

GEOGRAPHIC INFORMATION SYSTEMS IN BIOGEOGRAPHY AND LANDSCAPE ECOLOGY

D.A. Quattrochi

National Aeronautics and Space Administration, George C. Marshall Space Flight Center, USA

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Summary

Geoinformatics can be used to identify, observe, measure, and model the Earth's overall land surface. What attributes predominate at a particular geographic location on the Earth's land surface is a manifestation of a compendium of physical, biological and cultural characteristics that are extant at that location. Perhaps the most important, or at very least one of the most obvious, of these characteristics is the plants and animals that inhabit a specific location as well as how they are distributed across the globe. *Biogeography* is the study of the distributions and geographic characteristics of the Earth's flora and fauna. Key to the interpretation of biogeographical attributes as observed through Geoinformatics-related analyses are landscape structure, function, and change. Ultimately, these three aspects form the basis for how the biogeography of the landscape is viewed using Geoinformatics or how the distributions of plants and animals are driven by physical or climatic factors around the world.

1. Introduction

As a field of study, biogeography may be considered a bricolage – it has been

constructed from many different facets of an array of research disciplines including biology, botany, zoology, geography, and geology. Biogeography focuses on the study of the constantly changing ranges of plants and animals, over a multitude of space and time scales. It also includes the study of the structure and dynamics of biotic communities and ecosystems as they relate to both natural and anthropogenic processes. As it exists today, biogeography is an interdisciplinary research area founded in both the biological and Earth sciences.

From a purely biological perspective, biogeography may be perceived as one of two types of studies:

1. biotic distributions at broad scales, and interpretations of the evolutionary and dispersal history of a single taxon or a few taxa; or
2. biotic distributions at local-to-regional scales, and interpretations of these distributions in relation to contemporary environments and rates of immigration or extinction.

The first type of study is what is most usually associated with the term “biogeography” as a disciplinary research field. It is conventionally termed “classical biogeography” because it reflects the continuity of research foci on which biogeography was founded in the nineteenth century. The second type of biogeographical study has more modern-day roots and is termed “geographical ecology” to reflect the theoretical predilections of ecologists and population biologists. Geographical ecology for all intents has become merged with ecology and exists as a sub discipline within this larger field of study.

Classical biogeography as a praxis is conducted by systematists; these are biologists concerned with the classification of taxonomic characteristics and historical evolution of organisms. Here the techniques employed are directed to observing and quantifying phylogenetic and paleontological attributes and affinities of biotic species and the evolutionary histories of organisms. Geographical ecology, in contrast, is performed by those trained in ecology and population biology. Geographical biologists are usually concerned with the numbers of species and species turnover in restricted areas (e.g., islands or similar isolated habitats). They seek explanations for patterns of species diversity as related to non-historical variables, such as island area or distance from mainland species sources.

Closely allied with biogeography is the science of ecology. Ecology from a “formal” perspective is usually defined as the study of interrelationships of organisms with their environment; it has also been defined as “the science that seeks to understand the distribution and abundance of life on Earth”. In this light, the didactic interpretation of geographical ecology or biogeography and ecology becomes distinctly blurred. Moreover, landscape ecology has emerged as a vibrant area of study that embraces many overlapping syntheses espoused by biogeography and ecology. It is recognized that ecological processes operate at different temporal and spatial scales and this is the foundation for landscape ecology as a field of study. Thus, landscape ecology is concerned with the study of landscape heterogeneity or how dissimilar or diverse the components or elements of a landscape are in both space and time, and how these ecological constituents operate as a system. In a formal sense, therefore, landscape ecology is the synthetic intersection of many related disciplines that focus on the spatial

and temporal pattern of the landscape. As a field of scientific inquiry, it considers the development and maintenance of spatial heterogeneity, interactions and exchanges across heterogeneous landscapes, the influence on biotic and abiotic processes, and the management of landscape heterogeneity.

It is obvious, then, that biogeography and landscape ecology are both intimately concerned with the study of biological and biophysical constituents, and the space and time scales at which these attributes are distributed and interact across the landscape. Although there may be distinct semantic differences between biogeography and landscape ecology, for all intents and purposes these disciplines focus on the study of: 1) spatially heterogeneous areas; 2) fluxes and redistributions of materials and energy moving amongst or across landscape elements; and 3) human actions as responses to, and their reciprocal influence on, ecological or biological processes. Each of these three focal areas is concerned with the fundamental characteristics of landscapes – structure, function, and change, which can be defined as the following:

1. Structure: the spatial relationships among distinctive ecosystems or biological entities;
2. Function: interactions among the spatial elements – the flow of energy, materials, and species among the existing ecosystems; and
3. Change: alteration in the structure and function of the ecologic/biologic mosaic through time.

