LECTURE NOTES ON
REMOTE SENSING & GIS
IV B. Tech II semester (JNTU (A)-R13)

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CIVIL ENGINEERING

OBJECTIVES:

1. *To introduce the students to the basic concepts and principles of various components of remote sensing.*
2. *To provide an exposure to GIS and its practical applications in civil engineering*
3. *Analyze the energy interactions in the atmosphere and earth surface features*

OUTCOMES:

On completion of the course the students will have knowledge on

1. *Principles of Remote Sensing and GIS*
2. *Analysis of RS and GIS data and interpreting the data for modeling applications*

UNIT – V

WATER RESOURCES APPLICATIONS:

Land use/Land cover in water resources, Surface water mapping and inventory, Rainfall – Runoff relations and runoff potential indices of watersheds, Flood and Drought impact assessment and monitoring, Watershed management for sustainable development and Watershed characteristics.

Reservoir sedimentation, Fluvial Geomorphology, water resources management and monitoring, Ground Water Targeting, Identification of sites for artificial Recharge structures, Drainage Morphometry, Inland water quality survey and management, water depth estimation and bathymetry.

TEXT BOOKS:

1 Remote Sensing and GIS by B.Bhatta, Oxford University Press,New Delhi.
2 Fundamentals of remote sensing by gorge Joseph , Universities press, Hyderabad

REFERENCES:

1. Advanced surveying : Total station GIS and remote sensing – Satheesh Gopi – Pearson publication.
2. Remote Sensing and its applications by LRA Narayana University Press 1999.
3. Basics of Remote sensing & GIS by S.Kumar, Laxmi Publications.
4. Remote sensing and GIS by M.Anji Reddy ,B.S.Pubiliications,New Delhi.
5. GIS by Kang – tsung chang, TMH Publications & Co.,

UNIT-5
WATER RESOURCES APPLICATIONS

Application areas of Remote Sensing & GIS in Water Resources Engineering :

The interpretation of remotely sensed images may provide valuable information to the Water Resources Engineer, some of which are discussed below for various fields of applications.

Sl. No.	**Field of application**	**Useful interpreted information**	**Helpful in**
1.	Irrigation Engineering	Crop area, Crop yield, Crop growth condition, Crop areas that are water stressed and are in need of water.	Estimating the amount of irrigation water that is to be supplied to an irrigated area over different seasons
2.	2. Hydrology	Different types of soils, rocks, forest and vegetation of a water shed, soil moisture	Estimating runoff from a watershed, where the land-cover type and soil moisture would decide the amount that would infiltrate
3.	Reservoir sedimentation	Plan views of reservoir extent at different times of the year and over several years	Estimating the extent of sedimentation of a reservoir by comparing the extent of reservoir surface areas for different storage heights
4.	Flood monitoring	Flood inundated areas	Flood plain mapping and zoning
5.	Water Resources project Planning	Identification of wasteland (from MSS images), mapping of infrastructure features (from PAN images) like existing roads Project, embankments, canals, etc. apart from plan view of a river	Recent information helpful in planning and designing of a water resources project based on the present conditions of the project area

Geographic Information System (GIS)

A GIS is a computer application program that stores Spatial and Non-Spatial information in a digital form. Spatial information for an area is what is traditionally represented in maps which for a region, may broadly be classified as given in the following table. The corresponding source of such data for our country is also indicated.

Sl. No.	Spatial features of a region	May be obtained from
1.	Elevation contours • Drainage • Location of roads, towns, villages	Survey of India, in the form of Topo-Sheets
2.	Soil map	National Burean of Soil Survey and Land Use Planning
3.	Geological map	Geological Survey of India
4.	Latest information on land-use and landcover, like • Vegetation, forest, crops, etc • Roads, Embankments, Canals • Rivers • Towns, villages and other human habitation	Satellite imageries
5.	Maps of District, Block, Thana,Mouza, Taluk, etc	State Land Record office
6.	Location of ground water wells and corresponding water tables as observed over time	Central or State Ground Water Boards

Non-Spatial data, also called Attributes, refer to information like demographic distribution of a town or a village, width or identification tag of a road (like NH-6), daily discharge of a river at a particular place, etc.

