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USE OF GIS AND REMOTE SENSING IN DROUGHT MANAGEMENT

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Abstract

Space technology has made a significant contribution to all three phases of managing natural disasters, including the phases of preparedness, prevention, and relief. These phases include drought and flood management. The Earth Observation satellites, which include both geostationary and polar orbiting satellites, provide comprehensive, synoptic, and multi-temporal coverage of large areas in real time and at frequent intervals, and 'thus' - have become valuable for the continuous monitoring of atmospheric as well as surface parameters related to droughts and floods. Observations of the weather, including the tracking of cyclones, may be obtained in a continuous and synoptic fashion across wide regions by using geostationary satellites. Even though they have a low temporal frequency, polar orbiting satellites offer the benefit of giving images with a considerably greater resolution. These images, which may be utilized for thorough monitoring, damage assessment, and long-term relief management, can be obtained by the satellites. Recent developments in remote sensing technology and geographic information systems provide real-time monitoring, early warning, and speedy damage assessment after natural catastrophes such as droughts and floods. The use of remote sensing and GIS, as well as a discussion of the global picture, are topics that will be covered in this lecture on the management of drought and flood disasters.

keywords: *GIS, Remote, Drought, Management*

Introduction

Many people believe that drought is the most complicated but also the least understood of all natural hazards, despite the fact that it affects more people than any other kind of hazard (G. Hagman 1984). In spite of this, there is a great deal of misunderstanding about its properties among the scientific community as well as the policy community. It is exactly this uncertainty that helps to explain, to some degree, the lack of progress that has been made in preparing for drought in the majority of the world's regions. A drought is a natural hazard that has a sluggish beginning and creeps slowly over time; it is a typical feature of the climate for practically all parts of the globe. Droughts have major consequences for the economy, society, and the environment. It may be difficult to pinpoint the beginning or conclusion of a drought, as well as its exact severity. The effects of drought tend to be more non-structural in nature and are felt over a wider geographical region than the damages caused by other types of natural disasters. The non-structural nature of the effects of the drought has undoubtedly made it more difficult to establish accurate, trustworthy, and timely assessments of the severity of the drought's effects, which has, in turn, prevented the majority of governments from developing measures to mitigate the effects of the drought. The impacts of drought, like those of other hazards, can be reduced through mitigation and preparedness. Planning for readiness in the event of drought should be seen as an integral component of integrated water resources management. A crucial component of integrated water resources management is enhancing the capacity of society to better deal with the extremes of climate and the unpredictability of water resources (i.e., floods and droughts). Planning for contingencies such as drought will also be of significant assistance in becoming ready for the possibility of climate change. Throughout the course of history, flood control has received a greater amount of attention than drought management has. It is vital that all countries enhance their ability to manage water supplies during water-short years because of the rising pressure that is being placed on water and other natural resources as a result of growing and shifting populations (i.e., regional and rural to urban). This strain is being put on water and other natural resources as a result of expanding populations. According to D.A. Wilhite's research from 2000, the likelihood of a place being affected by drought is dependent on both its proximity to natural hazards and its susceptibility to long-term water scarcity. If countries and regions are going to make any headway in mitigating the devastating effects of drought, they will need to acquire a deeper comprehension of the threat posed by the hazard as well as the factors that determine susceptibility. It is essential for regions that are prone to drought to have a better understanding of their drought climatology (i.e., the probability of drought at different levels of intensity and duration) and to establish comprehensive and integrated drought information systems. These systems should take into account climate, soil, and water supply factors such as precipitation, temperature, soil moisture, snow pack, reservoir and lake levels, ground water levels, and stream flow. Instead than adopting the conventional strategy of crisis management, which places the focus on reactive, emergency response measures, all countries that are prone to drought should create national drought policies and preparation plans that put the emphasis on risk management. These plans and policies should be developed as soon as possible. The handling of crises results in a decreased capacity for self-reliance and an increased dependency on the government and donors.

