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Earth observations for terrestrial biodiversity and ecosystems

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Abstract

Earth observations, comprising satellite, aerial, and in situ systems, are increasingly recognized as critical observations for monitoring the Earth system and systems. Earth observation data are especially needed to fulfil the requirements of a host of international treaties and conventions, and to provide data and information to support conservation and resource management. The Group on Earth Observations, GEO was established to implement the Global Earth Observing Systems of Systems, GEOSS, which includes in its mandate the protection of ecosystems — Improving the management and protection of terrestrial, coastal, and marine ecosystems, and understanding, monitoring, and conserving biodiversity. This Special Issue focuses on Earth observations for terrestrial ecosystems and biodiversity. As such, it is a sampler of remote sensing assessments of the status and trends of biodiversity (species), and ecosystems.

Keywords: Earth observation; Biodiversity; Ecosystems; Terrestrial

1. Introduction

Earth observations, comprising satellite, aerial, and in situ systems, are increasingly recognized as critical observations for monitoring the Earth system and systems. Earth observation data are especially needed to fulfil the requirements of a host of international treaties and conventions, and to provide data and information to support conservation and resource management. The 2002 World Summit on Sustainable Development (WSSD) stated the need "to promote the development and wider use of Earth observation technologies." That vision built on a number of landmark environmental Summits, including the 1972 United Nations Conference on the Human Environment (Stockholm), the 1992 United Nations Conference on Environment and Development (Earth Summit), and the conventions on climate change and biodiversity. The WSSD and the many environmental treaties of the past 30 years explicitly reference the need for Earth observations to fulfil their commitments.

The Group on Earth Observations, GEO, was established by a series of three ministerial-level summits. GEO currently includes 72 member countries, the European Commission, and 52 participating organizations that have committed themselves to the establishment of the Global Earth Observation System of Systems (GEOSS; http://www.earthobservations.org). A chief objective is that data, services, analytical tools and modelling capabilities can be accessed through the GEO Portal (www.geoportal.org).

The GEOSS 10-Year Implementation Plan Reference Document (GEO, 2005) identifies nine societal benefits areas:

- *Disasters* — Reducing loss of life and property from natural and human-induced disasters.
- *Human Health* — Understanding environmental factors affecting human health and well-being.
- *Energy Management* — Improving management of energy resources.
- *Climate* — Understanding, assessing, predicting, mitigating, and adapting to climate variability and climate change.
- *Water Cycle* — Improving water-resource management through better understanding of the water cycle.
- *Weather* — Improving weather information, forecasting, and warnings.
- *Protection of Ecosystems* — Improving the management and protection of terrestrial, coastal, and marine resources.

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- *Agriculture* — Supporting sustainable agriculture and forestry and combating desertification.
- *Conserving Biodiversity* — Understanding, monitoring, and conserving biodiversity.

These nine societal benefit areas are purposely cross-related; for example, energy relates to ecosystems and biodiversity concerns human health.

In the area of ecosystems, observations are needed to monitor the extent, condition, and services of ecosystems such as forests, rangelands, and oceans. GEOSS implementation seeks to ensure that observations are available on a global basis to detect and predict changes in ecosystem condition and to define resource potentials and limits. Ecosystem observations will be better harmonized and shared, spatial and thematic gaps will be filled, and in situ data will be better integrated with space-based observations. A critical component is the continuity of observations for monitoring ecosystem status and services (GEO, 2005).

The Convention on Biological Diversity defines biodiversity as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (CBD; 1992). The consequences of changes to and loss of biodiversity are manifold but particularly acute for alteration of ecosystem services (Chapin et al., 2000). In the context of the Biodiversity Societal Benefit Area, GEOSS will link the many stand-alone biodiversity monitoring systems and connect them to other Earth observation networks that generate relevant data, such as climate and land cover. It will also help to fill in gaps in taxonomic and biological information, generate updated assessments of global biodiversity trends, track the spread and retreat of invasive alien species, and monitor how biodiversity responds to climate change (GEO, 2005).

GEOSS is envisioned to unify many disparate biodiversity and ecosystem observing systems and to create a platform for integrating biodiversity and ecological data with other geospatial data. This will support monitoring of the condition and extent of ecosystems, and the distribution and status of species. The GEOSS Architecture Components specify automated and manual components of remotely-sensed and in situ systems, the integration of national, regional and global data centres, as well as discipline data centres, access to data and to metadata about archived and on-line holdings, and planned data acquisitions.