Thus, a GIS conveniently manages all variety of data of a given region in a single electronic file in a computer. This is helpful to any regional planner, including that of a Water Resources Project since all information is conveniently stored and accessed with the computer. Further, though the scales of various printed maps may be different, a GIS stores all of them in the same scale. Normally, different spatial features are stored in sub-files, called layers. Hence, one may use the GIS to open all the layers showing all thematic features. Else, one may display one or a few themes at a time by activating the respective layers. For example, the land-use layer may be displayed along with elevation contours, the other layers being kept off.

Important features of GIS software includes handling of spatial and attribute data, data input and editing, data analysis and output of data, which are discussed briefly in the following sections.

A GIS may be considered to comprise of the following components:

- A software package, the components of which include various tools to enter, manipulate, analyse and output data
- A computer system, consisting of the hardware and operating systems.

Handling of spatial and attribute data in GIS

There are two types of data storage structures in a GIS-Raster and vector. According to the Raster system, the space is assumed to be divided into a grid of cells, with a certain value attached to each cell according to the data that is represented by a grid of cells, would be done by marking the corresponding cells black (and assigning a value 1), with all other cells remaining vacant (that is, assigning a value of 0). In the vector system of data storage, the particular point would be stored by the coordinates of the location. This was an example of a point feature. Other types of geographic features include line, area, network of lines and surface, which have been shown in Figure.Version

