Remote Sensing based Drought Information System for Palar and Thamiravaruni Basins using GIS

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ABSTRACT

This study analyses meteorological, hydrological and agricultural droughts of an area and integrates using GIS. For retrieving and querying the data stored in the database interactively by the user, the study further looks at creating the GIS based Drought Information System. Palar and Thamiravaruni river basins, located in Northeast and Southwest parts of Tamil Nadu State, India, respectively were selected as the study areas. All the relevant hydrological and other data were collected for the period from 1971 to 2000. Map/Info GIS software, VERTICAL MAPPER version 2.5 and MS Excel were used in analysis. The assessment of meteorological drought severity was carried out by employing India Meteorologic Department (IMD) method. Hydrological drought analysis was carried out using Herbst method, by executing a program written in C language. Agricultural drought severity assessment was carried out for all blocks using remote sensing data. Satellite based drought assessment and monitoring methodology was applied using IRS WiFS data and satellite based vegetation index NDVI. GIS is used to integrate of meteorological, hydrological and physical nature of basin in order to map the drought risk areas. Drought Information System (DIS) was developed comprising of modules namely water related database, meteorological drought, hydrological drought, agricultural drought and drought risk area analysis.

INTRODUCTION

Natural disasters include drought, flood, earthquake, landslide, environmental degradation, mining disaster and cyclone, which cause devastating impacts on various activities/properties of the earth. Prediction and ability to manage such natural disasters is an integral part in the overall natural resource management of any nation. Recurrent drought phenomenon requires immediate attention for evolving long-term strategies for combating. Regional drought analysis and monitoring need to be carried out for each basin, which requires water related information frequently over a larger area. Remote Sensing is capable of supplying data more frequently covering wide areas, which are essential for macro-level studies. Then, one requires a spatial data-handling tool for analysis and display/dissemination of the information and outputs/results of scientific analysis to the users. Geographic Information System (GIS) comes in handy to fulfil such a requirement. Water resources and Agricultural engineers, Meteorologists, Economists, Sociologists and the farmers will be able to use GIS maps easily. In this study, an attempt was made to develop a Drought Information System (DIS) that provides tools to handle, store, process, distribute and interpret the water related data needed for assessing the spatial and temporal variation of drought severity.

BASIC TERMINOLOGIES

Data is defined by the American National Standards Institute (ANSI) as a representation of facts, concepts or instructions in a formalized manner suitable for communication, interpretation or processing by human or by automatic means. Information are data that have been called, analysed, integrated and presented on a selective basis and in a format that helps the user to gain a better understanding of what is going on. The types of information for planning and control organization activities are, strategic, tactical and operational. Generally, lower level user is concerned with operational information for decision making, while tactical and strategic information are useful to middle and top level users respectively for making decisions.

A database is a shared collection of interrelated data designed to meet the needs of end users. Data are stored separately so that they are independent of the programs that use them. Databases are organized for searching and fast information retrieval rather than for high volume production runs. New types of data items can be added dynamically at any time to provide good end user query and report generation facilities. Map is a representation of features of the earth drawn to scale. It is a tool of communication and it has been in use since the days of primitive man who had to move about constantly in search of food and shelter. It is a spatial component of database. It consists of points, lines, regions and surfaces that represent the earth features. Attribute data can be clipped into the points or regions with the help of GIS so that spatial and non-spatial attribute data can be viewed at a time that make the administrators more comfortable to plan various alternative scenarios.

Information System

Information system is needed for organising, assessing and evaluating a wide range of information and alternative strategies regarding the major issues. An information system is a model of a small finite subset of the real world. There is a correspondence between things inside the information system and those in the real world. Information in the system is part of a communication process among people. A participant in this process recognizes the occurrence of an event associated with the real world things and records it as an information system, so that someone else in the future can have access to this fact and interpret it.

Geographic Information System

GIS consists of the following five basic technical modules using which a Drought Information System (DIS) could be developed:

(a) Data input and verification;
(b) Data storage and database management;
(c) Data output and presentation;
(d) Data transformation; and
(e) Interaction with the user.

