DEVELOPMENTS IN GLOBAL LAND COVER MAPPING

Belward, A. S.
Institute for Environment and Sustainability, EC Joint Research Centre, Italy

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Summary

There has long been a demand for land cover maps describing local conditions; there is now a growing demand for up-to-date global land cover maps. This demand comes from global change science, and from policy makers implementing multilateral environmental agreements, and development and aid programs.

Global descriptions of land cover have been made using diverse sources of information over many years. Yet the first attempts to create global maps from a single data source gathered over a fixed time period started less than a decade ago. Begun in 1992, this land cover mapping project produced a 1-km spatial resolution satellite sensor image database and from this mapped the Earth's land surface into17 classes. The map, completed in 1997, is called DISCover. An assessment of the map's accuracy concluded in March 1999.

New land cover maps with known mapping accuracies are now needed. This calls for data from suitable sensors on suitable platforms and suitable data processing and data distribution strategies. Space Agencies around the world recognize this and are supporting new efforts to provide new maps. NASA's latest Earth observing mission, TERRA, provides data for global maps based on the DISCover classification. New products describing continuous changes, such as percent forest cover now exist. The European space agencies responsible for the VEGETATION instrument support the

Global Land Cover 2000 project. International programs such as Global Observations of Forest Cover and the Global Mapping concept are emerging to sustain global land cover mapping.

Advances in research and better access to data through new space and ground systems make global land cover mapping easier than it was last century. It is still, however, a huge task. The international community cannot afford to become complacent. Not all the maps we need are available and not always when needed. The international efforts described here must continue.

1. Growing Demand for Global Land Cover Information

Throughout history, humans have mapped their "world". As a more complete perception of the geography of the Earth emerged, so too did global maps that we would recognize today. Yet global descriptions of land cover are a relatively recent occurrence. The first land cover maps, such as those appearing in most World Atlases, are heavily based on climatic zones and thus represent a mixture of actual and potential land cover. Since the 1970s, various land cover maps purporting to describe actual global land cover have been created. Although very valuable, these were made largely by assembling disparate primary data sources. This resulted in a lack of global consistency, in legends that were not always appropriate and in unknown and variable levels of map accuracy.

With the advent of civilian Earth observing satellites in the early 1970s, detailed maps of actual land cover over large areas could be produced more easily, but limited satellite sensor image acquisitions and available computing power meant that global mapping efforts were not possible. By the early 1990s, the demand for consistent, up-to-date global land cover maps was growing. The global change science program, the International Geosphere Biosphere Program (IGBP) was clearly feeling the lack of such data, and those setting international environmental and development policy agendas increasingly called for such information.

1.1 Scientific Users and Uses

The IGBP is implemented through a number of core projects. These are major undertakings planned and run by international teams of scientists. Among the IGBP's core projects the BAHC (Biospheric Aspects of the Hydrological Cycle), GCTE (Global Change and Terrestrial Ecosystems), IGAC (International Global Atmospheric Chemistry Project), and LUCC (Land Use Cover Change) all expressed the need for up-to-date, accurate baseline land cover data sets for their studies of global change.

Although only 30% of the Earth's surface is "land" and of this around 24% is barren or covered by snow and ice, land cover is an important component in global change science. It is a vital input to global models such as the General Circulation Models used to simulate and predict climate, biological process models for studies of Net Primary Productivity and the carbon cycle and land surface process models used for Earth system energy, water and material transport studies. The quality and validity of the data used by these models influences the reliability of the scenarios they generate. As a great deal of atmospheric variability is related to its interaction with the land surface, and especially vegetation, it is essential to represent global land cover in a reliable and accurate way. Ideally, such a map should be derived from a single data source obtained within a fixed and sequential time period. It should cover every part of the Earth's surface and each land cover class should be exclusive. To meet scientific needs these land cover classes should discriminate between perennial and annual above-ground biomass, as this is important for seasonal climate and carbon-balance modeling and also influences the surface roughness length boundary condition required by climate models for energy and momentum transfer equations. Evergreen and deciduous canopy types should be separated, as leaf longevity is an important variable in the carbon cycle, influences seasonal albedo and also influences energy transfer characteristics of the land surface. Leaf longevity must be taken into account as this determines whether a plant must completely re-grow its canopy every year, or only a portion of it. This has consequences for carbon partitioning, leaf litter fall dynamics and soil carbon. The land cover classification also needs to separate needle leaf, broadleaf, and grasses as gas exchange characteristics are affected by leaf type.

1.2 Policy Users and Uses

With the emergence of multilateral environmental agreements such as the UN Framework Convention on Climate Change (UNFCCC), policy and science are co-developing. The policy agenda is adapting to new scientific findings such as the reports by the Intergovernmental Panel on Climate Change (IPCC) that the biosphere is a strong determinant of the chemical composition of the atmosphere. Deforestation, conversion of natural vegetation to agricultural land, biomass burning and exploitation of the biosphere for fuel, food and fiber all contribute to increasing atmospheric concentrations of greenhouse gases, especially CO_2. Because of this the IPCC includes human activities that change the way land is used in national calculations of greenhouse gas emissions required for compliance with the UNFCCC.

