A Review on GIS in Irrigation and Water Management

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***Abstract*— In most part of the world, water resources are finite and most of the economically viable development has already been implemented. In addition, population growth and the effects of cyclic droughts on irrigated agriculture have put pressure on the available water resources. Such prevailing conditions have the effect of creating an imbalance between the increasing water demand and limited available water supply. Under this perspective, effective planning and management can only be obtained on the basis of reliable information on spatial and temporal patterns of farmer's water demand, on farming irrigation practices, and on physical and operational features of large-scale irrigation systems. The timely and reliable assessment and monitoring of water resources and systematic exploration and developing new ones is of paramount importance. For this, it is necessary to employ modern methods of surveying, investigations, design, and implementation. Remote sensing and GIS are viewed as an efficient tool for irrigation water management. Geographic Information System (GIS) and remote sensing techniques can provide managers and planners with the visualizing effects resulting from various management strategies, under different climatic and operational conditions. They can be used as analytical tools and can significantly enhance the ability of researchers and practitioners responsible for investigating water management alternatives.**

Keywords:- GIS; Irrigation; water mangement

INTRODUCTION

Where resources are scarce, proper planning and decision making at different levels is essential. In today's high-tech world, information technology provides easy solutions for decision making, where the key is the collection and collation of different information at usable format. A geographic information system (GIS) allows users to bring all types of information based on the geographic and locational component of the data. GIS provides the power to create maps, integrate information, visualize scenarios, solve complicated problems, present powerful ideas, and develop effective solutions like never before. More than that, GIS lets one model scenarios to test various hypotheses and see outcomes visually to find/identify the outcome that meets the needs of the stakeholders. Now a days, GIS and related technologies are increasingly being recognized as useful tools for natural resources inventorying studies and management because of their capability to bring together geographically referenced data from a variety of subject matters to aid in processing, interpretation, and analysis of such data.

METHOD AND MATERIALS

In May 2019, literature and reviews were collected on the differ aspect about the GIS in Irrigation and water management were confined to internet searches using search engines provided by Google throughout the world. The literature review found some published & some unpublished like reports of GIS in Irrigation and water management, research papers and thesis within the past Twenty years.

Definition of GIS: Geographic Information System (GIS) is computer-based system used to store and manipulate geographic information. A widely used definition of GIS is "an organized collection of database, application, hardware, software, and trained manpower capable of capturing, manipulating, managing, and analyzing the spatially reference database and production of output both in tabular and map form." In a more generic sense, GIS is a tool that allows users to create interactive queries, analyze the spatial information, and edit data [6].

Benefits of GIS Over Other Information Systems:

GIS is fundamentally used to answer questions and make decisions. A GIS like other information systems provides the following four sets of capabilities to handle geographic data:

(i) Input
(ii) Data management
(iii) Manipulation and analysis
(iv) Output

In addition, GIS is designed for the collection, storage, and analysis of objects and phenomena, where geographic location is an important characteristic or critical to analysis. The spatial searching and overlay of (map) layers are the unique functions of GIS. For example, maps of crop potential and ground/surface water situation can be combined in a GIS to produce map of the crop/land suitability on a temporal and spatial basis.

Since in a real world situation, complexity is large (e.g., in agriculture for decision making, data on land, soil, crop, climate, hydrology, forestry, livestock, fisheries, social and economic parameters are required), and the physical computing capacity to manipulate data is low and time consuming; GIS is an advanced and excellent planning tool for the resource managers and decision makers. GIS thus is the central element in the configuration of modern information technology[4].

Major Tasks in GIS: GIS performs major six types of jobs:

- *Input*: Digitalization from paper map, scanning and vector processing, image classification.
- *Manipulation*: Before all the information are integrated, they must be transformed into same scale of resolution.
- *Management*: The spatial and attribute database

management.

- *Query and viewing*: Once the data base is prepared, user can do any query on the data through GIS, e.g., where is the soil having land type MHL and clay-textured soils.
- *Analysis*: GIS has many powerful tools to generate "what-if" scenario. For exam- ple, "Does drought exists in an area? How intensive is it? What is the extent and what will be the crop yield loss?"
- *Visualization and printing*: Preparation of maps, legends, symbology, and other related elements, and providing facility to print from printers [1].

