Applications of Remote Sensing in Water Resources Management

Water is a fundamental resource for all life on the planet. Of the water on earth, only three percent is fresh and two thirds of that is trapped in ice caps and glaciers. Water resources management is the action of planning, developing, distributing, and managing the optimal use of water. Many issues that are faced within water resources management are floods, droughts, and water quality. This paper focuses arbitrarily on these three components and how remote sensing plays a key role in monitoring and collecting data.

Floods are among the worst natural hazards that we face today. Their frequency and wide spread devastation make it an important aspect of water resources management. Remote sensing is an important tool in providing life saving data. With current stream gauge equipment it may be difficult to collect data during an extreme flood event with a very high return period. In developing countries the density of gauging stations is very low which creates a shortage of ground data. This creates inadequate data for flood prediction and risk assessment modeling (Sanyal 2004). Remote sensing observations have become a cost-effective method in hydrologic predictions in poorly gauged or ungauged basins around the world (Khan 2011).

The current most applications used in flood management are synthetic aperture radar (SAR). SAR utilizes active remote sensing technique called radio detecting and ranging (RADAR). RADAR has the ability to penetrate cloud cover and has all weather capabilities. SAR has an important advantage in that it provides easily distinguishable data between land and water. Change detection is an excellent tool to detect flooded area in SAR imagery. It is performed by taking two imageries of before and after the flood. The only downside to SAR is the relation between radar wavelengths and the roughness of the terrain and water body. During extreme flood events windy conditions create ripples in the water making more backscatter. When the water is flat it registers as a dark tone in SAR imageries while rough water is a brighter tone. This makes it hard to determine a threshold value in order to delineate a flooded area.

Another current application that is used predominantly in developed countries such as the United States is LIDAR (Light Detecting and Ranging). LIDAR is excellent for determining accurate digital elevation mapping (DEM). LIDAR can also accurately map flood depth. The laser beam depending on its strength is accurate within 15 to 25 cm (Sanyal 2004). It has become the optimal application in creating flood maps on flat flood plains. The only downside to this technology is that it is more costly than SAR. These are just a few examples of systems and methods used in flood management which aid water resources management in accurately determining flood damage, severity as well as determining flood prone areas.

Droughts are responsible for affecting the economic and social wellbeing of millions of people a year, especially in developing countries. A major focus within the field of water resources management is the monitoring, reporting, and, mitigation of the impacts of drought on the environment. Remote sensing technology plays a vital role in determining a lot of these factors. Satellite sensor data is available that can be used to detect the onset of drought, its duration and magnitude (Thenkabail 2004).
Different sensors and platforms that are commonly used in determining these factors are NOAA National Environmental Satellite Data and Information System (NESDIS) using the Advanced Very High Resolution Radiometer (AVHRR) data to determine vegetation conditions. This provides real time dissemination of information.

One of the more modern sensors is the Moderate-Resolution Imaging Spectrometer (MODIS). MODIS utilizes an advanced narrow band-width sensor and provides composite reflectance data at no cost every eight days from NASA and the USGS (Thenkabail 2004). Through the Global Vegetation Phenology product we are able to determine many factors that determine drought conditions. Such as identifying the vegetation growth, maturity and marking seasonal cycles. Other global data is available through Indian National Satellite System (INSAT) and Kaplana-1 formally known as METSAT and is used for three types of rainfall predictions, long-term seasonal, medium range, and short term (RAO 2005).

Within the field of water resources management and the issues it faces a reoccurring statement is the fact that information is usually derived from a combination of data sources. In the case of drought monitoring and assessment Thenkabail et al. developed an approach to combine two generations of sensors (AVHRR and MODIS) to develop real time drought assessment and monitoring to developing regions of the world. This study proved to be successful due to the fact that one of the three remote sensing indices used was successful in correlating the data. They created the option for enhancing existing free data and the study is currently being used to develop a regional drought monitoring system in southwestern Asia (Thenkabail 2004).