DROUGHT INFORMATION SYSTEM

The information requirement for decision making during drought is diverse and spatial/temporal in nature. For efficient data management, the system should form a central facility for storage and retrieval of water resources related data. Development of a GIS based Drought Information System capable of providing the best available data to the local officials and other agencies through access by appropriate location to terminals becomes a necessity. It should possess the following characteristics:

- User friendly;

- Flexible;
- Robust;
- Extensible;
- Graphical User Interface;
- Comparability – comparing with past data / information;
- Locating areas; and
- Policy recommendation.

The objectives of a Drought Information System are:

- To develop user-friendly data bases helpful in the administration and management of water resources of a basin;
- To provide data and models to evaluate alternative water administration strategies, which can maximise utilisation of available resources in all types of hydrologic conditions;

* To be a functional system that can be used by decision makers and others, and be maintained and upgraded by concerned authorities;

* To have capabilities to accurately represent current and potential features of the basins; and

* To promote information sharing among Government agencies and water users.

- An attempt was made here to develop a Drought Information System (DIS) for Palar and Thamiravaruni river systems.

MODULES OF DROUGHT INFORMATION SYSTEM

DIS consists of menu driven modules developed for accessing, organizing, manipulating, querying, analysing and displaying the drought related information. Each module has menus, which can be invoked by clicking with mouse.

The Graphical User Interface (GUI) of DIS is more interactive and user-friendly created in Microsoft Visual Basic. Visual Basic was used as front end, MS-Excel as back end for handling the attribute and temporal data and MapInfo for Maps. Object linking and embedding technique was used to link the MapInfo maps and Excel table & graphs with Visual basic. Attribute data can be accessed from map by clicking the respective objects. As MS-Excel was used as back end for various information, it can be accessed and updated without any difficulty.

The DIS comprises of the following modules, as presented in Figure 1.

(i) Water related database;
(ii) Meteorological drought;
(iii) Hydrological drought;
(iv) Agricultural drought;
(v) Drought risk area mapping; and
(vi) DIS Report-Slides.