Applications of GIS: The GIS can be used in the following fields/disciplines:

(a) *Agriculture*
- – Climatic constraints of growing crops
- – Soil resources availability, assessment, and planning
- – Potential suitability of crops/cropping pattern
- – Crop hazard mapping and yield loss estimation
- – Agro-ecosystem characterization
- – Determining potential area suitable for crops
- – Extrapolation area delineation of agricultural technologies
- – Agricultural extension
- – Agricultural research planning
- – Agricultural development planning
- – Crop production planning

(b) *Natural resources management*
- – Water resources management
  - • spatial map of soil hydraulic properties
  - • map of groundwater table depth
  - • estimation of crop water stress and developing water demand map
  - • irrigation scheduling
  - • estimating water logging condition
  - • spatially distributed data sets that can be utilized for better management of large-scale irrigation systems and for supporting decision-making processes
- – Environmental impact assessment
- – Forest resources management
- – Flood and other natural disaster mitigation planning

(c) *Urban and rural planning*
- – Planning and zoning
- – Infrastructure planning
- – Land information system
- – Percale mapping
- – Tax assessment based on present land use

GIS has a wide range of potential applications in agricultural research. One aspect of agricultural research/planning for which the integration and analytical capabilities of GIS can be effectively utilized is characterization of crop-growing environments using agro-ecological approach. A GIS can convert existing digital information, which may not be in map form, into forms it can recognize and use. For example, digital satellite images generated through remote sensing can be analyzed to produce a map-like layer of digital information about vegetative covers.

Thus, the changes in vegetation vigor through a growing season can be animated to determine when drought is most extensive in a particular region.

GIS and related technology will help greatly in the management and analysis of large volumes of data, allowing for better understanding of terrestrial processes and better management of human activities to maintain world economic vitality and environmental quality [6].

Techniques Used in GIS

GIS software is the main method through which geographic data is accessed, transferred, transformed, overlaid, processed, and displayed. GIS-based modeling deals with different layers or information concerns. The model needs some rules or criterion based on which the analysis is done. The relevant scientists, who know the interactions of the layers and can apply their knowledge for the analysis, can develop the rules or criterion. The overlay technique of GIS provide the users flexibility in dealing with the interactions between the parameters concerned spatially and thereby demonstrate the results spatially as map form. The rules and the relevant database development are crucial for GIS modeling.

Implementation of GIS

It is generally understood that a system means a combination of workable hardware and software, but a GIS system is different, which includes the data base, trained personnel, and a methodology to operate the data for the application. Requirements of a GIS should be defined in terms of the applications the system is expected to support. A data base is the foundation needed to perform any application. GIS software is the central to the professional analysis and presentation of GIS data.

The following different steps have to follow to carry out a GIS application:

(e) Outline and elaborate the objective(s)
(f) Outline the analysis need
(g) Formulate the rule for analysis
(h) Outline the data need and their format
(i) Look the data availability at different sources
(j) Identify the data need to capture, collect, and collate
(k) Coding the data, assess its accuracy
(l) Capture the data, edit and clean it with proper documentation
(m) Do necessary analysis
(n) Produce output and validate (if applicable) (o) Prepare a report [6].

Data and Databases for GIS

GIS data are handled in a database or databases, which will have special functional requirements as well as the general characteristics of any standard database. Geographical data are inherently a form of spatial data. Spatial data that pertain to a location on the earth's surface are often termed geo-referenced data. Geographic data are commonly characterized as having two fundamental components:

(i) *Attribute data*: The phenomenon being reported such as a physical dimension or class
(ii) *Spatial data*: The spatial location of the phenomenon

Examples of a physical dimension might be the height of a

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forest canopy, the population of a city, or width of a river. The class could be a land type, a vegetation type. The location is usually specified with reference to a common coordinate system such as latitude and longitude.

A third fundamental component to geographic information is time. The time component often is not stated explicitly, but it often is critical. Geographic information describes a phenomenon at a location as it existed at a specific point of time. A land cover map describes the location of different classes of land cover as they existed at the time of data collection.

An agro-ecological zone (AEZ) is a geographical area delineated through a unique combination of physiography, soil, and hydrological and agro-climatic characteristics. Overlay of the agro-climatic inventory on the land resources inventory (physiography and soil map) produces agro-climatic zone/region. AEZ is an effective planning tool for agricultural development purposes. Thirty agro-ecological zones and 88 sub-zones in Bangladesh have been created which are relevant for land use and for assessing agricultural potential.

Sources of Spatial Data

The primary data sources are remote sensing and global positioning system (GPS).

Remote Sensing: Captures digital data by means of sensors on satellite or air- craft that provide measurement of reflectance's or images of portions of the earth. Remotely sensed data are usually in raster structure.

Global Positioning System: Allows capturing terrestrial position and vehicle tracking, using a network of navigation satellites. Data are captured as a set of point position readings and may be combined with other attributes of the object by means of textual/numerical devices such as data loggers. The data are structured as sequence of points, that is, vector format.

The spatial data is stored as *X*, *Y* coordinate pairs. Since the world is spherical

(3D), to store the geographic features in 2D system, one must project the geographic

Data to get the real world coordinate system. One of the key issues for the GIS

Database development is to specify a common coordinate system for the database.

Data Input

There are five types of data entry systems commonly used in GIS: keyboard entry, coordinate geometry, manual digitizing, scanning, and the input of existing digital files.

(i) *Keyboard entry and coordinate geometry procedure*: Attributes data are commonly input by keyboard, where spatial data are rarely entered in this way. Coordinate geometry procedures are used to enter land record information.

(ii) *Scanning*: Scanning, also termed scan digitizing, is a more automated method for entering map data. It converts an analog data source (usually a printed map) into a digital data set.

