INTEGRATED GIS AND SATELLITE REMOTE SENSING IN MAPPING THE GROWTH, MANAGING AND PRODUCTION OF INLAND WATER FISHERIES AND AQUACULTURE

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Abstract

Geographic Information System (GIS) Technology is becoming an essential tool for combining various map and satellite information sources in models that simulate the interactions of complex natural systems. With the help of GIS, management of incredible quantity of data such as traditional digital maps, database, models etc., is now possible. Remote sensing provides the most important informative contribution to GIS which furnishes basic informative layers in optimal time and space resolutions (Sivakumar and Donald, 2011).

Keywords: Geographic Information System, Remote Sensing, Mapping, Fisheries, Aquaculture, Inland water

Introduction

Geographic Information Systems (GIS) is an integral part of aquatic science and limnology. Water by its nature is dynamic. Features associated with water are thus ever changing. To be able to keep up with these changes, Technological advancements have given scientists methods to enhance all aspects of scientific investigation, from satellite tracking of wildlife to computer mapping of habitat (D. Schindler, 2011).

Satellite remote sensing is increasingly gaining recognition as an important source for data collection. Experts all over the world are now able to take advantage of a wealth of observation data product and services flowing from specially equipped and highly sophisticated environmental observational satellite (Sivakumar and Donald, 2011).

Integrated Gis and Satellite Remote Sensing Evolution

A Geographic Information System (GIS) generally refers to a description of the characteristics and tools used in the organization and Management of Geographical data. The term GIS is currently applied to computerized storage, processing and retrieval systems that have hardware and software specially designed to cope with geographically referenced spatial data and corresponding informative attribute. Spatial data are commonly in the form of layers that may depict topography or environmental elements (Sivakumar and Donald, 2011).

GIS was born when the virtues of classical map are wedded to the power of computers. It originated in the early 1960s from two independently functioning organization; the Harvard Laboratory for Computer Graphics (HLCG) and the Canadian Geographic Information System (CGIS) (Tasneem and Abbasi, 2010). The 1970s saw increase in the processing power of computers. This coupled with increasing awareness of the environmental issues, spurred the growth of GIS, with developments spreading to private software companies in North America and Europe.

In the 1980s, Environmental Systems Research Institute (ESRI) launches the Arc Info, the first GIS software package that was to become the Industry, standard for the next decades, then later the ArcView. MapInfo Corporation also came up with the first widely used software package with the ability to digitize images named MapInfo. They were later merged into a single product, ArcGIS (Tasneem and Abbasi, 2010).

Remote sensing is the science of deriving information about an object from measurements made of a distance from the object without actually coming in contact with it. Remote sensing provides spatial coverage by measurement of reflected and emitted electromagnetic radiation across a wide range of wavebands, from the earth’s surface and surrounding atmosphere. Each waveband provides different information about atmosphere and land surface: surface temperature, clouds, solar radiation, processes of photosynthesis and evaporation which can affect the reflected and emitted radiation, detected by satellites (Sivakumar and Donald, 2011).

Prior to the 1960s, Remote sensing was dependent on aerial photography which is very useful in many ways but doesn’t have the kind of wide and frequent coverage of earth that is possible with satellites in space (Tasneem and Abbasi, 2010).

In the years to come, remote sensing and GIS were to converge towards each other. As Remote sensing images greatly strengthen GIS, the two developments fuelled the growth of each other, especially with the lunching of the first-ever Remote sensing satellite (TIROS-1). The relationship further strengthened with the launchings of LAND SAT (1,2,3,4,5,6,and 7), National Oceanic and Atmospheric Administration (NOAA) satellite, Sea Sat, Geographic Operation Environmental Satellite (GOES), Television Infrared Observation Satellite (TIROS), Heat Capacity Mapping Mission (HCMM) Satellite, to mention but few (Tasneem and Abbasi 2010).

Gis and Remote Sensing in Mapping the Growth, Managing and Production of Inland Water Fisheries and Aquaculture

GIS analysis of fish habitat has become more sophisticated often combining numerical or statistical models of fish abundance, growth and prey availability with the physical characteristics of the habitat in a GIS framework. These combined models can be used to produce predictions of fish abundance in space or time (Le pape et al, 2003). Targeted sampling can then be used to test the robustness of the prediction (Stoner et al, 2001).

Recently, some new lines of research have started to show the advantages of Integrated GIS technologies into spatial dynamics of populations. Bioenergetics modeling attempts to relate prey size, prey density and water temperature to fish production and historically has been done for an entire area where a species is found. However, smaller scale variation in prey densities, physical factors and density dependent processes such as predation can cause large changes in fish growth and production that would be missed by only-using-scale “average” values. By linking the bioenergetics models to a GIS framework, rates of growth and production can be calculated for smaller areas and different times. Maps can be produced for an area which indicates areas and depths most important for fish growth. If a series of maps are produced using data throughout a seasonal cycle, particular times of the year may become apparent as most important for the growth of that species (Brandt et al, 1992, Mason et al, 1995).