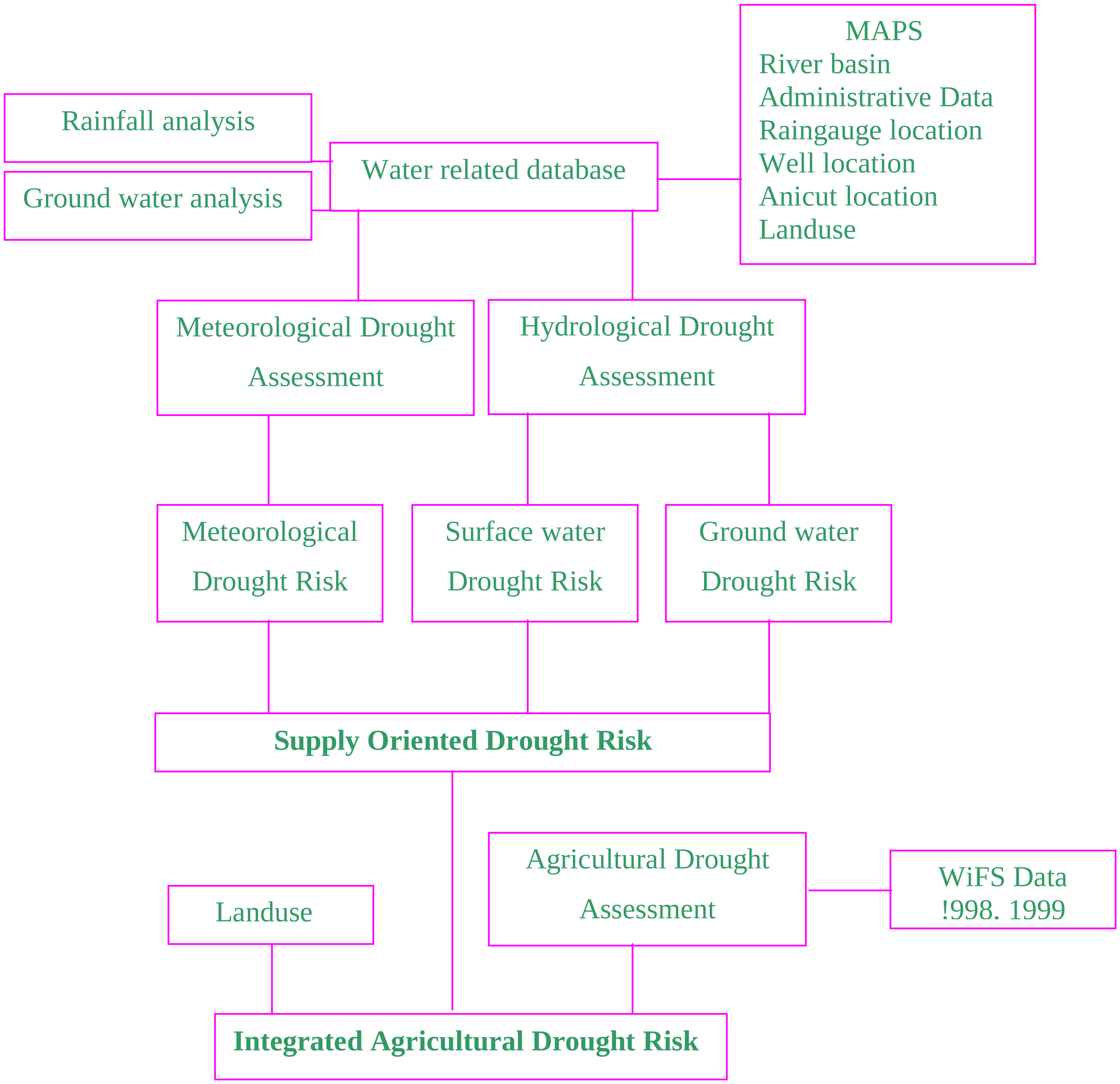

Figure 1 Flow Diagram of Drought Information System

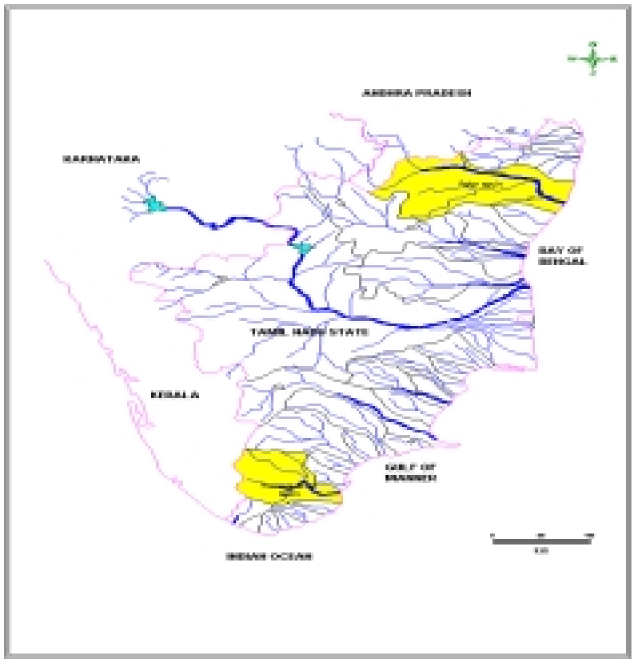

Figure 2 Study areas Map in Tamil Nadu

Each module has two main menu namely Palar and Thamiravaruni. Each main menu consists of various optional menus, which in turn have submenus to access the relevant information of a particular module. Figure 2 represents the study areas in Tamil Nadu State.

Water Related Database Module

The water related database module has the menus to display the maps and information relevant to the drought analysis in the form of maps, tables and graphs. Maps were registered and digitized and relevant attribute data were attached to the respective objects of the map using MapInfo GIS software. The menus such as river basin, administrative block boundary, raingauge location, well location, anicut location, land use are incorporated in this module. Each map can be accessed by invoking the respective menus. The attribute data for each map can be retrieved by clicking the respective objects of the map using the mouse.