Drought : Definitions

There is not one single accepted definition of drought. It is typically difficult to transfer criteria created for one location to another since drought is a regionally distinctive phenomenon that reflects changes in meteorological parameters and also incorporates diverse physical, biological, and socioeconomic elements. On the other hand, some of the more standard definitions of drought include the following:

- In 1965, the Director of the Common Wealth Bureau of Meteorology proposed a comprehensive definition of drought as "severe water shortage."
- According to Palmer's definition, a drought is "an interval of time, generally on the order of months or years in duration, during which the actual moisture supply at a given place rather consistently falls short of the climatically expected or climatically appropriate moisture supply" (Palmer, 1965). This definition was published in 1965.
- According to Mc Mohan and Diaz Arena (1982), "Drought is a period of exceptionally dry weather sufficiently for the absence of precipitation to generate a major hydrological imbalance. It also contains implications of a moisture shortage with relation to man's utilisation of water.
- Droughts can last for several months or even years."Drought" is defined by Flag as "a period of rainfall deficiency, extending over months or years of such a nature that crops and pasturage for stock are seriously affected, if not completely burnt up and destroyed, water supplies are seriously depleted or dried up, and sheep and cattle perish." This is an additional definition that is worth mentioning.
- The author Hangman (1984) writes that "Drought is considered by many to be the most complex but least understood of all natural hazards affecting more people than any other hazard." (Wilhite, 2000)

A drought is a multifaceted phenomena that may be understood from a number of different vantage points. Definitions of drought are divided into two categories by Glantz: conceptual, which refers to definitions given in broad terms, and operational. People are better able to comprehend the notion of drought with the aid of conceptual definitions that are articulated in general terms; nevertheless, these definitions typically do not give quantitative solutions. On the other hand, operational definitions make it possible to determine when a drought started, when it ended, and how severe it was. After reviewing the definitions presented above, one may gain an understanding of the primary cause of drought, which is a scarcity of water. This lack of water, in turn, has an effect on the availability of food and fodder, which ultimately results in migration and financial loss for economies as a whole.

REMOTE SENSING FOR DROUGHTS

The causes that generate drought and the elements of drought effect are important considerations in drought monitoring and evaluation using remote sensing and geographic information systems (GIS). Droughts may be broken down into three categories: those caused by weather and climate, those caused by water shortages, and those caused by agriculture. According to the findings of a comprehensive study conducted by the WMO on the topic of the definition of droughts, droughts can be categorised according to the following criteria: (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 (v) the general definitions and statements.

