Apr 25th, 2:00 PM - 5:00 PM

Paper Session I-C - Gap Analysis: Remote Sensing to Help Save Our Endangered Environment

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Gap Analysis: Remote Sensing to Help Save Our Endangered Environment

by

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Abstract

Satellite imagery is enabling land planners and research biologists to map disappearing habitats across the United States. In 1987, a program called Gap Analysis was established on the premise that acting early to monitor could possibly save disappearing habitats by changing certain practices of endangerment.

Gap Analysis is based on a methodology which identifies the gaps in representation of biological diversity or biodiversity in areas managed exclusively for the long-term maintenance of populations of native species and natural ecosystems referred to as biodiversity management areas (Figure 1). Once identified, gaps are filled through new reserve acquisitions or designations or through changes in management practices. The primary goal is to ensure that all ecosystems and areas rich in species diversity are represented adequately in biodiversity management areas.

Introduction

The Gap Analysis program was originally started with funding from the U.S. Fish and Wildlife Service under the direction of Michael Scott and Blair Csuti in response to the increasing number of endangered species, approximately 4,000 by 1992, and the inability of the Endangered Species Act of 1993 (ESA) to provide for sufficient protection and recovery of biodiversity management areas.

Biodiversity not only includes genetic, species, and ecosystem diversity, but ecological processes. The conservation of biodiversity must occur in the wild which requires a two-step process: 1) deciding which general areas need protection, and 2) drawing specific boundaries around each area to be managed.

In order to begin identifying conservation reserves, the Gap Analysis program was established to develop a series of spatial data layers on the distribution of several elements of biological diversity for comparison with the distribution of nature reserves and other areas managed primarily for their natural values. The name "gap analysis" was acquired from a paper by F. W. Burley which appeared in *Biodiversity* (Wilson 1988).

The first gap analysis program was initiated in Idaho in 1987. There are now currently 32 state programs.

The Gap Analysis Concept

Gap Analysis provides an overview of the distribution and conservation status of several biodiversity components. Through the use of geographic information system (GIS) technology and satellite remote sensing, gap analysis enables the preparation of maps of actual vegetation cover. It seeks to identify gaps in vegetation types and species that are not represented in the network of biodiversity management areas which can later be filled through establishment of new reserves or changes in land management practices.

Digital map overlays provided by a LANDSAT Thematic Mapper are used to identify individual species, species-rich areas, and vegetation types that are unrepresented or underrepresented in existing biodiversity areas.

Gap Analysis organizes existing survey information to identify areas of high biodiversity before they are further degraded. It serves as a preliminary step to the more intensive monitoring studies needed to establish actual boundaries for potential biodiversity management areas.

Biodiversity inventories or "filters" are designed to capture elements of biodiversity at various levels of organization. The Nature Conservancy has applied the filter concept to establish "natural heritage programs" in all 50 states mostly operated by state government agencies. The Nature Conservancy maintains a fine filter of rare species inventory and protection and a coarse filter of community inventory and protection (Jenkins 1995). An estimated 85-90% of species can be protected by the coarse filter, without having to inventory or plan reserves for those species individually.

Essentially, Gap Analysis can be viewed as a coarse-filter approach to biodiversity protection as the vegetation types mapped in Gap Analysis serve directly as a coarse filter with a goal to assure adequate representation of all types in biodiversity management areas.

Gap Analysis uses landscape-sized samples of several kilometers across (Forman and Godron 1986) as an expanded coarse filter to search biological regions for areas rich in landscape diversity. A second filter identifies areas of high species richness with maximum overlap in the ranges of mapped species and centers of endemism. Additional data layers can be used to evaluate indicators of stress or risk (i.e. human population growth, road density, rate of habitat fragmentation, distribution of pollutants, etc.) and the locations of habitant corridors between wildlands that allow for natural movements of wide-ranging animals and migration of species in response to climate change.