Mean monthly, monsoon seasonal, and crop seasonal spatial rainfall pattern were determined which are presented in the form of tables and graphs. Thirty years of water level data were analysed and crop seasonal ground water fluctuation was calculated to view the exploitation pattern. Results of above analysis in tabular format and graphical representation can be accessed and updated from CSGW-Table and CSGW-Graph menus respectively. As there are more number of menus present in this module, analysis part was incorporated inside the menu within which submenus such as Mean, Monsoon, Crop season, CSGW-Table, CSGW-Graph, were presented. The above tables and graphs can be retrieved and updated easily from submenus of this module. Northeast and Southwest rainfall variation maps can also be accessed from NE-map, SW-map submenus of this module.

Meteorological Drought Module

This module consists of menus, such as IMD-Table, IMD-Map, Drought86 and Drought99, which consist of results of meteorological drought analysis performed for two basins. Twenty-nine years monthly rainfall data were analysed and drought severity class namely no drought, mild, moderate, and severe was determined by IMD method for each station from 1971 to 1999. The above results in the form of table can be accessed and updated by invoking a menu named IMD-Table of this module. A map comprising blocks of the basin linked with IMD results so that the yearly drought severity classes can be retrieved from the IMD-Map menu. From the above results blockwise drought severity maps can be plotted for any year. Drought severity maps for the years 1986 and 1999, which are highly drought affected, were plotted. The above maps can be accessed from the Drought86 and Drought99 menus, which depict the drought status in the basin.

Hydrological Drought Module

Hydrological drought module consists of surface water and ground water menus within which submenus with relevant information are incorporated.

Surface water drought

Surface water menu consists of submenus such as SW-Table, SW-Graph, SW-Map that show the results of hydrological drought analysis. Thirty years of irrigation release data of anicuts and reservoirs of the two basins were analysed. Using Herbst method, onset, termination and intensity of dry spells were determined. A map consisting of anicuts and reservoirs linked with the above results as attributes can be accessed from SW-Map menu. Drought results in tabular format can be retrieved and updated from the SW-Table menu. From SW-Graph menu, graph depicting the monthly flow, mean monthly flow, drought severity can be accessed and updated without any difficulty.

Ground water drought

Ground water component menu consist of submenus such as GWD-Map, GWD-Table, GWD-Graph,. GWDI-Ma p. Using Herbst method, from 29 years water level data of the study basins, onset, termination and intensity of ground water dry spells were determined. The above results in tabular format can be retrieved and updated from GWD-Table menu. GWD-Graph menu depicts the graphical representation of monthly water level, mean monthly water level, drought severity, which can be retrieved and updated without any difficulty. The characteristics of dry spells such as duration and intensity were attached as attributes to the Well map that can be accessed from GWD-Map menu. Attribute data of wells can be viewed by querying the respective wells. Interpolating the intensity of dry spell values over the basin, a map depicting the variation of ground water drought intensity during the most drought affected years were plotted. The above maps which could be retrieved from the GWDI-Map menu.

Agricultural Drought Module

This module consists of menus namely Rainfall, Vegetation status, Agridrought, and Crop area. In the agricultural context, crop seasonal drought analysis can be performed using remote sensing data. Rainfall data were analysed to select the recent normal year. The vegetation status during the drought year was compared with normal year to assess the agricultural drought. In this study, the recent years 1998 and 1999 vegetation statuses were analysed.

Normal year and deficit year rainfall distribution map of 1998 and 1999 were plotted and analysed for both the study basins and retrieved through the Rainfall menu. NDVI analysis was performed using WiFS data of IRS 1C and 1D to plot the vegetation status map that can be obtained through Vegetation status map. Crop area map of 1998 and 1999 were plotted using the above data and retrieved through Crop area menu. Block wise agricultural drought severity maps were developed by NDVI statistics. AgriDS Map menu can be invoked to access the above maps.

Drought Risk Area Module

This module consists of menus namely Meteorological drought risk, Hydrological drought risk, Supply oriented drought risk and Land based Integrated drought risk menus within which the submenus are present which can be invoked using mouse to access the relevant drought risk information. For effective drought proofing, vulnerable areas have to be identified accurately. Moreover, the drought proofing works may be made as per the nature of drought such as meteorological, hydrological and agriculture. Each context of drought was analysed separately and risk maps were plotted which were incorporated in this module. Combining the meteorological and hydrological drought aspects, supply oriented drought risk map was plotted which is presented in this module. Integrating the above Supply oriented drought risk and Landuse, Land based integrated drought risk map was plotted which is also presented in this module.

