

CHAPTER 26

Application of Remote Sensing and GIS Technologies for Biodiversity Management

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INTRODUCTION

According to FAO (1981), land is composed of several natural resources such as soils, climate, water, *vegetation*, people as well as *animals*. Remote-sensing and geographic information systems (GIS) technologies are the most cost-effective techniques for providing information for land resource management, including biodiversity. *Remote-sensing* is commonly defined as a technique of collecting information (*using a sensor*) about an object without coming into physical contact with the object (Rees, 1990). To make the definition more focused so as to exclude sensors like animal eyes, a number of restrictions are imposed to the above definition: the object to be sensed is located on or near the earth's surface (vegetation or clouds), the sensor is vertically (ideal case) above the object, and at reasonable distance from it. Examples of sensors are photographic cameras, SPOT, Landsat TM, and MSS.

While remote-sensing is a data-collection technique, (GIS) is a computerised data-handling system. GIS has been defined as a computerised system that allows integration of hard- and software for both spatial and non-spatial data. A GIS must be capable of data input (digitising, scanning, keyboard entry and importing); manipulation; display and analysis. The only relationship between remote-sensing and GIS is that the former provides data or information for use in the latter. However, there are other data and information sources for GIS operations such as field observations with the help of compasses, topographic maps and global positioning systems (GPS).

Because biological diversity is dynamic in both *space* and *time*, remote-sensing, among other techniques, is used to measure and monitor several parameters of biodiversity. While there are several levels of biodiversity (*allele diversity; genetic diversity; polygenic genetic diversity; species diversity; patch diversity; habitat diversity; community diversity; landscape diversity, and regional diversity*), it should be noted that remote-sensing techniques may be limited in measuring or monitoring biodiversity parameters at a level of patch diversity or higher. This may be partly due to the low resolution of the remotely-sensed data and partly due to the

limitation of remote-sensing techniques. Research efforts are under way to try and identify plant species using various types of remotely-sensed data. However, it is possible to measure specific indices of biodiversity at higher levels, e.g. vegetation structure, and relate it to lower biodiversity levels such as animal species.

Remote-Sensing and GIS: Application for Biodiversity Measurement, Monitoring, and Modelling

Remotely-sensed data have been used to measure a number of quantitative and qualitative biodiversity parameters such as what is at point X, where is it, how much of it and its status. Repeated measurements of such biodiversity parameters over a period of time generates data for biodiversity monitoring. Remote-sensing and GIS technologies are ideal tools for measuring, analysing and monitoring of biodiversity resources either directly or indirectly. Ideally, one would like to use remote-sensing tools to measure biodiversity at three levels:

Ecosystem or ecological diversity: This is possible using remote-sensing and GIS techniques. Examples include identifying and mapping forest, woodland, savanna, grassland, water and cultivated ecosystems in any given geographic area.

Species diversity: It may be possible to discriminate between different plant species based on factors like amount of ligno-cellulose and arrangement of leaves. However, it is difficult to identify different plant species systematically when using remotely-sensed data. This is the reason why plant species mapping is carried out by use of remotely-sensed data to identify vegetation boundaries and then carry out intensive field work to know which plant species belong to any of the mapped vegetation polygons. However, GIS can be used to model the presence or absence of plant species if conditions suitable for any given species are known.

Genetic diversity: Genetic diversity is often measured by techniques of provenance, progeny, clonal test or genetic markers like DNA analysis. Remote-sensing is not yet directly used for such genetic diversity measurement.

Satellite imagery data

Satellite data are acquired by several types of sensors such as Landsat TM and MSS; SPOT, AVHRR, and Radar. The sensors are mounted on satellites and then placed in outer space. The data is then collected by ground receiving stations located in several regions around the globe.

The principle used to collect remotely-sensed data is that electromagnetic radiation react differently (*by reflection or absorption*) when it interacts with different objects

on the earth's surface or in the lower atmosphere. Thus, green vegetation will react differently than clouds to electromagnetic radiation and hence the two objects can be uniquely discriminated by use of remotely-sensed data. Satellite data are captured in form of images (smallest unit of the image being a square or grid). The size of the grid (raster) cells vary from sensor to sensor such as TM (30m by 30m); MSS (80m by 80m); SPOT (20m by 20m and 10m by 10m); and AVHRR (4.0km by 4.0km and 1.1km by 1.1km).

The resolution of a sensor relates to the smallest object that can be scanned by and captured as a unique raster cell in the resulting image. The presence or absence of reflected or absorbed electromagnetic radiation is recorded by the sensor and then expressed on a digital scale of 0 – 256. The recorded numbers are called digital values (DNs).

Most commonly-used remotely-sensed data are multi-spectral, i.e. the data are collected using more than one channel or band of electromagnetic radiation. TM data are collected in seven bands and SPOT uses three bands. To maximise the measurement of land resources from remotely-sensed satellite data, at least three bands of the raw data should be used.

The processing and analysis of satellite data for biodiversity measurement may be done by manual or automated techniques. Manual image classification is the oldest and simplest (but not necessarily the most cost-effective and accurate) technique for extracting information from remotely-sensed data. The only requirements needed to carry out manual image classification are a knowledge of terrain features as they express themselves on the remotely-sensed imagery data.

Digital camera data technique (recent advances in remote-sensing)

In the recent past, it was believed that the failure of remotely-sensed data to allow plant species mapping was due to low resolution of satellite data. This led to the development of powerful sensors to collect very high resolution data, as small as 0.01 μm . Such data have been collected for experimental research by the *Airborne Visible/Infrared Imaging Spectrometer* (AVIRIS) sensor. However, preliminary research has shown that high resolution imagery may not necessarily perform better than low resolution data in mapping different plant species, soil or rock types (Price, 1994).