2. Biogeographic and Landscape Ecological Research Themes

As noted above, biogeography and landscape ecology are highly interdisciplinary fields of study. The common thread between both of these research areas is the interpretation and measurement of the spatial and temporal integrity of biological or biophysical phenomena as manifested on the landscape. Although they occupy a diverse cross-section of research and study, there are several areas of focus that may be perceived as being the core foundation for biogeography and landscape ecology. These are: 1) Ecosystem Structure and Function; 2) Human/Biota Interactions; 3) Landscape Pattern and Process; 4) Zoogeography and Animal Ecology; and 5) Methodological Analysis and Modeling. The relationships of each of these areas with biogeography and landscape ecology are described below.

2.1. Ecosystem Structure and Function

Ecosystems are complex systems composed of organisms, the physical environment, and their interaction. Terrestrial ecosystems occur at many scales, and most have been influenced by human actions in one way or another. Approaches to ecosystem studies include mechanistic (process-oriented), empirical and model-based investigations that address composition (i.e., the type of species present), structure (the arrangement of species in space), and function (energy flow and nutrient cycling). Such studies cover an enormous range of scales, from molecules and microorganisms to entire landscapes. The ultimate goal of ecosystem structure and function research is to generate new knowledge, theory, experimentation and simulation modeling about the nature of complex interactions that lie at the heart of ecosystem functioning.

At the core of the analysis of ecosystems is description of their *community* structure. An ecological community may be described as the assemblage of species populations at a particular place and time. Usually there are interactions among the species of a community, and in many regions clusters of distinctive species can be recognized. Species and species clusters are highly variable, with a wide range of patterns evident within and across communities. Ecosystem structure has both vertical and horizontal characteristics. For example, the vertical structure of a plant community is a product of factors such as canopy, subcanopy, and understory extent and composition. Animal species also stratify by vertical characteristics, with certain animals mainly in the canopy and others endemic to the understory level. Horizontal distributions of species exhibit complex patterns. At one extreme, the boundary between two types of vegetative species (e.g., field and forest) may be relatively abrupt. This area exists as an ecotone or zone of transition that is composed of species from both sides of the vegetation boundary. In the case of a field versus forest boundary, the ecotone may be quite narrow; this overlap zone can, however, be quite wide with a mosaic of vegetation clusters from each vegetation type intermingling in the overlap zone. At another extreme, no ecotone may be readily distinguishable and there is a gradual change in species composition called a continuum. These factors contribute to the overall structure of ecosystems, which is one of the primary facets for study in biogeography and landscape ecology – the observation, measurement and analysis of ecosystem structure as a key to developing a methodological understanding of ecosystems as they exist on the landscape.

In concert with identifying the structure of landscape ecosystems is assessment of the functional processes attributed to ecological communities. Ecosystem function focuses on the flows of energy and material into, within, and out of an ecosystem or community. These flows exist, for example, in the form of nutrient fluxes that ebb and flow through the ecosystem as a result of periodicity of natural inputs (e.g., solar radiation, rainfall) or disruption of nutrients, such as resulting from a forest fire. In this realm, the modeling of net primary productivity, which is defined as the net flux of carbon from the atmosphere into green plants per unit time and refers to the amount of biomass produced over time that is available to support overall ecosystem health, is a primary research element within biogeography. Analysis and modeling of ecosystem functioning is complex and involves the study of many factors including soil moisture and soil characteristics, meteorological and climatic variables, vegetation indices (e.g., the correlation of vegetation attributes, such as height or canopy to develop an index of biomass and related characteristics), and other attributes.

2.2. Human/Biota Interactions

The examination of how humans impact or modify plant and animal communities comprises one of the key foci of both biogeography and landscape ecology. Here the study of how humans have impacted the integrity, composition or ecological synergism in plant and animal communities takes the forefront. The emphasis here is either on the cultural significance of plant and animal uses or on the modification of plant and animal genotypes as a consequence of human intervention or selection. Thus, this biogeographical or landscape ecological theme has roots in ethnobiology and ethnoecology where human manipulation or modification of plant and animal

communities as part of cultural predispositions is a dominant force in changing these communal relationships.

The human impacts on the structure and composition of communities is also an integral part of this research theme within biogeography and landscape ecology. Of importance to the study of human impacts on ecological interrelationships is the assessment of how alien species – or those species introduced by humans – have impacted plant and animal communities. This, in fact, is one of the primary theses of landscape ecology as a discipline; i.e., the study of the spatial and ecological integrity of plant and animal species and the assessment of how humans have modified the stability of these communities. The alteration of existing or “native” plant and animal communities has had important economic ramifications throughout human history. Introduction of species as a product of agricultural cultivation and the concomitant stabilization of human settlement patterns that have been brought about by agriculture have had profound economic ramifications on human society. The obvious consequences of the introduction of both plant and animal cultivars, however, into native communities have had an equal, if not greater, impact on the integrity, persistence and existence of multifold native species across the world. One of the major findings from biogeographical research on human/biota interactions is that the successful invasion by alien plants, specifically, occurs mainly in native communities that are chronically disturbed by humans.

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Biographical Sketch

Dale A. Quattrochi is a Geographer and Senior Research Scientist with the National Aeronautics and Space Administration, Earth Science Department at the George C. Marshall Space Flight Center in Huntsville, Alabama U.S.A. He has research interests in remote sensing, GIS and geostatistics.