The 1992 UNFCCC objective is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The Kyoto Protocol to the Convention is a key policy tool for the Convention's implementation. The Protocol contains legally binding commitments to either reduce or limit the emissions of six greenhouse gases (Carbon dioxide [CO_2], methane [CH_4], nitrous oxide [N_2O], hydrofluorocarbons [HFCs], perfluorocarbons [PFCs] and sulphur hexafluoride [SF_6]). There are agreed targets for the industrialized countries that collectively amount to a 5% reduction on 1990 emission levels of all six gases (expressed in "equivalent CO_2").

The terms of the Kyoto Protocol are such that signatories must account for biological sources and sinks when calculating their overall carbon budgets, with the resulting Carbon credits or debits then included in national reporting. Much of the biological accounting centers on Land Use, Land Use Change and Forestry (LULUCF) activities. Once ratified, signatories to the Protocol will be required to monitor measures promoting the protection and enhancement of greenhouse gas sinks and reservoirs and measure changes in carbon stocks resulting from human-induced land-use change and forestry activities. The Protocol also makes provision for countries to trade these

credits/debits via the so-called flexible mechanisms. These are governed by the Joint Implementation scheme in the industrialized nations, and by the Clean Development Mechanism (CDM) for the rest of the world. If carbon sink projects become acceptable activities within the CDM then world-wide assessment of changes in land use, especially afforestation, reforestation and deforestation becomes a requirement. Land cover inventories, thus, have a key role to play in the implementation of the Protocol and in terms of judging compliance with it.
Policy users increasingly need information on the state of the World's land cover to support the implementation of development and aid programs. The sustainable development of rural areas occupies a central position in many development programs. Sustainable land resource management and conservation issues are particularly sensitive as they link environment and development issues. Integration of the environmental dimension in the development process generates its own information requirements. Many projects based on bilateral aid to developing countries or multilateral action with international institutions, including United Nations organizations and Non Governmental Organizations would benefit from accurate and up to date information on global land cover. The sustainable management and use of forests and other land resources in developing countries, forest conservation and restoration, environmental impact assessments, trans-boundary environmental issues such as desertification and watershed degradation are all subjects of development aid projects. Adequate information on global land resources (inventory, mapping, monitoring trends, changes and major driving factors such as forest fire) is needed to develop sustainable rural development policies and strategies at different levels and to judge their impact and success.

Global land resource monitoring is more and more necessary if we are to quantify the changes taking place and bring corrective measures where required, and when required. The disappearance of forests and general land degradation in the developing world presents clear threats to the environmental, social and economic stability of societies. The developed World's aid programs recognize this and there is an overall need for regular information-gathering capabilities to support their planning and project implementation. Having said this, land resource information should be made available not just within the public administrations of donor countries but to partner countries directly. It is also important that access to the technology used to derive such information is provided to the partners. Attention needs to be paid to capacity building and technology transfer, and particular efforts should be made to make environmental databases and databanks available to key actors in the development process as well as for raising the awareness of local populations and the general public.

2. Past Experiences

How well is the demand for global land cover information from our science and policy communities being satisfied? The simple answer at present is less than perfectly. There is little more than a decade of experience to build on in terms of global land cover mapping from spaceborne systems. The first attempt to create consistent global maps from a single data source gathered over a consistent time period came from the IGBP at the beginning of the 1990s. The IGBP's Data and Information System (DIS) coordinated the project and set objectives of producing a global land cover map with known accuracies. The land cover map, called DISCover, was to be produced at 1-km spatial resolution and would map the entire Earth's land surface into 17 distinct cover classes identified on the basis of the science requirements of the IGBP's core projects. The first global land cover classification was completed in July 1997. An accuracy assessment method was then defined, and implemented so as to provide statistical statements concerning the accuracy of the global land cover product. The accuracy assessment was finalized in September 1998 and preliminary analysis concluded in March 1999. The following section describes the process by which DISCover version 1.0 was created.

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Biographical Sketch

Alan Belward works for the European Commission’s Joint Research Centre in Italy where he is Head of the Global Vegetation Monitoring Unit in the Institute for Environment and Sustainability. Dr Belward’s research focuses on the characterization of terrestrial ecosystems on regional and global scales. Having completed a BSc in Plant Biology at the University of Newcastle-upon-Tyne, he went on to receive an M. Phil and PhD in satellite remote sensing studies of vegetation, from Cranfield University’s School of Agriculture Food and Environment. He was Chairperson of the IGBP’s Land Cover Working Group during its work to create the IGBP’s global land cover data set in the 1990s and currently chairs the Global Climate Observing System’s Terrestrial Observing Panel for Climate.