Prior to Gap Analysis, there was no broad-scale assessment of the protection given actual vegetation types of areas of high species richness in the United States. In Hawaii, a gap analysis focused on endangered birds (Scott et al. 1986) during which the distribution of each endangered forest bird species was first plotted individually, based on extensive field inventories. Individual range maps were then combined to produce a map of species richness and then compared with a map of existing reserves to reveal that less than 10% of the ranges of endangered forest birds were protected. As a result, several of the areas of high endangered bird species richness have since been protected by the Nature Conservancy and state and Federal agencies.

Gap Analysis tools include maps and tables summarizing the predicted distribution and conservation status of vegetation types and species. They also include a conservation evaluation identifying areas potentially rich in vegetation types and species unrepresented or underrepresented in biodiversity management areas. Biodiversity management areas are also evaluated for representation of threatened, endangered, and other species of concern.

Vegetation Mapping and Classification

A LANDSAT Thematic Mapper provides digital imagery for gap analysis vegetation maps. Vegetation reflects many physical factors found at a site including climate, soil type, elevation, and aspect. It is also composed of the ecosystem's primary producers and it serves as habitat for the animal community. Vegetation acts as an integrator of many of the physical and biological attributes of an area, and a vegetation map can be used as a surrogate for ecosystems in conservation evaluations (Specht 1975, Austin 1991). Subsequently, a vegetation map provides the foundation for gap analysis assessment of the distribution of biodiversity.

Digital imagery delineates through computer classification and/or on-screen interpretation boundaries between landscapes dominated by different vegetation types. Ancillary data, including aerial photography, airborne video photography (Graham 1993) and field surveys, are used to assign labels that identify dominant plant species.

The Gap Analysis program utilizes vegetation classification systems for vegetation mapping with the following properties (Scott et al 1993):

1. Vegetation classes must be discriminable in remotely sensed imagery and identifiable in large- to medium-scale aerial photographs.
2. Vegetation classes must correspond to or at least be compatible with recognized vertebrate habitat classification systems.
3. Vegetation classes must describe seral as well as climax vegetation.
4. Vegetation classes used in Gap Analysis by adjacent states should be compatible to allow for regional and national analyses.

A vegetation map prepared for Gap Analysis of biodiversity serves 2 major purposes. First, it enables quantification of the extent, distribution, and representation in biodiversity management areas of the major vegetation types in a particular study area. Second, it enables inappropriate habitat to be excluded from predicted distribution maps for individual animals species.

The vegetation map can also be used for analysis of the degree and pattern of habitat fragmentation, the location of present or potential linkages between biodiversity management areas, and the identification of landscape-level processes affecting the vegetation such as fire regimes. It is also a model of the recent vegetation of a study area, from which predictions can be made about the probable pathways of past and future vegetation change. The map can be updated to quantify changes in vegetation structure and composition resulting from management activities or natural events (e.g. fires, floods, succession) (Scott et al 1993).

Conclusion

The Gap Analysis program, now a part of the Department of the Interior's National Biological Survey (NBS) uses satellite imagery to map endangered ecosystems and identify gaps in the protection of biodiversity at state-wide, regional, national, and eventually, international scales. The usefulness of data obtained through Gap Analysis covers a broad spectrum that includes, but is not limited to, identification of gaps in networks of management areas designed to maintain biodiversity. Data obtained, and the geographic information system (GIS) framework in which they are stored can also serve as the basis for monitoring and evaluating changes in biodiversity at both fine and coarse scales.

The increasing loss of many types of natural ecosystems lends urgency to a pre-emptive conservation evaluation and planning process. Gap Analysis provides that process by developing the knowledge of the distribution and spatial relationships of the elements of biodiversity and then applying it to a conservation evaluation that identifies a set of areas in which the elements of biodiversity are represented most efficiently.

Acknowledgments

This paper is based on information provided by Blair Csuti who directs the Oregon Gap Analysis Program and is a Research Associate and Adjunct Associate Professor, Idaho Cooperative Fish and Wildlife Unit, University of Idaho.

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