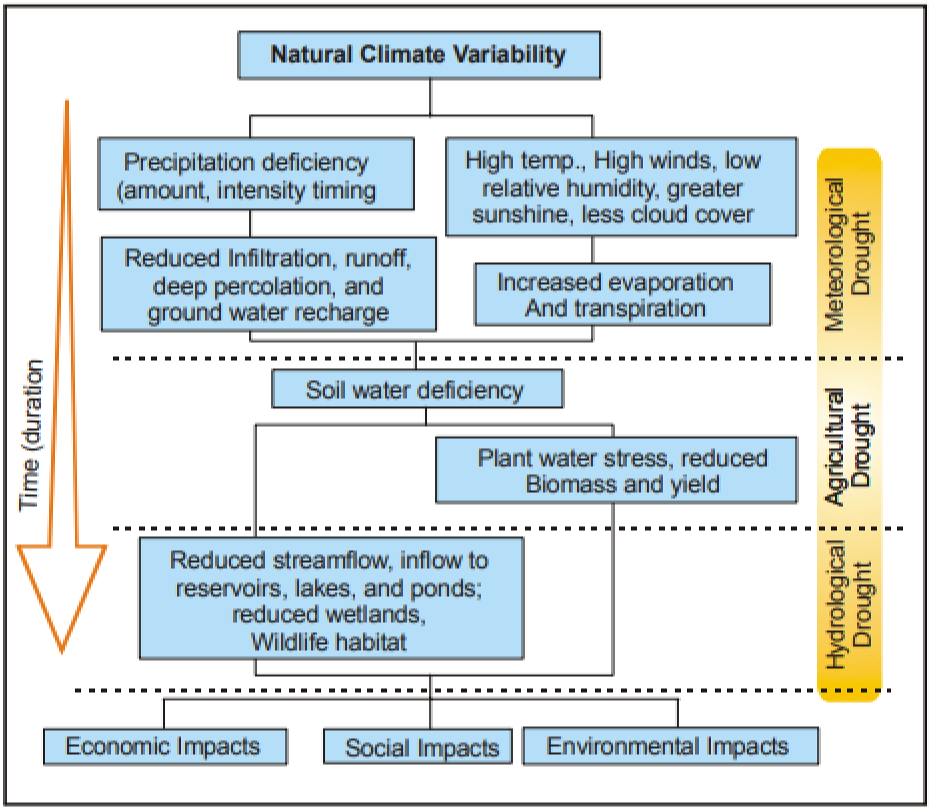

Figure 1: Sequence of Drought impacts

A drought is a natural, periodic element of the environment that may be found in all climatic zones, despite the fact that the features of a drought might vary greatly from one location to another. The effects of drought are widespread and far-reaching, affecting a multitude of economic subfields and extending well beyond the region that is actually experiencing drought conditions. The effects of a drought are often classified as either direct or indirect. Direct affects include, but are not limited to: decreased crop, rangeland, and forest productivity; increased fire danger; decreased water levels; increased livestock and wildlife death rates; and damage to wildlife and fish habitat. Indirect impacts include: decreased crop, rangeland, and forest production; increased fire hazard; reduced water levels; and reduced water levels. The effects that these affects have on other things are examples of indirect repercussions. Every aspect of drought management can benefit considerably from the utilisation of remote sensing and geographic information system technologies.

Drought Monitoring and Early Warning

In the majority of nations, there is a process for monitoring drought that is based on information gathered from the ground about drought-related indicators such as rainfall, weather, crop status, and water availability, among other things. The observations of Earth made by satellites provide a valuable supplement to the data acquired by systems located on the ground. When it comes to the supply of synoptic, wide-area coverage and the frequent information required for spatial monitoring of drought conditions, satellites are frequently necessary. The current status of remotely sensed data for drought monitoring and early warning is based on rainfall, surface wetness, temperature, and vegetation monitoring. This is the case since rainfall is the most reliable indicator of future drought conditions.

At the moment, multi channel and multi sensor data sources from geostationary platforms like GOES, METEOSAT, INSAT and GMS as well as polar orbiting satellites like NOAA, EOS-Terra, Defence Meteorological Satellite Programme (DMSP), and Indian Remote Sensing Satellites (IRS) have been used or are planned to be used for the evaluation, interpretation, validation, and integration of meteorological parameters. These data are utilised in the estimation of the intensity, quantity, and coverage of precipitation, in addition to the determination of ground impacts such as surface (soil) wetness.