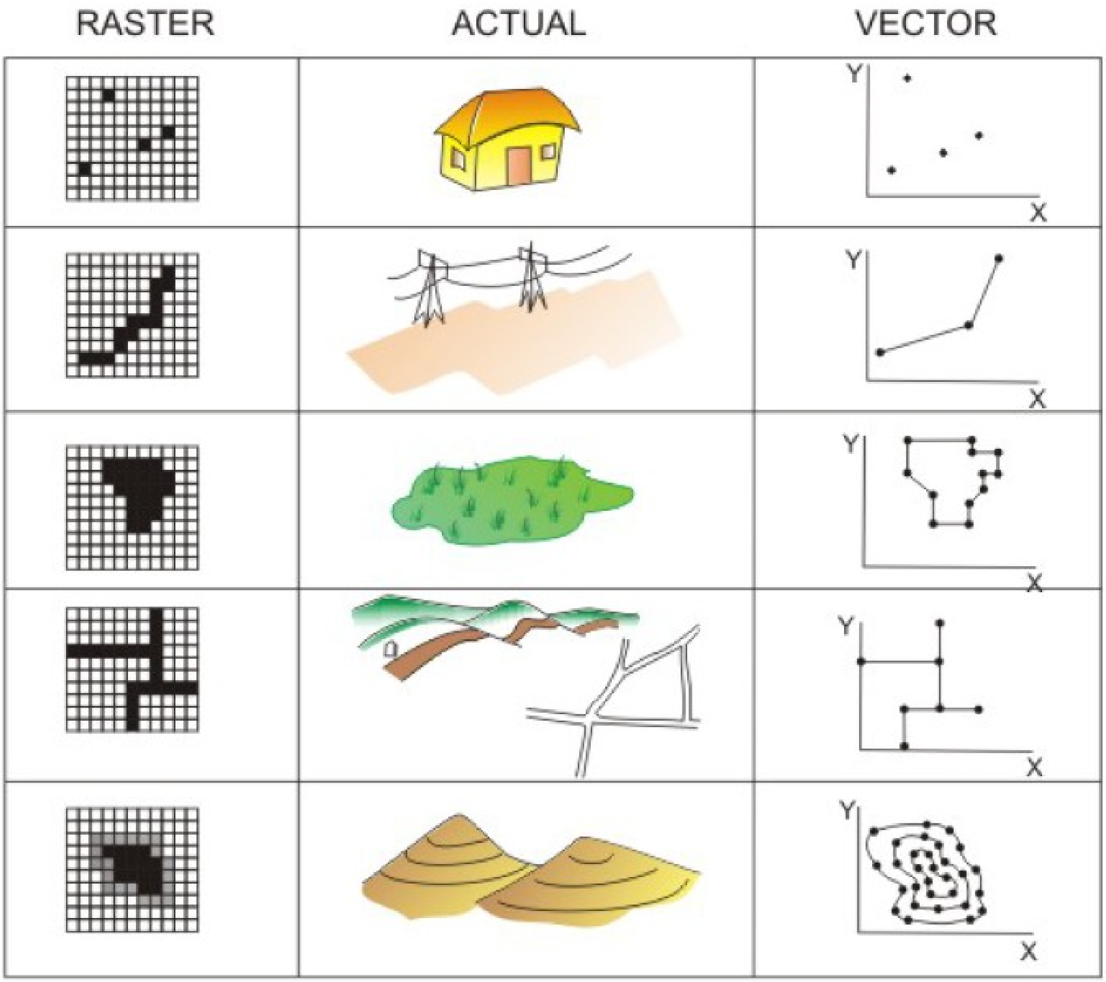


FIGURE 9. Raster and Vector representations of actual objects

It may be noticed that in the raster grid representation of an area, the size of the grids is a choice of the person using the GIS. For example, in representing the spatial information of a town, a grid size of 10 to 25 m may be sufficient but for a state, 100 to 250 m would be enough.

Adopting a finer grid size would, naturally, provide a better representation of data. But that would require a higher computer storage space, which therefore has to be judged optimally.

For vector data representation, too, a better resolution of data may be achieved for line features by selecting more number of points closely. This applies also for representing the lines defining the boundary of an area. For surface representing more number of points defining the elevation contours would result in a more precise definition of the region.
Attribute data is non-spatial, that is, it is not something that varies continuously in space. This is actually the database that defines the spatial data. For example, the location of ground water wells is a spatial data, but the water level record or variation of water level with time is an attribute data of the particular well. Similarly, rivers may be represented as a network of lines, but the width and average depth at different points would be represented as attribute data.

Application areas of GIS in Water Resources Engineering

There are many areas in Water Resources Engineering where GIS may be successfully applied. Some examples have been given in this lesson in the previous sections, and some more are illustrated below. Project planning for a storage structure In this example, a dam is proposed to be constructed across a river, **for which the following information may be desired:**

- Watershed area contributing to the project site
- Reservoir surface area and volume, given the height of the dam
- villages that may be inundated under reservoir

For the above, the following themes may be stored in a GIS:

- Elevation contours of the watershed area, including the project site
- Satellite image derived land-use map of the watershed
- Village boundary map, showing location of habitation clusters

Using the above data, one may obtain desired in information as follows:

- Watershed area may be found by using the elevation contour data, and using a suitable GIS software that has a tool to delineate the watershed boundary. Once the boundary is identified, the area calculation tool may be used in the GIS software to calculate the watershed area.
- Reservoir surface area can similarly found using the area calculation tool. Volume calculation tool of the GIS software may be used to find out the storage volume, which is the space between a plane at the reservoir surface and the reservoir bottom.
- By overlying the reservoir extent over the village boundary map and the locations of habitation clusters one may identify the villages that are likely to be inundated once the reservoir comes up. The area of the cultivable village farms that would be submerged may also be similarly identified, as it would be required to pay compensation for the loss to the villagers.
- The amount of forest land that is going to be submerged may be identified by overlaying the reservoir area map over the land use map, for which compensatory afforestation has to be adopted.

Project planning for a diversion structure

Here, a barrage is proposed across a river to divert some of its water through a canal, for which the following information may be desired:

- Location site of the barrage
- Location and alignment of the off taking canal
- Command area that may be irrigated by the canal

Land Cover & Land Use

Although the terms land cover and land use are often used interchangeably, their actual meanings are quite distinct. Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other. Identifying, delineating and mapping land cover is important for global monitoring studies, resource management, and planning activities. Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps.

Land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture. Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know what current quantity of land is in what type of use and to identify the land use changes from year to year. This knowledge will help develop strategies to balance conservation, conflicting uses, and developmental pressures. Issues driving land use studies include the removal or disturbance of productive land, urban encroachment, and depletion of forests.

It is important to distinguish this difference between land cover and land use, and the information that can be ascertained from each. The properties measured with remote sensing techniques relate to land cover, from which land use can be inferred, particularly with ancillary data or a priori knowledge.

