International Journal of Information and Computation Technology.
ISSN 0974-2239 Volume 3, Number 7 (2013), pp. 723-728

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Geographical Information System (GIS) in Geography: A Conceptual Analysis

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Abstract

The aim of this paper is to analyse the conceptutal and basics of GIS. This paper gives a brief account of the GIS technology to in geography, its methods, steps and appllication, as now a days it is a very evolving technique for the geographers to work upon.

Keywords: GIS, concept, steps, application.

1. Introduction

Geography is the study of Earth's features and patterns of their variations in spatial location and time. Many questions of agricultural production are geographic in nature as the production depends on the environment and prevailing socio economic conditions, both of which vary spatially and in time.. Examples are questions related to natural resources management, precision agriculture, agroecological classification for land use planning, regional trends and patterns in technology adaptation, agricultural productivity and income, non-pont source pollution fromagricultural lands, etc. Answering these questions requires access to large volumes of multidimensional geographical (spatial) information of weather, soils, topography, water resources, socio economic status, etc. Further, answers to even apparently simple questions require that the data fromseveral sources be integrated in a consistent form. Geographical Information Systems or GIS enable representation and integration of such spatial information.

The traditional method of presenting geographical information in two dimensions is in the form of maps. Maps are graphic representations of the earth's surface on a plane paper They shape the way we visualize, assess and analyze spatial information. A map consists of points, lines and area elements that are positioned with reference to a common coordinate system(usually latitude and longitude). They are drawn to specified scales and projection. Map scales can vary and depend on the purpose for which the maps are created. Projection is a mathematical transformation used to represent the real 3-dimensional spherical surface of the earth in 2-dimensions on a plane sheet of paper. The map legend links the non-spatial attributes (name, symbols, colours, thematic data) to the spatial data. The map itself serves to store and present data to the user. Such, analogue maps (on paper) are cumbersome to produce and use, particularly when there are a large number of themto be used for analysis.

Computer based GIS facilitates both creation ofmaps and using themfor various complex analyses. It allows working with geographic data in a digital format to aid decision making in resources management GIS is a generic termimplying the use of computers to create and display digital maps. The attribute data which describe the various features presented in maps may relate to physical, chemical, biological, environmental,social, economic or other earth surface properties. GIS allows mapping, modelling, querying, analyzing and displaying large quantities of such diverse data, all held together within a single database. Its power and appeal stemfrom its ability to integrate quantities of information about the environment and the wide repertoire of tools it provides toexplore the diverse data. The history of development of GIS parallels the history of developments in digital computers and database management systems on one hand and those in cartography and automation of map production on the other. The development of GIS has also relied upon innovations made in several other disciplines – geography, photogrammetry, remote sensing, civil engineering, statistics, etc.

A GIS produces maps and reads maps. Its major advantage is that it permits identifying spatial relationships between specific different map features. It can create maps in different scales, projections and colours. But it is not just a map making tool. It is primarily an analytical tool that provides new ways of looking at, linking and analyzing data by projecting tabular data into maps and integrating data fromdifferent, diverse sources. This it does by allowing creation of a set of maps, eachwith a different theme (soils, rainfall, temperature, relief, water sources, etc.). From its early beginnings, GIS has been anintegrating technology both fromthe point of view of its development as well as its use. This is because, once geographic information of any kind is translated into the digital form in a GIS, it becomes easy to copy, edit, analyze, manipulate and transmit it. This allows vital linkages to be made between apparently

unrelated activities based on a common geographic location. This has led to fundamental changes in the way resource management decisions are made in a variety of situations - forest management, marketing management, utility management, transportation, as well as in agricultural, environmental and regional planning and management. Somepotential agricultural applications where GIS can lead to better management decisions are: precision farming, land use planning, watershed management, pest and disease management, irrigation management, resources inventory and mapping, crop area assessment and yield forecasting, biodiversity assessment, genetic resources management, etc.

2. Definition of GIS

A GIS is basically a computerized information systemlike any other database, but with an important difference: all information in GIS must be linked to a geographic (spatial) reference(latitude/longitude, or other spatial coordinates). There are many different definitions of GIS, as different users stress different aspects of its use. For example:

- ESRI defined GIS as an organized collection of computer hardware, software, geographic data and personnel designed toefficiently capture, store, update, manipulate, analyze and display geographically referenced information.
- Duecker defined GIS as a special case of information systems where the database consists ofobservations on spatially distributed features, activities or events, which are definable in space as points, lines or areas. A GIS manipulates data about these points, lines or areas to retrieve data for ad hoc queries and analyses.

2.1 What A GIS Can Do

There are five basic questions which a complete GIS must answer. These are:

- What exists at a particular location? Given a geographic reference (eg latitude, longitude) for a location, the GIS must describe the features of that location.
- Where can specific features be found? This is the converse of the first question. For example, where are the districts with rainfall greater than 500 mmand less than less than 750 mm?
- Trends or What has changed over time? This involves answering both questions above. For example, at what locations are the crop yields showing declining trends?
- What spatial patterns exist? if occurrence of a pest is associated with a hypothesized set of conditions of temperature, precipitation, humidity, where do those conditions exist?
- Modelling or What if …? This is a higher level application of GIS and answers questions like what would be the nitrate distribution in groundwater over the area if fertilizer use is doubled?