Rainfall Monitoring

The absence of rain is the primary element that contributes to drought. Because the traditional technique relies on point information and has only a small network of observations, the method that is based on remote sensing is able to produce more accurate spatial estimations. Despite the fact that the satellite-based approach for estimating rainfall is still in the testing phase, the techniques may be broken down into three categories: the visible and infrared (VIS and IR) methodology, the passive microwave technique, and the active microwave technique. VIS and IR technique: The VIS and IR procedures were the first to be conceived of, and while they are quite straightforward to implement, they demonstrate a rather low degree of accuracy. VIS and IR techniques were developed initially. Barrett and Martin (1981) and Kidder and Vonder Haar (1995) offer a comprehensive summary of the early work that was done on VIS and thermal IR (10.5 – 12.5 m) approaches, as well as the physical premises upon which these techniques are based. Cloud-indexing, bi-spectral, life history, and cloud models are the four categories into which rainfall estimating approaches may be placed. With the use of satellite photography, each of the categories focuses on a different element of the physical characteristics of clouds. The techniques of cloud indexing give a certain rain rate level to each cloud type that may be distinguished in the satellite picture. The one that was invented by Arkin (1979) is the simplest and maybe the one that is utilised the most. The University of Bristol is responsible for the creation of a series of cloud indexing algorithms, which were first designed for polar orbiting NOAA satellites but have now been modified to work with geostationary satellite images. The occurrence of IR brightness temperatures (TB) that are lower than a certain threshold is what distinguishes "Rain Days" from other days. The bi-spectral approaches are based on the extremely basic association between cold and bright clouds and a high possibility of precipitation; however, this relationship is not always true. Cumulonimbus clouds are characterised by having these qualities. Clouds that are warm but not bright (stratus) or clouds that are cool but not brilliant (thin cirrus) are connected with lower likelihood. Rainfall was estimated across a 10 x 10 pixel array by O'Sullivan et al. (1990) using brightness and textural properties throughout the daylight as well as IR temperature trends. The researchers divided the rainfall into three categories: no rain, light rain, and moderate/heavy rain. The life-history methods are a family of approaches that primarily need geostationary satellite images. These methods rely on a comprehensive investigation of the life cycle of the cloud, which is especially significant for convective clouds. A good illustration of this would be the Griffith-Woodley method (Griffith et al., 1978). The goal of the methodologies used to model clouds is to incorporate cloud physics into the data retrieval process in order to achieve a quantitative improvement that is derived from a more accurate physical description of the rain-making processes as a whole. Gruber (1973) was the first person to present a cumulus convection parameterization in order to establish a relationship between fractional cloud cover and rain rate. A one-dimensional cloud model is used in the Convective Stratiform Technique (CST) (Adler and Negri, 1988; Anagnostou et al. 1999). This model establishes a relationship between cloud top temperature and rain rate and rain area. Passive microwave technique: The presence of precipitation may be deduced from the structure of cloud tops since visible and infrared light cannot pass through clouds. At passive MW frequencies, the primary cause of attenuation of the upwelling radiation is precipitation particles. Consequently, methods based on MW radiation are physically more direct than those based on VIS/IR radiation. The rise in the signal that is received by the satellite sensor as a consequence of the emission of radiation from atmospheric particles is somewhat offset by the reduction in the radiation stream that is caused by the scattering of radiation that is caused by hydrometeors. The frequency of the upwelling radiation determines not only the kind but also the size of the hydrometeors that are found. Above 60 GHz, ice scattering predominates, and radiometers can only detect ice; rain cannot be detected at this frequency or higher. Absorption is the principal process that affects the transport of MW radiation below around 22 GHz, and ice that lies above the rain layer is nearly transparent at those frequencies. Radiation with a frequency range between 19.3 and 85.5 GHz interacts with the two most common forms of hydrometeors, which are water droplets and water particles that are either liquid or frozen. Scattering and emission both take place at the same time, and inside the cloud column that is visible in the field of view (FOV) of the sensor, radiation goes through a number of different transformations. Diffraction, which restricts the ground resolution for a given satellite MW antenna, and the fact that MW sensors are consequently only deployed on polar orbiters are the two factors that contribute to the poor spatial and temporal resolution. This is the most significant drawback of microwave remote sensing. Differences in the radiative properties of the water and land surfaces beneath further complicate the situation. The SSM/I is a scanning-type instrument that measures MW radiation over a swath that is 1400 kilometres wide at four different frequencies: 19.35, 22.235, 37.0 and 85.5 GHz. The latter frequency extends the spectral range of previous instruments into the strong scattering regime (as regards to precipitation-size particles). This instrument is the primary instrument that is used for MW-based rainfall estimations.

Microwaves that are active: The PR, or precipitation radar, is the first instrument of its kind to be flown on board a spacecraft and is considered the most essential instrument for sensing precipitation from space. The PR operates at 13.8 GHz and is carried by TRMM. The purpose of the instrument is to provide the vertical distribution of rainfall for the analysis of its three-dimensional structure, collect quantitative measurements over land and seas, and improve the overall retrieval accuracy by combining the use of the radar with the use of the TMI and VIRS sensors. These goals may be accomplished through the usage of the instrument.