Water quality is distinguishable by its intended use such as human consumption, industrial use, or the environment. Water resources management focuses on all these aspects and utilizes remote sensing to monitor these water quality applications. Remote sensing is used to monitor water quality parameters such as suspended sediments (turbidity), chlorophyll, and temperature. These parameters are categorized as physical indicators. Optical and thermal sensors aboard boats, planes and satellites provide the spatial and temporal information needed to monitor water quality. In return this provides the information to create management practices to improve water quality.

An example of a sensor used to detect water quality under the parameters of turbidity would be the use of IKONOS satellite. IKONOS provides high resolution data for mapping turbidity. The best correlation of turbidity is through red reflectance. A case study that used remote sensing to determine turbidity in ice marginal lake at the Bering Glacier, Alaska was undertaken by Liza Kay Liversage. She used simple and multiple linear regression analyses conducted using different Landsat 7 ETM-f bands to determine the best predictors of turbidity (Usali 2010).

Remote sensing is an excellent tool for the mapping of chlorophyll concentrations. Chlorophyll is one of the photosynthetic agents that contribute to the color of water. By determine the concentration of chlorophyll contained in plankton cells one can quantify the eutrophication of a water body (Usali 2010). Measurements are taken using aircraft, Landsat, SPOT, and SeaWiFS to determine chlorophyll concentrations and patterns. Most studies of chlorophyll and water are based on the observed relationship between radiance in narrow bands or bands ratio and chlorophyll concentration. It is found that chlorophyll absorption occurs in short wavelengths. Hyperspectral imaging, with its ability to record over two hundred spectral channels is a perfect tool used in to determine water quality. Hyperspectral imaging provide many narrow, contiguous wavelength bands that allow the many aspects of water quality to be measured and monitored (Ritchie 2003).
Another physical indicator for determining water quality is temperature. Thermal pollution is evident when anthropogenic activities occur. An example of this would be the water runoff used to cool power plants. Thermal remote sensing is a useful tool in determining water temperatures. Advanced Very High Resolution Radiometer (AVHRR) is most commonly referred to throughout the research as a beneficial sensor in the collection of data (Ritchie 2003). Aircraft mounted thermal sensors are the best way to collect data due to the ability to control the timing of the data collection. This provides a basic idea of the platforms and sensors used as well as analytical procedures that are undertaken in remote sensing to determine water quality. Using remote sensing techniques allows water resources managers to develop effective management plans to reduce the effect of man-made thermal releases.

When developing this overview on the applications of remote sensing in water resources management the paper focuses on three components in order to find out how remote sensing plays a role in the issues that are faced. Remote sensed data provides a historical, permanent geographical image based data that can be used as a baseline for future comparison within all the issues of water resources management. This provides an invaluable tool that many professionals are becoming aware of and utilizing. Water management is one of the biggest issues that mankind will face in the near future. Currently many agencies are working in designing more advanced sensors that will incorporate higher spectral and spatial resolution. As the human population rises and an increased demand on a dwindling fresh water supply, remote sensing is sure to play a much larger role in the wide scoping issues of water management.

**Annotated Bibliography**


Khan et al. discuss the development of remote sensing as a viable alternative to in situ observations in ungauged water basins. The article is accessible, reader friendly, and well organized. When researching the uses of remote sensing in flood management this article is an excellent example of its potential and current uses within the field. The article begins with a history of satellite imagery for flood mapping. They focused on the Nzoia Basin, a subbasin of Lake Victoria in Africa. Khan et al. discuss the study area, data collected, the methodologies used, and the results and analysis of their studies on satellite remote-sensing based flood inundation mapping in the Nzoia Basin. Their study focused on finding the most current satellite products within a distributed hydrologic model to show the spatial extent of flooding in poorly gauged basins. The data was derived from MODIS and ASTER sensors and one of the various methodologies mentioned is the Iterative Self-Organizing Data Analysis Technique Algorithm (ISODATA).
They concluded that hydrologic predictions and flood management can improve based off the development of more accurate hydrologic models derived from remote sensing optical sensors.