3. Geographic Referencing Concepts

A GIS is to be created from available mapsof different thematic layers (soils, land use, temperature, etc). The maps are in two-dimensions whereas the earth’s surface is a 3-dimensional ellipsoid. Every map has a projection and scale. To understand how maps are created by projecting the 3-d earth’s surface into a 2-d plane of an analogue map, we need to understand the georeferencing concepts. Georefencing involves 2 stages: specifying the 3-dimensional coordinate systemthat is used for locating points on the earth’s surface that is, the Geographic Coordinate System(GCS) and the Projected Coordinate Systemthat is used for projecting into two dimensions for creating analogue maps. Geographic Coordinate System is the traditional way of representing locations on the surface of the earth is in the 3-dimensional coordinate systemis by its latitude and longitude.

3.1 Creating a GIS

Like for any other Information System, creating a GIS involves 4 stages: Data input , Data Storage , Data Analysis and modelling, and Data Output and presentation . The distinction from other Information Systems is that for a GIS the data inputs are of two types:

i. Spatial data (latitude/longitude for georeferencing,the features on a map, eg soil units, administrative districts), and
ii. Attribute data (descriptive data about the features, eg soil properties, population of districts, etc.)

Spatial data sources for creating a GIS are analogue maps (soil map, land use map, administrative districts, map, agroecological zone map, etc.) or aerial photographs and satellite imageries. Data input is the process of encoding analogue data in the formof maps, imageries or photographs into computer readabledigitized formand writing data into the GIS database.

3.2 GIS Data Input

Spatial Data capture (representing locations in a database) can be in two basic formats:

(i) Vector format (ii) Raster format

In the Vector format reality is represented as points lines and areas and in the raster format reality is represented as grid ofcells/pixels.The Vector format is based on dicrete objects view of reality (analogue maps) and the raster format is based on continuous fields view of reality (photographs, imageries, etc. In principle, any real world situation can be represented in digital formin both raster and vector formats. The choice is up to the user. Each format has its advantages and disadvantages.

3.3 Vector data capture

This is generally used for capturing datafro analogue maps. It is based on the observation that any map consists of 3 basic kinds of features –

(i) point features, (ii) line features and (iii) polygon or area features.

Points do not have length, width or area.They are described completely by their coordinates and are used to represent discrete locational information on the map to identify locations offeatures such as, cities, towns, well locations, rain gauge stations, soil sampling points, etc. A line consists of a set of ordered points.It has length, but no width or area. Therefore it is used to represent features such as roads, streams or canals which have too narrow a width to be displayed on the map at its specified scale. A polygon or area is formed when a set of ordered lines formclosed figure whose boundary is represented by the lines. Polygons are used to represent area features such as land parcels, lakes, districts, agroecological zones, etc. A polygon usually encloses an area that may be considered homogeneous with respect to someattribute. For example, in a soil map, each polygon will represent an area with a homogeneous soil type. A vector based system displays graphical data as points, lines or curves, or areas with attributes. Cartesian coordinates (x, y) or geographical coordinates (latitude, longitude) define points in a vector system.

4. Raster data capture

A raster based GIS locates and stores map data by using a matrix of grid cells or pixels. Each cell or pixel is represented eitherat its corner or centroid by a unique reference coordinate (cell address). Each cell also has discrete attribute data assigned to it. The raster data resolution is dependent on the pixel or grid cell size. Data can be conveniently captured from remote sensing imageries, areal photographs, and other such imageries of the earth's surface in a raster data format. In this format, the various features are identified by superposing the imageries over a fine rectangular grid of the earth'ssurface which they represent. Raster data capture does not build topography, that is derive spatial relationships between the identified features. But it facilitates simple scalar operations on the spatial data which a vector format does not permit. Raster data requires to be converted to vector format before topology can be built and spatial operations can be carried out. The raster format also requires more storage space on the computer than the vector format. Most standard GIS software have the facility to transform maps from raster formats and vice versa.

5. Geographic Analysis

What distinguishes GIS from other databases or information systems are its spatial analysis functions. These functions use spatial and non-spatial data to answer questions about the real world. The answers could relate to a presentation of the current data (first level use), some patterns in the current data (second level use) and predictions of what the data could be at a different place or time (third level use). Geographic analysis is carried out using the layers of map information created in vector orraster data formats and associated attribute data to find solutions to specific problems. In each case the problemneeds to be defined clearly before the relevant map layers and analysis procedures can be identified. For instance, if the problemis to find optimal locations for siting of wells for conjunctive use in an irrigation project area, information about the geographical features influencing the groundwater recharge will be required. These will include maps of existing well locations, rainfall, land use, soils and command area of the project, all of which influence recharge. Regions with recharge above a selected threshold value may be considered suitable for additional wells. Further, if the area happens tobe near the coast, a buffer zone may be required within which no wells can be sited toprevent sea water intrusion. Similarly buffer zones may be required on either sides of canals to prevent drawal of canal water by the wells. What could happen to the ground water levels and quality in the area if the present use is persisted with or changed could be the subject of another study where the GIS can help to provide more realistic answers.