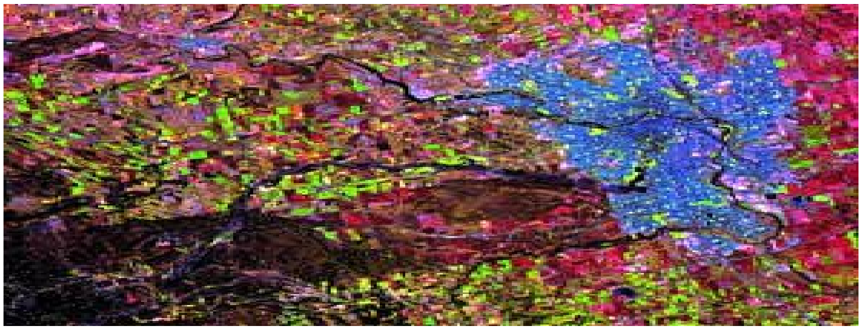
Land cover / use studies are multidisciplinary in nature, and thus the participants involved in such work are numerous and varied, ranging from international wildlife and conservation foundations, to government researchers, and forestry companies. Regional government agencies have an operational need for land cover inventory and land use monitoring, as it is within their mandate to manage the natural resources of their respective regions. In addition to facilitating sustainable management of the land, land cover and use information may be used for planning, monitoring, and evaluation of development, industrial activity, or reclamation. Detection of long term changes in land cover may reveal a response to a shift in local or regional climatic conditions, the basis of terrestrial global monitoring.

Ongoing negotiations of aboriginal land claims have generated a need for more stringent knowledge of land information in those areas, ranging from cartographic to thematic information.

Resource managers involved in parks, oil, timber, and mining companies, are concerned with both land use and land cover, as are local resource inventory or natural resource agencies. Changes in land cover will be examined by environmental monitoring researchers, conservation authorities, and departments of municipal affairs, with interests varying from tax assessment to reconnaissance vegetation mapping. Governments are also concerned with the general protection of national resources, and become involved in publicly sensitive activities involving land use conflicts.

Land use applications of remote sensing include the following:

- Natural resource management
- Wildlife habitat protection
- Baseline mapping for GIS input
- Urban expansion / encroachment
- Routing and logistics planning for seismic / exploration / resource extraction activities
- Damage delineation (tornadoes, flooding, volcanic, seismic, fire)
- Legal boundaries for tax and property evaluation
- Target detection - identification of landing strips, roads, clearings, bridges, land/water interface



Calgary (Landsat-TM)

This is a TM scene of Calgary, Canada, where the 1988 Winter Olympics were held. Calgary appears quite blue; the agricultural fields to the east are red, while grazing land to the west is green. Abutting the southwest corner of the city, is a long rectangular section of land stretching towards the west that is darker and more monotone than the other areas around it. This is the area of the Sarcee Reserve which has been held by native people, and protected from urbanization and residential construction. Of all the land on the image, this land is the closest to the original state of the Calgary region before agriculture and settlements reworked the landscape. It looks like an oasis amidst suburbia and farmland.

More alien circles

These are even stranger circles than the ones we first encountered. The outer circles are tens of kilometers across. What could have created this shape, and other than being a landing target for UFOs, what possible land use could it serve?

You had a good guess if you thought these circles were created by an ancient civilization, like the Aztecs, or it represents a giant teepee ring. But it's not correct. Try again.

The circles are part of a military base in southern Alberta. The land is used for practice maneuvers and is "protected" from the ranging and farming on nearby dry grassland. The circles identify radial distances from 'ground zero', where various real and simulated explosions were conducted by the military.

Rainfall – Runoff relations and runoff potential indices of watersheds

Land use is an important characteristic of the runoff process that affects infiltration, erosion, and evapotranspiration. Hydrologic models, distributed models in particular, need specific data on land use and its location within the basin. Remote sensing can provide measurements of many of the hydrologic variables used in hydrologic and environmental model applications, either as direct measurements comparable to traditional forms, as surrogates of traditional forms, or as entirely new data set. The pixel format of digital remote sensing data makes it suitable to merge it with geographic information system (GIS). Most of the previous work on adapting remote sensing to hydrologic modeling has involved the Natural Resources

