Briefs for the SWALIM remote Sensing Workshop Land

A. Comprehensive Land Cover Status and Trends Program

The socio-economic, climatic and environmental challenges facing the mankind at the dawn of the twenty-first century have been addressed by the United Nations Millennium Development Goals. Their aim is to increase food security, improve health and reduce poverty in developing countries. FAO estimates that the food security risks periodically threaten over 50% of developing countries. In spite of technological advances and improvements in food and feed production systems, there is a finite limit to the supply of land suitable for agricultural production. Yet, the population of developing countries is steadily increasing. The latest population growth projection by the United Nations estimates another 40% increase during the next 50 years. That would represent an increase by about 2.5 million people, which equals the world's total population in 1950. In addition, the competition for land among different sectors is increasing and all too often, the best agricultural land is converted into different uses.

The degree to which the United Nations Millennium Development Goals are attained will determine the mankind's future. Industrialized countries have developed their economies without paying much regard to preservation of natural resources and environmental protection. However, such a development model cannot be applied any longer because of growing scarcity of natural resources and environmental degradation. Intensification of agricultural production has to be based on sustainable development and management of land and fresh-water resources to succeed.

Reliable information on current land cover, its past changes and future trends has become an essential prerequisite to sustainable development and management of land and water resources and environmental protection at a country level. However, it has to be understood that the land cover information by itself, although essential, is not a sufficient input to the above tasks. It has to be integrated with other relevant geo-information layers reflecting the environmental, economic, social and political factors affecting rural land management and environmental protection. These additional geo-information layers may include information on topography, soils, fresh-water resources, climate, land use, cost/benefits associated with land use types and agricultural production systems, land tenure, population density (including age distribution, health and rural poverty statistics), agricultural policy (including forestry and fresh-water resources), etc.

In most countries, the above inputs, except of information on current land cover and its dynamics, are usually available. They are collected and managed by government organizations with mandates for respective disciplines. Some of these inputs may also be available from non-governmental organizations. However, there are no organizations with the explicit mandate for systematic, country-wide mapping of land cover and monitoring its changes in developing countries. Ad hoc land cover mapping and monitoring activities are typically undertaken by a number of organizations, such as remote sensing centers, mapping organizations, agricultural and forestry institutes, with no harmonization of methodologies and little cooperation among them.

In the past, such sectoral *modus operandi* for implementation of land cover mapping projects served its purpose and provided required information to respective organizations. However, with the rapid advancement of geo-information technologies, in particular remote sensing and GIS, such approach is not any longer effective and efficient. Rational land use planning requires a holistic approach, based on integration of land cover information with geospatial and socio-economic data, their joint analysis and modeling. Furthermore, the high priority global tasks, in particular the United Nations Millennium Development Goals, have set new standards for the type, availability and quality of geospatial information required for their implementation.

New paradigm for land cover mapping is clearly required that would account for these new developments and effectively respond to new challenges. It should facilitate the harmonization of land cover mapping procedures across sectoral barriers and national borders, increase flexibility of land cover classification to support diverse applications worldwide, enable effective integration of land cover data and other types of geospatial data with socio-economic data, and provide links to attribute information. In order to address these challenges, the FAO and UNEP, with the support by the Italian Government, jointly established a Global Land Cover Network Topic Centre (GLCN-TC) in Florence, Italy. The GLCN-TC activities include establishing links and cooperation with the existing land cover databases, promoting and assisting harmonization among land cover mapping projects and standardization of land cover classification based on the GLCN Land Cover Classification System (LCCS). One of its most important activities is the provision of training and advisory services on GLCN land cover mapping and monitoring methodology to developing countries and countries with economies in transition.

The societal benefits of improved access to harmonized information products of land cover mapping and change monitoring projects can be summarized as follows:

- Inputs to sustainable land use planning, including agro-ecological zoning;
- Improved preparedness for natural disasters, assessment and mitigation of their impacts (e.g. agricultural drought, floods, wind damage, forest fires, pest infestations, etc.);
- Inputs to food security regional and national early warning systems;
- Assessment and mitigation of impacts of climate variability and change;
- Inputs to greenhouse gas accounting and carbon management;
- Monitoring changes in croplands, including irrigation, abandoned fields, conversion to other land uses;
- Assessment and change monitoring of surface fresh water bodies and their watersheds, including fresh water wetlands;
- Assessment and monitoring of forest cover, including the extents and rates of deforestation, reforestation and afforestation;
- Assessment and monitoring of land degradation;
- Monitoring land erosion and accretion in coastal areas;
- Monitoring the extent of urban sprawl.