Meteorological drought risk

As far as meteorological drought is concerned, frequency analysis was performed using twenty-nine years rainfall data and a meteorological drought risk index was developed for each rainfall station. Interpolating the above index by Natural neighbourhood method, using vertical mapper, meteorological drought risk area map was plotted and presented in this module.

Meteorological drought risk menu consists of submenus such as Met risk table Index map and Risk map. The sub menu named Met risk table consisting of risk index values, drought severity class for each station, which can be accessed and updated by invoking the menu using mouse. A layer consists of all thirty five raingauge stations along with attribute data of risk index values and drought severity class is incorporated in the sub menu named Index map which can be accessed by clicking the raingauge station in the map. From the sub menu named risk map the meteorological drought risk index map, can be accessed. From this map, pockets or parts of a block, prone to meteorological drought can be identified and suitable drought proofing measures may be taken.

Hydrological drought risk

Hydrologic drought risk menu consists of surface water risk and ground water risk sub components menus. Using 29 years irrigation release data of anicuts and reservoirs of the study basins, the drought duration and drought intensity were determined by Herbst method. Using drought duration and intensity obtained, surface water drought risk index was developed. Blocks benefited by each anicut were determined. Surface water risk menu consists of sub menus such as SW risk table, Index map and Risk map. Table containing risk index, command area and drought proneness can be accessed and updated from the SW risk table menu. A layer containing the anicuts and reservoirs linked with risk index values and drought severity class can be viewed by invoking the Index map submenu. Surface water drought risk indices were assigned to respective blocks and surface water risk area map was plotted which could be accessed from submenu named Risk map.

Supply oriented drought risk

Supply oriented drought risk menu consists of submenus such as Supply risk table, Index map and Risk map. The individual risk maps give the idea to perform some specific drought proofing works. However, drought risk status in all aspects is needed to prioritise the areas of the basins for taking up the relief measures. Supply oriented drought risk index was developed by combining the meteorological, surface and ground water drought risk indices of each block and classified into four categories namely very mild, mild, moderate and severe. Supply risk table menu contains the risk index values and drought severity class which can be retrieved and updated. A map consisting all blocks was attached with the risk values and severity class can be accessed by invoking the Index map submenu. The map showing the spatial distribution of supply oriented drought risk can be accessed from the submenu named Risk map.

Landuse based integrated drought risk

The above map was only based on supply factors which must be checked whether it satisfies the demand. For this, the above supply oriented drought risk map was overlaid with the landuse map after assigning ranks to various landuse categories and the Landuse based integrated drought risk map was plotted. This map can be retrieved through Landuse based integrated drought risk menu that consists of submenus namely, Land risk table and Risk map. Risk index values and drought severity class in tabular format can be accessed and updated from Land risk table. Using Risk map menu, Landuse based integrated drought risk map can be retrieved that shows the overall drought risk scenario. The risk areas depicted by the above map need immediate attention for drought proofing and relief measures. Integrated drought risk maps of Palar and Thamiravaruni basins are presented in Figures 3 and 4.