2. The need for Earth observation for biodiversity and ecosystem

Earth observation data are needed to fulfil the requirements of a host of international treaties and conventions. The foremost convention in terms of biodiversity and ecosystems is the Convention on Biological Diversity (CBD; 1992). The CBD Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) recommends monitoring of trends in extent of selected biomes, ecosystems and habitats, and the connectivity and fragmentation of ecosystems.

The CBD Focal Area B, *Indicators for immediate testing*, further calls for characterization and monitoring of:

- Status and trends of the components of biological diversity
- Trends in extent of selected biomes, ecosystems and habitats
- Trends in abundance and distribution of selected species
- Sustainable use of forest area, agricultural and aquaculture ecosystems under sustainable management numbers and cost of alien invasions
- Ecosystem integrity and ecosystem goods and services
- Connectivity/fragmentation of ecosystems
- Incidence of human-induced ecosystem failure
- Health and well-being of people living in biodiversity

Earth observation data and information are equally important to monitoring ecosystem and habitat extent and condition for the Convention on the Conservation of Migratory Species (CMS), the Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971), the Convention on International Trade in Endangered Species (CITES, 1973), the Framework Convention on Climate Change (1992), the Kyoto Protocol (1997), and the Convention to Combat Desertification (1994). For additional information on relevant conventions and treaties, see de Sherbinin (2005).

In addition to being needed to fulfil international agreements, Earth observation data are needed for national, regional and global protected areas systems planning, protected areas monitoring and management, and to support the science needed to understand biodiversity and ecosystem processes and services.

Biodiversity and ecosystem structure and function are intimately interrelated. Changes in biodiversity significantly change ecosystem composition and impact ecosystem processes and services (Chapin et al., 1998, 2000). While biodiversity encompasses species and genetic diversity, ecosystems are also the "coarse filter" that capture underlying species and genetic diversity.

3. Earth observations in research and application

Earth observations have a rich history in characterizing and monitoring biodiversity and ecosystems. The need for remotely sensed data for monitoring biodiversity was identified at the dawn of Earth observations and has been widely used for decades (e.g. Stoms & Estes, 1993). Remotely sensed data can cost-effectively track changes in ecosystem distribution and status (Teder et al., 2007). The new generation of high-spatial and spectral resolution offers more hope for more direct monitoring of species and populations (Aplin, 2004; Turner et al. 2003). Remote sensing provides a potential means to scale from plot-based studies to regional analyses (Malhi & Roman Cuesta, 2008-this issue). Turner et al. (2003) provide an excellent overview of the use of remotely sensed data for biodiversity science and conservation. Estes et al. (2008-this issue) review remote sensing for rare species assessments particularly pointing out issues of scale and limited presence/absence and abundance data. The Sourcebook on Remote Sensing and Biodiversity Indicators (Strand et al., 2007) presents the uses of remote sensing for monitoring indicators relevant to biodiversity.

A call for global monitoring of biodiversity change (Pereira & Cooper, 2006), specifically identifies the role of GEOSS and the Earth observation component.

This Special Issue focuses on Earth observations for Terrestrial Biodiversity and Ecosystems. A second Special Issue focusing on Earth observation for Marine, Coastal and Freshwater Biodiversity and Ecosystems is forthcoming. It demonstrates the use of many types of remotely sensed data both of individual and multisensor analyses including aerial color-infrared photography, CASI and HyMap Data, Shuttle Radar Topography Mission Elevation Data, ICEsat/GLAS, QuickBird and Hyperion, MISR, MODIS, EO-1 Hyperion, Landsat Thematic Mapper, aerial and satellite-borne LIDAR, and Multiangle Imaging SpectroRadiometer data.

The applications range from invasive species mapping, to biological soil crusts, forest distribution and change, predicting habitat and species distribution and ecosystem parameter mapping and modelling. The analytical approaches employed include modelling of species distribution, 3-d modelling of forest canopies, spectral and lacunarity analysis, change detection, and data fusion and scaling. As such, this Special Issue represents a sampling of data, analytical techniques, and applications of Earth observation data for biodiversity and ecosystems.

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