In the past, GIS was not a practical source of analysis due to the difficulty in obtaining spatial data on habitats or organisms in underwater environments. With the advancement of radio telemetry, hydro acoustic telemetry and side-scan sonar biologists have been able to track fish species and create databases that can be Incorporated into a GIS program to create a geographical representation , using radio and hydro acoustic telemetry, biologists are able to located fish and acquire related data for those sites. This data may include substrate samples, temperature, and conductivity (D. Schindler, 2011).

Over a period of time, large amounts of data are collected and can be used to track patterns of migration, spawning locations and preferred habitat.

Before, this data would be mapped and overlaid manually. Now this data can be entered into a GIS program and be layered, organized and analyzed in a way possible to do in the past. Laying within a GIS program allows for the scientist to look at multiple species at once to find possible water shade that are shared by those species, or to specifically choose one species for further examination. The US Geological Survey (USGS) in, cooperation with other agencies, were able to use GIS in helping map out habitat areas, and movement patterns of pallid sturgeon. At the Columbia Environmental Research Centre their effort relies on a customized Arc Pad and ArcGIS, both ESRI (Environmental Systems Research Institute) applications to record sturgeon movements to streamline data collection. A relational database was developed to manage tabular data for each individual sturgeon, including initial capture and reproductive physiology. Movement maps can be created for individual sturgeon. These maps help track the movements of each sturgeon through space and time (D. Schindler, 2011).

Developments in sensor-controller Technology, computers and position systems now bring new opportunities for farm management and aquaculture (Goddard et al, 1995). The development of the publicly available global positioning system (GPS) has opened new doors in opportunities for spatial data. This is a passive positioning system from a constellation of 24 orbiting radio-navigation satellites. They provide continuous position data provided the receivers have a line of site access to the satellites (Goddard et al, 2011).

Differential GPS (DGPS) uses a stationary monitor receiver to calculate the difference between the true position and the determination of a position from the satellites for a point in time. This allows the positions of a roving receiver to have a three dimensional accuracy of 20cm or better (Goddard et al, 2011). Agencies like the Geological survey, US Fish and Wildlife service as well as other federal and state agencies are utilizing GIS to aid in their conservation efforts. GIS is being used in multiple field of aquatic science from limnology, hydrology, aquatic botany, stream ecology, oceanography and marine biology. Applications include using satellite imagery to identify, monitor and mitigate habitat loss. Imagery can also show the condition of inaccessible areas. GIS can be used to track invasive species, endangered species, and population changes. One of the advantages of the system is the availability for the information to be shared and updated at any time through the use of web-based data collection (Kapetsky, 1987).

GIS allows researchers to present data in an easily interpreted, user-friendly and web-accessible format which makes communication with costal and fisheries managers much easier. It makes it easy to combine very different data types, such as socio-political boundaries, land use habitat types and fish distributions so that managers can more easily make educated and informed decisions (Stanbury et al, 1999, Brook Longral, 2004).

Nigeria is a costal state with a lot of fisheries resources both in marine and inland waters. The potentials for aquaculture are no doubt enormous with about 12.5 million hectares estimated to be suitable for aquaculture development in freshwater and marine environment (Gaffar, 1996). The Inland fisheries are estimated to be capable of producing over 1.5 million metric tons of fish annually with adequate management (Ita, 1993, Omoyeni, 2005). It is Ironical that Nigeria's 15 million hectares of Inland water mass (Ita, 1993) and 12.5 million hectares suitable for aquaculture land mass (Gaffar, 1996) have not translated to abundance of fish production. The use of computer-assisted analytical tools such as GIS so that appropriate management decisions can be made quickly and confidently (Omoyeni, 2005).

Aqua model is an information system to assess the operations and impacts of fish farms in both water column and benthic environment (www.aquamodel.org.). It is a "plug in" model that resides within the EASy Marine Geographic Information System which has been used on numerous studies and Investigations involving fisheries and oceanographic topics. All environmental information from field measurements to satellite imagery is readily available for model development and use (http://netviewer.usc. edu/aquamodel/overviewAquaculture,html).

The scope of earth observation by satellite remote sensing is very broad. It covers the physical system, as well as the ecosystem and water quality and surveillance. All of these are relevant to fisheries and aquaculture. Remotely-sensed data have been used in near-shore aquaculture site selection for more than 20 years (Kapetsky, 1987).

Conclusion

As fisheries and aquaculture are fundamentally spatially distributed, responsible management requires a solid understanding of the underlying spatial dimension. GIS and Remote sensing provide the technologies for mapping and analyzing the distribution of aquatic resources, their environment, fishery management units, and production systems which can support decision –making. Indeed, the ultimate aim of GIS is to support spatial decision-making. Remote sensing is as an essential tool for the capture of data subsequently to be incorporated into a GIS and for real time monitoring of environmental conditions for operational management of aquaculture facilities.

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