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ANALYZING ANTHROPOGENIC LANDSCAPES WITH GIS AND REMOTE SENSING: A LITERATURE REVIEW

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Anthropogenic landscapes are those that have been modified, to varying degrees, by human. Their development is affected by the over-use of natural landscapes in the past such as overgrazing, frequent fires, or excessive depletion of forests. Anthropologists analyzing land-use intensification are now realizing the promise of geographical information systems (GIS) and remote sensing for their research. A literature review of case studies done on varying anthropogenic landscapes will highlight how GIS can give practical integration of geographic spatial structures (habitation, soils, river drainage) to past and current relationships between the environment and human systems when combined with local-level knowledge. Research of this kind also requires a culturally specific temporal and spatial perspective applied to a regional scale. Three case studies are presented, featuring present-day landscapes that are followed at a regional level. The rate of human disturbance and types of anthropogenic modifications from small scale grazing to large-scale mining by corporations are seen in the reviewed case studies involving Russia, Nepal and Botswana.

Anthropogenically modified landscapes are natural complexes that have been significantly altered as a result of direct management impact. The landscapes have been controlled, actively exploited, and utterly changed by human. Agricultural lands, including farmland and pastures, are the most common examples of anthropogenic landscapes; together with forests they make up 80 to 90% of the area in some regions (Hölzel 1998). More extreme changes by humans result in "technological landscapes," which have undergone the most severe degree of man-induced transformation, including urban landscapes and mining centers (Hölzel 1998). The amount of land use intensity can vary, and so the problem arises of measuring levels of landscapes modification. The rate of disturbance, and other types of anthropogenic modifications are studied using a variety of tools, more recently including remote sensing data and Geographic Information Systems (GIS). These tools, when combined with local level knowledge, can document features of landscapes at a regional level, allowing for a more in depth-study. Anthropologists' focus on fieldwork and cultural knowledge allows for an added dimension to the final analysis.

Anthropocentric perspectives of environmental degradation use human consequences of change for measuring criticality (Kasperson 1995). It is where the long-term sustainability of the human-environment relationship is threatened most that regions of criticality exist. Remote sensing data is gathered from the landscapes under study in spatial and temporal scales. GIS can play an important role in analyzing the data, it can efficiently storing and extracting data parameters for ecosystem modeling (Stow 1993). Case material from examples of field research incorporating remote sensing and GIS in analysis of critical environments will be presented. The review will show how GIS is used to create spatial models from regional to global scales that are then used in updating environmental policies.

Case Study I: Sustainable Land Management in Russia

Dr. Alexander Kirsanov, of St. Petersburg, Russia, designed a long-term field study to collect information to make recommendations for sustainable land management in various regions of Russia (Kirsanov 1998). Spatial monitoring was done using remote sensed data, focusing on the changes in the environmental state under influences of natural and technological factors. Along with the remote sensed data, important information from multi-spectral satellites, including LANDSAT, become the basis of and integrated Geographical Information Systems. Other GIS data includes vector layers such as geological, mineral resources, soils, vegetation, economic, and medical-biological. Finally, statistical data on the environment, economy, natural resources, and infrastructure was collected. Using ARC-INFO, GIS software, the collected geographic and landscape data is processed and compiled. Later, the anthropogenic changes are processed and overlaid into the GIS.

The results of Kirsanov's work on the Kola Peninsula in Russia identified desertification around industrial centers, growing 1-2 km each year. The study also showed industrial waste from several plants leaking into the nearby lake—also the main source of drinking water for the region. Additionally, dust from construction of large dumps, quarries, and reservoirs were shown to have transferred over a large distance by wind (Kirsanov 1998). High-resolution imagery along with aerial photography aided in the analysis.

The importance of the study is in the data reflecting the possible permanent ecological damage. Kirsanov, after the completion of the GIS project, outlined stages of the study, which could apply to any research using GIS. Stage I involves the planning and creation of the topographic database utilizing spatial geographic and remote sensed data, along with the input of attribute data. Stage II is the interpretation of the remote sensed data and completion of the preliminary "initial state" map. In Stage III, analysis and preparation of cartographic data in the form of GIS spatial modeling is completed. Finally, during Stage IV the graphic documents are presented and recommendations for environmental monitoring, planning and projects are compiled and presented to government planning commissions. These stages summarize the important parts of an integrated GIS study, but when designing a model for sustainable land management. Kirsanov (1998) also stresses the need for a long-term data collection and continued analysis.

Case Study II: Managing Mountain Soil Erosion in Nepal

Rita Gardner, Martin Frost and John Gerrard used GIS applications in "Managing Mountain Soil Erosion" in the Middle Hills of Nepal (Gardner et al. 1995). In this study it is understood that soil erosion has become an increasingly critical environmental problem both scientifically and politically, especially for developed lands in temperate zones. This case study evaluates the appropriateness for the application of GIS to the problem of soil management by using the distinctive environment of the Middle Hills of Nepal. The GIS allows one to pinpoint where specific land use patterns and slope formations coincide, and where roads and pathways create areas at high risk for erosion. This approach lacked in giving quantitative estimates of soil losses, but rather predicted levels of sensitivity to various erosion processes, and responds to simulated changes in land use (Gardner et al. 1995). Additionally, including remote sensing data would extend the GIS use to broader regions for use as a tool in identifying high-risk locations (Gardner et al. 1995). Despite the usefulness of GIS software technology, an adequate evaluation of the erosion could not be made because a model to represent the transport and storage of sediments in the mountainous terrain of Nepal does not exist (Gardner et al. 1995).