Conservation Service (NRCS) runoff curve number (CN) model (US Department of Agriculture, 1972). This involvement used remote sensing data as a substitute for land cover maps which had been obtained by conventional means. Still and Shih (1984, 1985, 1991) used Landsat data to develop a basin-wide runoff index and successfully demonstrated how remotely sensed data can be used to track the changes in runoff that occur in a basin due to land use change. GIS is a computer-based tool that displays, stores, analyzes, retrieves and generates spatial and non-spatial (attribute) data. The GIS technology provides suitable alternatives for efficient management of large and complex databases. It is used in hydrologic modeling to facilitate processing, management and interpretation of hydrologic data. Several studies have been done to incorporate GIS in to hydrologic modeling of watersheds. These studies have different scopes and can be generally grouped in to four categories. Computation of input parameters for existing hydrologic models is the most active area in GIS related hydrology. Unlike lumped models, distributed models require large amounts of spatial data, which can be computed using GIS. Hydrologic assessment refers to the mapping and display in GIS of hydrologic factors that pertain to some situation. Measuring the spatial extent of hydrologic variables from paper maps may be tedious, labor-intensive and error-prone. Watershed surface mapping refers to the uses of GIS in representation of watershed surface through the use of digital elevation model and gridded geographic data. Identification of hydrologic response units is also another contribution of GIS to identify areas of watershed’s having similar hydrologic response. The traditional method for establishing CN on small watersheds includes field surveys and interpretations of aerial photographs. For large drainage basins, field surveys are prohibitively expensive and an excessive number of aerial photographs may be required for complete coverage. A further disadvantage of conventional techniques may be the infrequency of the surveys and the consequent failure to account for changes in vegetative cover and land use. Objectives of this research work are to outline the strategy of employing Landsat images from different sensors and GIS in determining spatially distributed runoff and to estimate spatially variable runoff depth using GIS. This is demonstrated for three different years, to account for temporal changes in a sub-basin of Kissimmee River basin in south Florida.

Flood and Drought impact assessment and monitoring

Droughts and floods are water-related natural disasters which affect a wide range of environmental factors and activities related to agriculture, vegetation, human and wild life and local economies. Drought is the single most important weather-related natural disaster often aggravated by human action, since it affects very large areas for months and years and thus has a serious impact on regional food production, life expectancy for entire populations and economic performance of large regions or several countries. During 1967-1991, droughts have affected 50 per cent of the 2.8 billion people who suffered from all natural disasters and killed

35 per cent of the 3.5 million people who lost their lives. In the recent years large-scale intensive droughts have been observed in all continents leading to huge economic losses, destruction of ecological resources, food shortages and starvation of millions people. Floods are among the most devastating natural hazards in the world, claiming more lives and causing more property damage than any other natural phenomena. Several users such as top level policy makers at the national and international organisations, researchers, middle level policy makers at the state, province and local levels consultants, relief agencies and local producers including farmers, suppliers, traders and water managers are interested in reliable and accurate drought and flood information for effective management. The disaster management activities can be grouped into three major phases: The Preparedness phase where activities such as prediction and risk zone identification are taken up long before the event occurs; the Prevention phase where activities such as Early warning/Forecasting, monitoring and preparation of contingency plans are taken up just before or during the event; and the Response/Mitigation phase where activities are undertaken just after the event which include damage assessment and relief management. Remote sensing techniques make it possible to obtain and distribute information rapidly over large areas by means of sensors operating in several spectral bands, mounted on aircraft or satellites. A satellite, which orbits the Earth, is able to explore the whole surface in a few days and repeat the survey of the same area at regular intervals, whilst an aircraft can give a more detailed analysis of a smaller area, if a specific need occurs. The spectral bands used by these sensors cover the whole range between visible and microwaves. Rapid developments in computer technology and the Geographical Information Systems (GIS) help to process Remote Sensing (RS) observations from satellites in a spatial format of maps - both individually and along with tabular data and “crunch” them together to provide a new perception - the spatial visualisation of information of natural resources. The integration of information derived from RS techniques with other datasets - both in spatial and non-spatial formats provides tremendous potential for identification, monitoring and assessment of droughts and floods. REMOTE SENSING FOR DROUGHTS Monitoring and assessment of drought through remote sensing and GIS depend on the factors that cause drought and the factors of drought impact.