The author Rao addresses the benefits of using satellite imagery in the various areas of water resources management. The areas he focuses on are groundwater detection, monitoring rainfall, snow, glaciers, irrigation management, reservoir sedimentation, watershed management, flood management, drought management, and water quality. Rao understands the need to integrate both remote sensing and a ground approach in an effort to provide information on large areas where most of the data needed within water resources management resides. He identifies the various satellites and sensors, but does not touch base on any studies taken place within the various areas of water resources management that he mentions. His article clearly states the benefits of remote sensing in that it fills the gap between in situ observations that can suffer from the limitations of reliability, time effectiveness, and adequacy. He also states that remote sensing is less costly, requires less manpower, and is not affected by inhospitable or inaccessible terrain. When writing the overview Rao provided a basis of information which aided in arbitrarily choosing three issues within water resources management and provides an excellent summary of remote sensing in water resources management.


In this study Ritchie et al. provides the potential uses of remote sensing to assess water quality. The article offers an excellent insight on the different methods of detecting water quality such as, suspended sediment, algae chlorophyll concentrations, observation of aquatic vascular plants, and temperature. Within each one of these methods they provide various case studies and analytical approaches for detecting the waters quality using remote sensing. Ritchie et al. believe that with the advent of greater spectral and spatial resolutions that we can one day move away from empirical approaches being used and develop algorithms that will allow us to use full resolution electromagnetic spectrum to monitor water quality parameters. This article provides specific examples and insight which makes it beneficial in extracting information on a vast topic such as water quality. This article allows you to gain a great deal of knowledge on how remote sensing applications play an instrumental role in data acquisition and assessment.


This article discusses the advancements in remote sensing within the field of flood management. It mentions the progression of optical remote sensing to active remote sensing which provides unimpeded all weather, day or night information. The field of flood management revolves around the creation of flood zones and flood hazard maps. The study focuses on the use of digital elevation modeling (DEM) as the most effective way to estimate flood depth and in turn create an accurate flood hazard map. The area of study is in developing countries within Asia and touches on the fact that accurate DEMs are hard to come by in this region. The use of microwave remote sensing such as synthetic aperture radar (SAR) and LiDAR are discussed as the most current tools. Sanyal et al. mentions the use of a combined approach which is common within fields that do not have data derived for their specific purpose. The article is summed up by mentioning the difficulty of capturing data during the various flood stages which
can occur quickly and without warning. The various techniques mentioned provide a great deal of information and identify where remote sensing can be used in developing areas such as Asia in order to create a comprehensive flood management plan where it is especially needed.


This article discusses the drought assessment and monitoring in Southwest Asia using remote sensing. Many areas in this region such as Afghanistan are lacking any kind of drought monitoring and management procedures. As of right now there is no efficient system to analyze and deliver drought-related information. Thenkabail et al. bring to light the method of utilizing two generations of sensors (AVHRR and MODIS) to bring a near-real-time drought assessment and monitoring. The two data sets overlapped during a two year period between 2000 and 2001. This gave them the ability to explore the relationships between the two data sets such as spatial resolution and atmospheric correction. The established relationships then allowed them to examine drought occurrences across sensors and time periods from 1982 to present day, and into the future. In conclusion the study was a success and validated the methods of assessing droughts across two different sensors. It created the option for enhancing existing free remote-sensing data. The study is being implemented to develop regional drought monitoring system in Southwestern Asia.


This article discusses the use of GIS and remote sensing in Malaysia to determine water quality. Usali et al. focused on monitoring water quality parameters such as suspended matter, phytoplankton, turbidity and dissolved organic matter. Each one of these parameters are touched upon within the reading and provide methods used in determining their value using remote sensing. The use of remote sensing in this region is viewed as an excellent tool to monitor and manage water quality. Remote sensing is a huge benefit to this region in that it limits field costs, improves the information content in order to create an accurate digital map and allows the monitoring of water quality on a larger scale.

This article is a high-quality example of a current study within the past three years and shows the growing trend of implementing remote sensing and GIS in regions all around the world. The overview of monitored water quality perimeters and remote sensing techniques makes this an excellent resource to extract valuable research in creating an overview of water quality in the field of water resources management.