Global scenario on Remote Sensing use

There have been several examples of the operational use of these satellites for the thorough monitoring and mapping of floods and for assessing the damage caused by floods after they have occurred. For the purpose of monitoring floods in China, information obtained by remote sensing is collected from a variety of sensors and platforms, including satellites, aeroplanes, and the ground. Estimation of real-time flood damages was made possible thanks to the creation of a specialised geographical information system called the flood analysis damage information system (Chen Xiuwan). High-resolution satellite data were operationally employed for mapping post-flood river configuration, flood control works, drainage-congested regions, bank erosion, and producing flood danger zone maps. This was in addition to mapping the flood and conducting a damage assessment. A number of satellite photos taken during the floods that occurred in the St. Louis area in 1993 were analysed and merged together to provide timely data sets. The maps that were produced were helpful for a number of users because they enabled them to easily detect both natural and man-made elements, establish the magnitude of the floods in a precise and quantitative manner, and characterise flood consequences and flood dynamics. (Petrie et al., 1993). The presence of clouds has made it difficult for satellites to make optical observations of flooding, which has resulted in a shortage of data collections in a timeframe that is nearly real-time. Even when there is a significant amount of cloud cover, the Synthetic Aperture Radar (SAR) system is able to carry out routine observations of the earth's surface. Applications such as those used in hydrology, which require a periodically obtained image for monitoring purposes, are therefore able to satisfy the data requirements of their respective applications. application of SAR data is not limited to the mapping of floods; rather, it may also be helpful in the calculation of a variety of hydrological parameters. SAR data were utilised in the process of estimating soil moisture, which was then employed as an input in the TR20 model for the purpose of flood forecasting (Heike Bach, 2000). Using ERS-SAR data, researchers analysed the flooding that occurred in Northern Italy, Switzerland, France, and England in October of 2000. Scientists are now able to investigate, map, and anticipate the impacts of floods with a precision that has not been seen before because to the information obtained by the Earth Observation satellites operated by the European Space Agency (ESA). The ability of SAR photos to accurately detect open water, which often appears dark in such photographs, is another important capability of this technology. It is possible to generate an incredibly precise and comprehensive digital map by combining the data from this satellite with the optical and infra-red imagery from other satellites. Quantitative Precipitation Estimates (QPE) and predictions (QPF) employ satellite data as one source of information to assist flood and flash flood predictions in order to offer early warnings of flood danger to communities. This is done in order to equip communities with the ability to prepare for and respond to flooding. The less direct but better resolution (space and temporal) pictures are being incorporated into new algorithms that are currently under development. Integration of radar, rain gauges, and remote sensing techniques is helping to enhance real-time flood forecasting. This has led to an improvement in rainfall spatial distribution measurements. Research has been done to investigate whether or not employing weather radar in flood forecasting may be beneficial. (Report of the United States to the International Union of Geodesy and Geophysics for the Years 1991–1994). A distributed rainfall-runoff model was applied to a basin that was 785 kilometres long and was covered by radar. The basin also included two rain gauges. The rainfall measured by rain gauges, the rainfall estimated by radar, and the rainfall measured by rain gauges and radar together served as inputs for the computation of three different flood hydrographs that were generated after a storm that had occurred in the past. The hydrograph that was calculated from the combined input was the one that was the most similar to the hydrograph that was observed. There has been a significant amount of effort put into the development of the methodology required to combine these remotely sensed estimations and data collected in-situ into hydrological models for the purpose of flood forecasting. In order to better serve the needs of the insurance business, a comprehensive flood risk assessment model was built for the River Thames. The model was constructed utilising Geographic Information Systems and image processing methods that are routinely utilised. It was based on data obtained from aerial Synthetic Aperture Radar. The ortho-rectified images were used to create a land cover map.

CONCLUSIONS

Floods and droughts are two of the most destructive natural disasters that can occur anywhere in the world. These natural disasters are responsible for the loss of the most lives and cause considerable damage to agriculture, vegetation, human and animal life, and local economies. The remote sensing and geographic information system (GIS) technology makes a substantial contribution to the activities of all three key phases of drought and flood management, namely: 1. The Preparedness Phase, in which activities such as prediction and risk zone identification are carried out a very long time before the event actually takes place. 2. The Response Phase, in which activities such as response and recovery are carried out after the event has taken place. 2. The Phase of Prevention, which includes activities such as Early Warning and Forecasting, Monitoring, and the Preparation of Contingency Plans; 3. The Phase of Response and Mitigation, which Includes Activities Just After the Event and Includes Damage Assessment and Relief Management. This presentation will provide a quick review of remote sensing and GIS methodologies, as well as examine their application to the management of drought and flood conditions.

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