Based on the causative factors, drought can be classified into Meteorological, Hydrological and Agricultural droughts. An extensive survey of the definition of droughts by WMO found that droughts are classified on the basis of: (i) rainfall, (ii) combinations of rainfall with temperature, humidity and or evaporation, (iii) soil moisture and crop parameter, (iv) climatic indices and estimates of evapotranspiration, and finally (v) the general definitions and statements

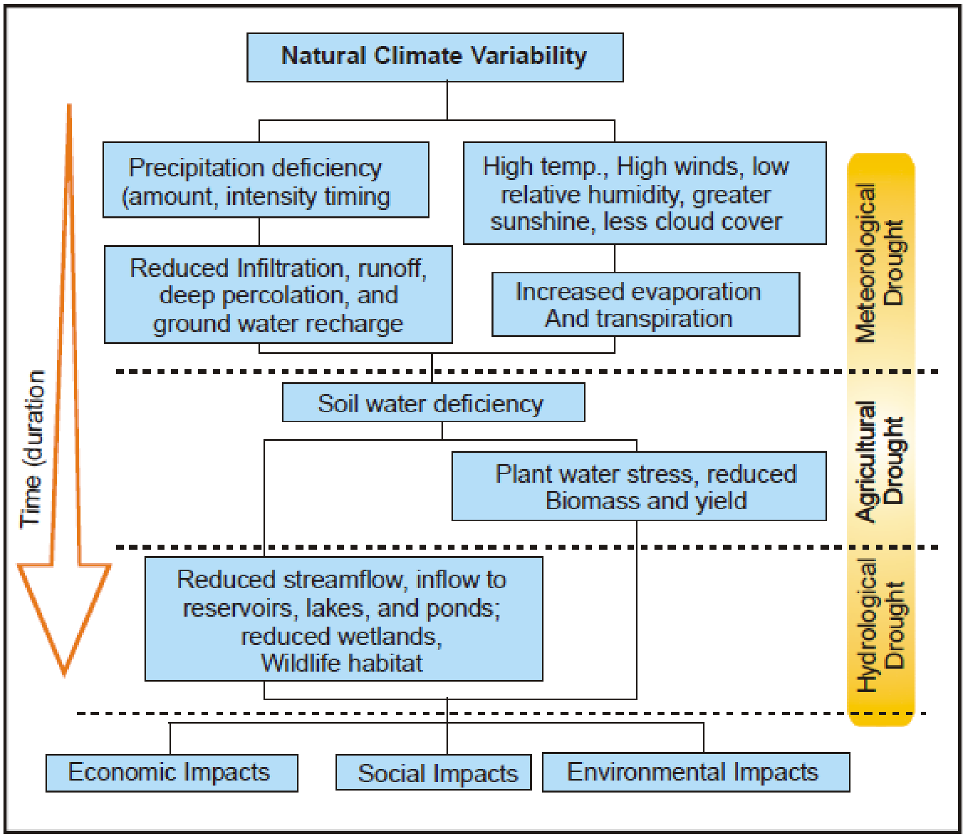


Figure 1: Sequence of Drought impacts

Drought is a normal, recurrent feature of climate and occurs in all climatic zones, although its characteristics vary significantly from one region to another. Drought produces a complex web of impacts that span many sectors of the economy and reach well beyond the area experiencing physical drought. Drought impacts are commonly referred to as direct or indirect. Reduced crop, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat are a few examples of direct impacts. The consequences of these impacts illustrate indirect impacts. The remote sensing and GIS technology significantly contributes to all the activities of drought management.

Drought Preparedness Phase

Long before the drought event occurs, the preparedness in terms of identifying the drought prone / risk zone area and the prediction of drought and its intensity is essential.

Drought Prone/Risk zone identification

The drought prone area or risk zone identification is usually carried out on the basis of historic data analysis of rainfall or rainfall and evaporation and the area of irrigation support. The conventional methods lack identification of spatial variation and do not cover man's influence such as land use changes like irrigated area developed and the area affected due to water logging and salinity. The remote-sensing based method for identification of drought prone areas uses historical vegetation index data derived from NOAA satellite series and provides spatial information on drought prone area depending on the trend in vegetation development, frequency of low development and their standard deviations.

Drought prediction

The remote sensing use for drought prediction can benefit from climate variability predictions using coupled ocean/atmosphere models, survey of snow packs, persistent anomalous circulation patterns in the ocean and atmosphere, initial soil moisture, assimilation of remotely sensed data into numerical prediction models and amount of water available for irrigation. Nearly-global seasonal climate anomaly predictions are possible due to the successful combination of observational satellite networks for operational meteorological, oceanographic and hydrological observations. Improved coupled models and near-real time evaluation of in situ and remote sensing data - allows for the first time physically-based drought warnings several months in advance, to which a growing number of countries already relate their policies in agriculture, fisheries and distribution of goods.