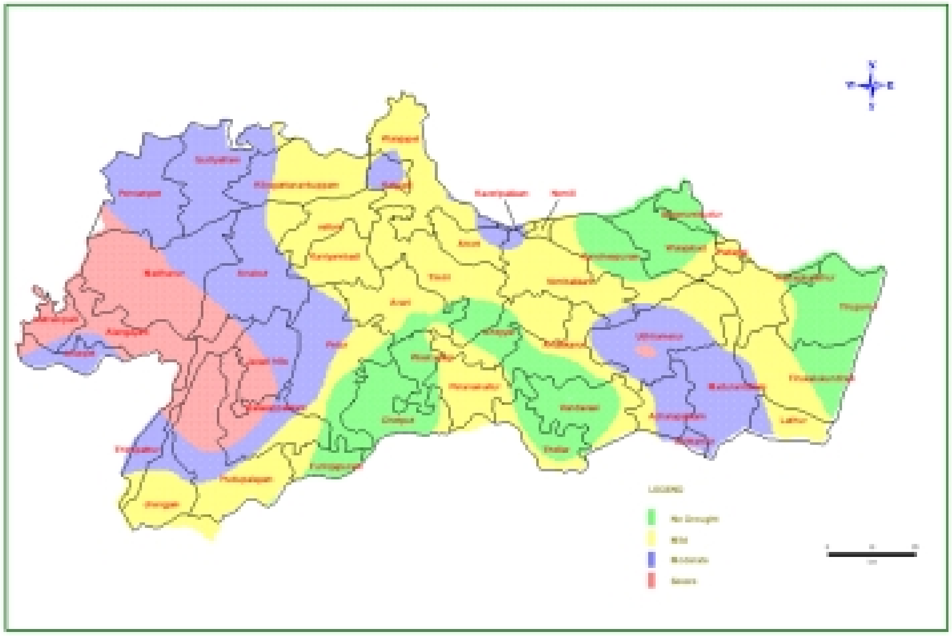

Figure 3 Integrated drought risk map of Palar basin

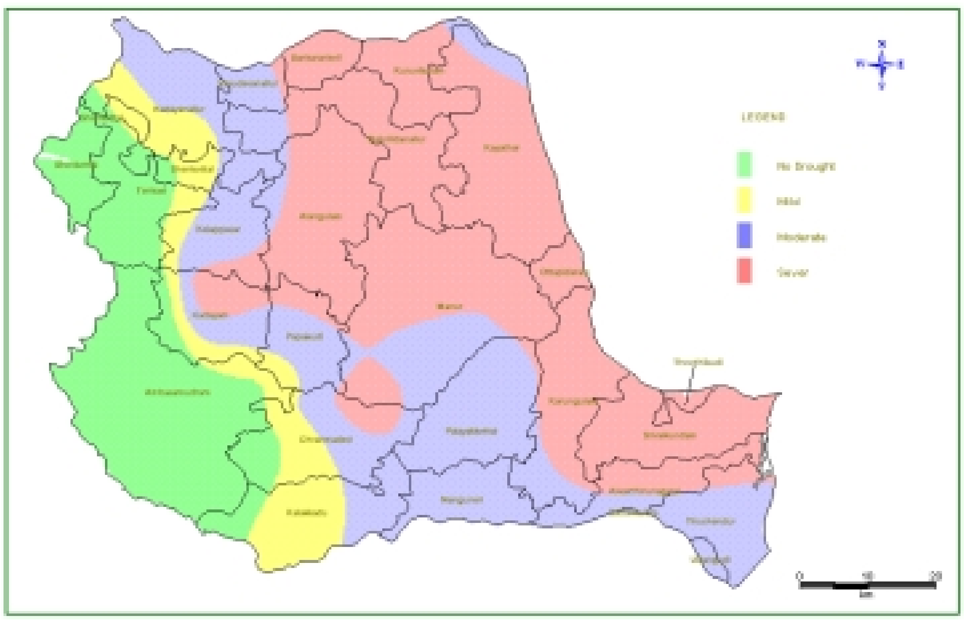

Figure 4 Integrated drought risk map of Thamiravaruni basin

CONCLUSION

Administrators go for a crisis management based on short term data after the occurrence of disaster which is not a wise option. It is necessary to have a long-term experience, historical and technical data for each region in a suitable format, so as to enable the administrators to go for a risk management rather than to go for short-term crisis management.

The DIS developed in the present study provides a spatial and temporal pattern of drought of the study basins to the decision-makers. Further, it also provides the respective information for operational and strategic planning. It is very easy to use at field level by relief and administrative personnel. The effective drought relief and proofing measures based on various aspects of any particular region such as soil class, land use pattern, cropping pattern, irrigated and unirrigated area, availability of storage structures, condition of storage structures, topography of land, drainage condition, presence of rivers and streams etc which can also be provided by DIS. Thus, the developed DIS can be extended to a Decision Support System, which will provide more useful options for water managers and administrators.

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