(iii) *Digitizers:* Manual digitizing is the most widely used method for entering spatial data from maps. It provides a means of converting an analog spatial data source to a digital data set with a vector structure.

(iv) *GIS-Based Modeling or Spatial Modeling:* Geographic information systems (GIS) are quite common and generally accepted in surveying and mapping, cartography, urban and regional planning, land resources assessment, and natural hazard mapping, e.g., crop loss estimation; for environmental applications such as hydrological modeling, climate change modeling, and land management. Current trends in GIS in interrogation of vector and raster data sets resulting a hybrid GIS make easy to accommodate database layers, specifically the remote-sensing-based satellite images and subsequent classification of the images for spatial modeling.

RESULT AND DISCUSSIONS

Modern techniques such as remote sensing (RS) and geographic information systems (GIS) have the capabilities of water resource management and conservation tool. RS/GIS analysis can show where water enters a system and how it leaves through evapotranspiration and runoff. Using this information, planners can identify areas where there is potential for development of new water resources; where water can be reallocated from one use or one basin to another; and identify potential areas of water scarcity before water shortages occur. GIS helps in generation of irrigation water demand map by modeling of water demand considering variation in crop, soil and climate [2014]. The GIS technique helps in integration of satellite and ground information to evaluate the system performance and to diagnose the inequality in the performance to aid in improving the water management.

Approaches for modeling under GIS could be of two types: a decision support system based on rule formation for individual layers or integrating the layers by a series of equations, which expresses the relationship among the parameters and finally providing an output. The second type of model also called lumped parameter model. If under GIS environment all the basic functions (data input, management, analysis, and output generations) are integrated with the rule-based or other necessary tools for the modeling under one graphical users interface (GUI), then it is called the GIS-based modeling or decision-support system.

GIS have been used in many areas such as agricultural watershed management [8]. Hydrology [5]. Water productivity estimation [2]. monitoring of irrigation delivery [9]. groundwater assessment (11. estimating water demand [10]. hydrologic impacts of land-use change [3]. and water resources management [4 and 7].

Remote sensing is the collection of data through imaging sensor technologies, usually on an aircraft or satellite. The remote sensing techniques involve close examination of enlarged landsat imageries and aerial photographs followed by identification, interpretation, and mapping of various water and agricultural resource data connected with water bodies, forests, soil and land types, crop areas, roads, villages, etc. In addition to collection and mapping of various resources data, correlation studies between two or three types of data can easily be made from the imageries and air-photos. Remote sensing technique can be used in water resources management [5].

Crop yield estimation can be improved by using agro meteorological and remote sensing data which involve the development of crop-specific and area-specific crop growth and yield models. Soil moisture also plays an important role under both irrigated and rain-fed conditions. Thus monitoring of soil moisture status in a region using remote sensing data would be useful for assessing the crop condition as well as for advising the farming community for providing life saving irrigation, thinning operation, post-ponding fertilizer, and pesticide application.

Remote sensing techniques are useful for irrigation water management in the following areas:

• Identifying, inventory and assessment of irrigated crops
• Determination of irrigation water demand over space and time
• Assessment of water availability in reservoir for optimal management of water to meet the irrigation demand
• Distinguishing lands irrigated by surface water bodies
• Estimating crop yield
• Water logging and salinity problems in irrigated land
• Irrigation system performance evaluation

The information on the crop and water availability derived from remote sensing methods form a reliable database for further investigation and analysis across space and time. Integration of remote sensing and ground inputs can be very effectively organized and analyzed in GIS environment [3].

CONCLUSION

With increasing population pressure throughout the world and the need for increased agricultural production, there is a definite need for improved management of the world's agricultural resources. To make this happen, it is first necessary to obtain reliable data on not only the types of resources, but also the quality, quantity and location of these resources. Satellite-or aerial-based RS technologies will become important tools in improving the present system(s) of acquiring and generating agricultural and natural resource data. Agriculture surveys are presently conducted throughout the world in order to gather empirical information on crops, rangeland, livestock and other agricultural resources. Such information is critical for effective management of depleting and scarce resources. Surveys that are based on the PA concept can facilitate planning and allocation of limited resources to different sectors of the economy. RS technology has the Am. J. Agri. & Biol. Sci., 5 (1): 50-55, 2010 54 potential of revolutionizing the detection and characterization of agricultural productivity based on biophysical attributes of crops and/or soils. Essentially, like other PA components, the information gained from RS data is more meaningful when used in combination with ground data. Although RS cannot capture all types of agricultural information, it can reliably provide accurate and timely information to guide agronomic and economic decision-making.

AUTHOR PROFILE

Mr. Nazir khan Mohammadi was born in 1984 in Paktia city, Afghanistan. He received his Master of Science in Agriculture (Agronomy) from Navsari Agricultural University, Navsari India in 2017. He has been working as academic member and Assistant professor since 2008 in Paktia University, Agriculture faculty, Agronomy Department, Afghanistan.

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