Another new remote-sensing technique of great potential is the use of *Kodak digital colour infra-red camera* that captures images between 400 – 1000 nm. Optimal image resolution of 15cm can be achieved. The images are taken by mounting the camera on a low altitude flying aeroplane and the resolution of the images are pre-determined by height of the flight. The images can be used to measure individual

canopy cover of woody vegetation and hence it is a cost-effective technique of biomass assessment (using canopy area to predict woody biomass). It may be possible to use digital camera data for counting of big game in savanna national parks (provided such game is exposed). However, both AVIRIS and digital camera may not overcome the limitations of using remote-sensing for plant species identification.

The invention of a digital camera may reduce the demand of panchromatic aerial photography for natural resource management. Aerial photography is the oldest form of remote-sensing and is still widely used by urban planners and was widely used for natural resource inventories (vegetation, land use, soils, geology) before the advent of satellite remote-sensing techniques.

Application of Remote-Sensing and GIS for Biodiversity Management: Selected Case Studies

The only alternatives to remote-sensing and GIS techniques for land resource management would be field surveys and manual GIS. Field surveys to carry out inventories of natural resources such as boundaries of vegetation types, soils, geological material and land-use types is only cost-effective for small geographical areas. Manual analysis of geographical data is limited if different map layers have different scales. The following examples provide case studies for the application of remote-sensing and GIS techniques for biodiversity management.

Integration of Remote-Sensing and GIS for Biodiversity Conservation in Sango Bay area, Uganda

The project to integrate remote-sensing, GIS and field biodiversity surveys techniques was executed by MUIENR (*Makerere University Institute of Environment and Natural Resources, Uganda*) and ITE (*Institute of Terrestrial Ecology, UK*) between 1994 and 1996. The major objective of the study was to generate information that would be useful in formulating and designing an ***Integrated Conservation and Development Project*** for Sango Bay area, Uganda. Sango Bay was selected for the study because the area has high biological diversity (Howard, 1991; Taylor, 1991). However, it was realised that the assessment of biodiversity in Sango Bay area was based on limited access to just a small portion of the area due to extensive wetlands and tropical forests. It was also true that historical vegetation maps produced from aerial photographs of the 1950s were being integrated with limited field observations to interpret and assess the biodiversity of Sango Bay.

It was thus decided to update spatial information of Sango Bay habitats through the use of remote-sensing techniques. Landsat TM data were used for the mapping of the Sango Bay habitats. Field biological and socio-economic surveys were simultaneously undertaken in Sango Bay area. The data were integrated in a GIS environment to produce a biodiversity-rated map of Sango Bay. Finally, integration and analysis of biodiversity spatial and socio-economic data can be used to obtain a zoned map that will be used for conservation management.

Vegetation Mapping of Murchison Falls National Park

Murchison Falls National Park (about 5,000 km²) is composed of woodland and savanna ecosystems. Like many parks in Uganda of the same ecosystem set-up, Murchison Falls National Park lacked an up-to-date vegetation map. Production of a vegetation map from panchromatic aerial photography would have been possible but more expensive and time consuming. The management of the park contracted MUIENR to produce a vegetation map using satellite data (Landsat TM) and field work.

Automated computer methods, using TNTmips, combined with GPS-field recorded data of dominant plant species yielded a vegetation map of the park. While traditional computer image classification techniques yielded a vegetation map that was characterised by a lot of misclassifications, using *fuzzy c means classifier* produced acceptable vegetation map. The resultant vegetation map of the park can be used for a variety of applications beneficial to park management and research activities. There is a proposal to use the newly-produced vegetation map of Murchison Falls National Park to set up an in-park monitoring system.

Some GIS techniques relevant to biodiversity management

GIS has several capabilities for data manipulation and to some extent data analysis. As mentioned earlier, GIS integrates data from different sources to ease analysis. The following are some of the commonly-used GIS applications.

Buffer zone creation

GIS can be used to calculate a constant distance from point, line or polygon data. The calculated region between the reference line or point and the new boundary is called a *buffer zone*. Buffer zones may be useful in locating areas suitable or unsuitable for a specified land-use type.

Home range analysis

This is a GIS tool used for creating “home range” polygons from point elements that represent observation events. Polygon fitting statistical methods are employed to create the home range polygons from point observations. Home range calculation is a polygon-fitting technique developed by ecologists to study animal movement behaviour in relation to environmental factors such as food, change in weather and many others.

Overlaying

Overlaying is one of the commonly-used GIS tools to derive information from map layers representing different data. Hence, overlaying is commonly used in GIS modelling procedures such as land-use allocation to meet specified conditions. For example, given several map layers of individual species as collected in the field, overlaying can be used to find out if there is any relationship between the occurrence of an animal and plant species by overlaying. Overlaying is only possible if the different map layers are georeferenced to the same map projection and co-ordinate system.

REFERENCES

- FAO, 1981: *A framework for land evaluation*. Soil Bulletin No. 32. Rome
- Price, J. C., 1994: *How Unique are Spectral Signatures?* Elsevier Science Inc., 181–186
- Howard, P. C., 1991: *Nature conservation in Uganda's Tropical Forest Reserves*. IUCN, Gland, Switzerland and Cambridge
- Taylor, A.R.D., 1991: *Sango Bay wetlands and forests: status and recommendations* – paper II. Unpublished report of the National Wetlands Conservation and Management Programme. Ministry of Environment protection.