetation Index Method:

When crops are suffered from drought, their leaf apertures are partly closed in order to reduce the loss of water. It makes the increase of temperature of leaf surface. The more severe the drought is, the higher the temperature of leaf surface is. At the same time, the growth of crops is affected by drought, resulting in the decrease of **L**eaf **A**rea **I**ndex (LAI). Besides, leaf will also be withering under high air temperature. All of these may result in reduction of NDVI. **W**ater **S**upply **V**egetation **I**ndex (WSVI) is defined as follows:

WSVI = NDVI / Ts **(4)**

Where Ts is the brightness temperature of the forth channel of NOAA (AVHRR). The smaller this index is, the more severe the drought is.

4.5 Irrigation Area Investigation and Development Planning:

In order to contend water, irrigation area is blindly developed in some places. The irrigation area from statistics way is smaller than the actual one. It results in water shortage in downstream basin. In order to realize comprehensive management of water resources for the whole basin, the irrigation area is important and basic information. The definition of irritable area is as follows: land with leveled ground, conveyance irrigation system and water supply in normal years. At present the major irrigation modes are channel and well irrigation. Drip and sprinkler irrigation are only developed in the area near cities. Grain production increases 4 to 5 times after the construction of irrigation system. From above description, it can be know that land, major channel; land use and water body can be distinguished through Tofts Model (TM) and extended Tofts Model (ETM), Crop growth situation can be learnt from meteorology satellites. On the basis of remote sensing, the irrigation area can be determined and a GIS-based irrigation information system can be established.

In arid regions, it is not suitable to overly develop irrigation area. If there is enough water resources the irrigation planning can be done on the basis of GIS-based database including water body, precipitation, soil, groundwater table, temperature, topography, runoff, water quality of groundwater. After weighting different factors separately, the place suitable for developing irrigation can be optimally selected.

4.6 Water Environment Monitoring:

Water pollution results in part of water resources which are already very limited can not be used, so the monitoring for water environment is also very important at present, remote sensing is very effective for monitoring blue green alga due to eutrophication in lakes and reservoirs and red tide along the coastal area. With the sampling on water surface, the water quality classification into five grades can be roughly done. In general it is carried out by the multi-band composition of ETM digital images. Which bands would be used is decided according to the major pollutants in the water body under investigation. The quantitative determination of various chemical elements by means of high spectrum is a forward research subject in the world.

4.7 Planning, Construction and Management:

Apart from the consideration of hydrological factors and economic evaluation, the site selection of reservoir and key water control project must consider the topography and the geological evaluation which can be done by RS, GIS and GPS. The planning of water diversion project can be performed on the digital platform. Remote sensing is the major source of data and information into GIS-based database, the spatial analysis and on-line virtual reality technology can play their important role on this basis. It is being carried out for the “water diversion project”, including route selection, geological investigation, simulation of water transportation, selection of dam and tunnel sites, estimation of cubic meter of earth and stone, as well as the distribution of water after diversion.

After the completion of "water diversion project", the arid and semi-arid regions can share more water from the Krishna River. These projects are the relatively thorough solution of water shortage in most of arid and semi-arid regions in North Karnataka.

4.8 Real-time monitoring:

Due to the importance of water resources and extensity and complexity of its information, it is very necessary to establish a special system for real-time monitoring and information management to provide basis for decision-making on an integrating information platform. The data and information sources from remote sensing and conventional measures. There are real-time data and historical data. Information is managed by GIS and can be used together through network. System consists of four sub-systems, i.e. data acquisition, data transmission, data processing and decision-making support system (DSS).it can automatically acquires real-time data of hydrological data including rainfall, discharge and water elevation in river channel, lakes and reservoir, groundwater table, soil moisture content and so on, as well as water quality of surface water and groundwater. Data is transmitted by communication satellite, microwave, extra-short wave, short-wave radio or computer network to the sub-center or center of information management. In spatial database, there are real time data and historical data. The spatial data includes basic geographic data, such as water body, topography, and land use, land cover, administrative boundary, communication, plant distribution, social-economic data, water resources data concerning utilization and development, such as water supply and demand. Besides, there are banks of maps and remote sensing images. Data processing includes the processing for remote sensing images and other data, also the update of database. In the respect of DSS, there are bank of models and expert knowledge; it can provide comprehensive and synthetic basis for decision making. The functions of the system are in Table 3.

Table 3: Decision Support System Function

Sr. No.	DSS System	Functions
1	Inquiry	Information inquiry can be carried out in two directions, namely to inquire attribute from location on map and to inquire location from attribute or condition, rule and term.
2	Statistics	The statistics can be done both in time and space and according to the condition, rule and term.
3	Prediction and warning	Combining with special models, what is made are water resources prediction, storm-flood forecasting, low flow prediction, soil moisture content forecasting, runoff forecasting and prediction of water supply and demand.
4	WebGIS	WebGIS is adopted for this kind of system in order to realize operation and transfer in distance and in multi terminals including the figures in vector format.
5	Planning.	The planning includes water resources utilization and development, irrigation development, water project, agriculture distribution, returning farmland to forest or grass and so on.
6	Consultation	Consultation is often held for finding a solution concerning water resources management. This system can no doubt provides information, alternatives and corresponding consequence for decision making.

5.0 Conclusions:

1. Through long-term practice in North Karnataka, it can be seen that Geoinformatics can play an important role in water resources management particularly in arid and semi-arid regions.
2. It is very helpful to apply Geoinformatics technology including RS-GIS, GPS and conventional measures.
3. Geoinformatics with geo-spatial data from various satellites, Geographic Information System and integrating tools provide immense opportunities to evolve a variety of drought indicators and integrate the same with ground based indicators for objective assessment of drought at different spatial scales.
4. High resolution and Multi spectral images are necessary for solving some issues concerning

water resources management in some key places of arid or semi-arid regions.
5. Geospatial technologies are also useful for hazard and vulnerability mapping to help development of long term strategies of water resource management.
6. Further study is necessary, especially on water demand and quantitative determination of various water bodies by Geoinformatics technology.
7. Institutionalization of contemporary technologies, development of spatial decision support systems, impact assessment and that needs to be addressed to strengthen the water resource management system of the country.

6.0 Acknowledgement:

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