Case Study III: Semi-Arid Rangelands of Botswana

Julie Cox (1995) established a project to monitor the semi-arid rangelands of Botswana utilizing GIS and remote sensing. In the field (Northern Botswana) the data collection should emphasize monitoring of grassland biomass change over periods of several days using NOAA NDVI, remote sensing technology (Cox 1995). The information could therefore be used in the management of the rangeland. The most urgent issue is the distribution of boreholes for the pumped water supply. These wells must meet the demand of water for both wild animals and the domestic cattle herds. Left uncontrolled, soil and vegetation degradation can occur. Cox's prototype for an integrated GIS and remote sensing project for rangeland management includes the input of satellite images (NOAA, AVHRR, NDVI), rangeland thematic overlay information, and field data; rangeland thematic overlay information includes: rivers, pans, swamps, boreholes, soils, fences, vegetation, land tenure, cattle and wildlife distribution (Cox 1995). Field research stations collect the field data to be stored in a regional database for livestock numbers and productivity, rangeland condition, vegetation quality and quantity, soil moisture and drinking water availability. By first using the carrying capacity model to establish the carrying capacity number, the GIS data could then aid in creating a policy of environmental monitoring to help maintain the stability. This case study involves an integrated ecology approach to rangeland management, an anthropogenically modified landscape.

Analysis

Each case study involved a project incorporating GIS and remote sensing in evaluating an anthropogenically modified landscape. Case Study I involved Russia's western regions modified by the establishment of industrial plants and urbanization (Kirsanov 1998). Case Study II centered on the mountains of Nepal where soil erosion was caused by simple human infrastructure (Gardner et al. 1995). Case Study III involved the rangelands of Northern Botswana where man-made boreholes need constant monitoring to avoid soil and vegetative destruction (Cox 1995). A diversity of anthropogenic modifications are seen by these three cases, however comparisons can be drawn.

A common theme throughout all cases is the importance of spatial relationships. It is noted that GIS encompasses a global scale in its use of micro satellites, yet it is easily incorporated for use at a regional scale, from the Western Region of Russia, to more specifically a rangeland in Northern Botswana. This is best done using an integrated approach of data collection, and by incorporating local-level knowledge as seen in the thematic overlay information used in Case Study III. GIS is produced from the thematic sets of features that are georeferenced; the data can be processed to extract spatial relations from the GIS maps (Lanter 1994). It is also useful to input remote sensing data into a GIS package as noted in Case Study II. Remote sensing data is functioning data on features from satellites; including soils, vegetation, moisture, urban sprawl, and water-covered area (Moran 2000). GIS allows for the incorporation of a number of different spatial data types.

These case studies also emphasize the usefulness of GIS to create long-term studies. When projects are designed for the long term they are more helpful for creating policies and future plans for the monitored landscapes. GIS allows for presentable graphical data to be produced, which aids in the political process of implementing policies, as well as producing Environmental Impact Assessments. Factors leading to threats of the geographical patterns of the natural environment or the management systems are the environmental background, cultural and political overlays, and developmental and land use overlays—all of which can be input into GIS programs for analysis (Newson 1992). These factors coincide with anthropogenic modifications, yet it is important to identify permanent landscape transformations versus periodic and reversible changes, all of which can be noted in the GIS model.

The priorities of GIS can be broken down into three parts including: functionality, organization, and presentation (van den Toorn et al. 2000). GIS is governed functionally by cultural factors and communication, organizationally by monitoring and evaluation, and by the quick, creative, attractive and precise visuals that can be created for presentation if data is inputted correctly (van den Toorn et al. 2000). These priorities amplify the reasons for using GIS in ecological anthropology and answer the question, "why should one apply GIS technology to ecological anthropology?" Anthropologists deal extensively with the cultural element and strategy development; by applying van den Toorn's priorities, these factors can become an even more important and accomplished part of research.

The future of GIS is an exciting frontier, and with the organizational and functionality aspects of GIS understood, one important factor remains. To date, most field studies in land-use changes involving GIS data have been designed to produce models assessing the consequences (Hall et al. 1995). Only a few have attempted to assess the spatial pattern of the process of change; n a study modeling spatial and temporal patterns of tropical land use, factors that affect the land use change process are mimicked, then the processes are to used develop spatial patterns of land use change in a realistic manner (Hall et al. 1995). Ultimately, a model predicting the environmental change is produced. The implications for models predicting change are large, considering a main goal of most GIS studies with anthropogenic research is future policy planning and monitoring strategies. Models showing consequences of land use change are important, especially when accumulating over time.

Conclusions

Analyzing land-use intensification through the use of GIS and remote sensing is a promising topic for ecological anthropologists. GIS gives practical integration of spatial structure (habitation, soils, river drainage) and aids in gaining practical understanding of past and current relationships between the environment and human systems when combined with local-level knowledge. This type of research requires a culturally specific temporal and spatial perspective applied at a regional scale. The data created by GIS is used in created and updating policies for all environments, chiefly, anthropogenic landscapes. Features of present-day landscapes can be followed at a regional level, including types of anthropogenic modifications from small scale grazing near water boreholes in Northern Botswana to large-scale mining by corporations in Russia.

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