Drought Prevention Phase

Drought Monitoring and Early Warning

Drought monitoring mechanism exists in most of the countries based on ground based information on drought related parameters such as rainfall, weather, crop condition and water availability, etc. Earth observations from satellite are highly complementary to those collected by in-situ systems. Satellites are often necessary for the provision of synoptic, wide-area coverage and frequent information required for spatial monitoring of drought conditions. The present state of remotely sensed data for drought monitoring and early warning is based on rainfall, surface wetness, temperature and vegetation monitoring Currently, multi channel and multi sensor data sources from geostationary platforms such as GOES, METEOSAT, INSAT and GMS and polar orbiting satellites such as National Oceanic Atmospheric and Administration (NOAA), EOS-Terra, Defense Meteorological Satellite Program (DMSP) and Indian Remote Sensing Satellites (IRS) have been used or planned to be used for meteorological parameter evaluation, interpretation, validation and integration. These data are used to estimate precipitation intensity, amount, and coverage, and to determine ground effects such as surface (soil) wetness.

Rainfall Monitoring

Rain is the major causative factor for drought. As the conventional method is based on the point information with limited network of observations, the remote sensing based method provides better spatial estimates. Though the satellite based rainfall estimation procedure is still experimental, the methods can be grouped into 3 types namely Visible and Infrared (VIS and IR) technique, passive microwave technique and active microwave technique.

VIS and IR technique: VIS and IR techniques were the first to be conceived and are rather simple to apply while at the same time they show a relatively low degree of accuracy. A complete overview of the early work and physical premises of VIS and thermal IR (10.5 – 12.5 μm) techniques is provided by Barrett and Martin (1981) and Kidder and Vonder Haar (1995). The Rainfall estimation methods can be divided into the following categories: cloud-indexing, bi-spectral, life history and cloud model. Each of the categories stresses a particular aspect of cloud physics properties using satellite imagery.

Cloud indexing techniques assign a rain rate level to each cloud type identified in the satellite imagery. The simplest and perhaps most widely used is the one developed by Arkin (1979). A family of cloud indexing algorithms was developed at the University of Bristol, originally for polar orbiting NOAA satellites and recently adapted to geostationary satellite imagery. “Rain Days” are identified from the occurrence of IR brightness temperatures (TB) below a threshold.

Bi-spectral methods are based on the very simple, although not always true, relationship between cold and bright clouds and high probability of precipitation, this is characteristic of Cumulonimbus. Lower probabilities are associated with cold but dull clouds (thin cirrus) or bright but warm (stratus) clouds. O’Sullivan et al. (1990) used brightness and textural characteristics

Surface Temperature Estimation

The estimation of water stress in crop/ vegetation or low rate of evapotranspiration from crop is another indicator of drought. As water stress increases the canopy resistance for vapor transport results in canopy temperature rise in order to dissipate the additional sensible heat. Sensible heat transport (ET) between the canopy (Ts) and the air (Ta) is proportional to the temperature difference (Ts-Ta). Therefore the satellite based surface temperature estimation is one of the indicators for drought monitoring since it is related to the energy balance between soil and plants on the one hand and atmosphere and energy balance on the other in which evapotranspiration plays an important role. Surface temperature could be quite complementary to vegetation indices derived from the combination of optical bands. Water-stress, for example, should be noticed first by an increase in the brightness surface temperature and, if it affects the plant canopy, there will be changes in the optical properties. During the past decade, significant progress has been made in the estimation of land-surface emissivity and temperature from airborne TIR data. Kahle . (1980) developed a technique to estimate the surface temperature based on an assumed constant emissivity in one channel and previously determined atmospheric parameters. This temperature was then used to estimate the emissivity in other channels .Other techniques such as thermal log residuals and alpha residuals have been developed to extract emissivity from multi-spectral thermal infrared data Based on these techniques and an empirical relationship between the minimum emissivity and the spectral contrast in band emissivities, a Temperature Emissivity Separation (TES) method has been recently developed for one of the ASTER (Advance Space borne Thermal Emission and Reflection Radiometer) products .