While the government policy-makers and rural land use planners require reliable information on land cover and its dynamics at the national and sub-national levels to support sustainable development and management of land and water resources, the international science community requires land cover information at the global and regional levels for implementation of the UN Millennium Development Goals, UNCED Agenda 21, WSSD Plan of Implementation and the following UN-coordinated environmental initiatives:

- The Framework Convention on Climate Change (FCCC);

- The Kyoto Protocol to FCC;
- The Convention on Biological Diversity (CBD);
- The Convention to Combat Desertification (CCD);
- The United Nations Forest Forum (UNFF).

Examples of recently completed or ongoing global land cover mapping projects include:

- **GLOBCOVER**, a multi-agency global land cover mapping initiative led by the European Space Agency (ESA). Its objective is to develop a global land cover map for the year 2005. The input multispectral data were recorded with 300m ground resolution by MERIS remote sensing system on-board of ESA Earth observation satellite ENVISAT. Land cover classification is based on the FAO Land Cover Classification System (LCCS), which assures its worldwide applicability and compatibility with other land cover mapping projects. An important component of GLOBCOVER is global validation of its land cover products in sample sites.
- **Global Land Cover 2000 Project (GLC-2000)** was implemented by the Global Vegetation Monitoring Unit of the European Commission-Joint Research Center (EC-JRC). The VEGA 2000 dataset, consisting of image data recorded with 1km ground resolution by the SPOT 4 Vegetation remote sensing system during November 1999 – December 2000, provided the input multispectral data for GLC-2000 mapping and vegetation index assessment. Land cover classification was based on LCCS. High resolution image data were used for global validation of land cover products in sample sites.
- **IGBP Global Land Cover Mapping Project** was implemented by the International Geosphere-Biosphere Programme (IGBP) in cooperation with NOAA, USGS, NASA, and EC-JRC in mid 1997. The NOAA AVHRR multispectral image data with 1km ground resolution recorded during mid-1990s provided the input data. The IGBP global land cover database consists of 17 land cover classes and vegetation index series.
- **GeoCover LC** global land cover dataset was completed by the US EarthSat company at the end of 1990s. The Landsat TM multispectral image data with 30m ground resolution recorded in 1990 were the inputs for land cover classification. The land cover dataset, which consists of 12 broad land cover classes, was geometrically rectified to a horizontal accuracy of about 50m, based on the EarthSat GeoCover Ortho global map. The updated global land cover dataset based on TM/ETM data recorded in 2000 is in production.

Examples of recently completed or ongoing regional land cover mapping projects include:

- **FAO Africover** land cover mapping project. Its East African module, covering 10 countries with a total area of 8.5 million km^2, was completed, with the Italian government funding, in 2004. The Landsat TM/ETM multispectral image data, with 30m ground resolution recorded in the years 1996-2002, provided the inputs for land cover classification. The Africover project’s implementation was based on innovative land cover classification and mapping methodology, which enables global harmonization of land cover classes while providing the flexibility for designing the project’s outputs to suit the users’ requirements. In particular, the Land Cover Classification System (LCCS) is becoming the land cover classification standard used by growing number of land cover mapping projects. The Africover land cover database is compatible with mapping scales

1:100 000 – 1:250 000. The Africover North African and Sahelian modules are in the preparatory phase.

- **FAO Asiacover** land cover mapping project. Its preparatory phase has been completed with FAO funding in 2005. Its land cover mapping methodology is based on the suite of software modules that were developed for the Africover project. The main differences will be the use of ALOS-AVNIR image data as the primary data inputs, the inclusion of socio-economic data layers in the Asiacover database, and development of integrated land cover & socio-economic products.
- **CORINE Land Cover (CLC)** project. The land cover mapping of the European Union countries by CLC project started in the mid-1980s. Its objective was to facilitate harmonization of the assessment of the state of the environment in all EU countries. In the beginning of 1990s, the CLC project was extended to include 13 Central and East European countries. Each participating country was responsible for CLC implementation, guided by the EU-CORINE land cover mapping unit. The primary data inputs were the Landsat TM image data recorded in the years 1986-1995. The digital and hard-copy land cover maps at 1:100 000 scale, produced by the project in each participating country, have 44 land cover classes, with the threshold area of 25 hectares.
- **Image and CORINE Land Cover 2000 (I & CLC 2000)** project. The European Topic Centre on Land Cover of the European Environment Agency (EEA) coordinated its implementation, which started in 2000. The I&CLC 2000 project's objectives were to (a) provide a satellite image snapshot of Europe in 2000, (b) update the CORINE land cover map, and (c) produce land cover change map for the period 1990-2000. The primary inputs were the Landsat 7 ETM+ image data recorded in 2000 (± 1 year), with the SPOT image data used for land cover mapping of coastal zones. The outputs, which cover the European Union and consist of land cover statistics, digital land cover vector or raster map at 1:200 000 mapping scale, digital change map 1990-2000, and a set of digital ortho-rectified color composite image mosaics, the last three products distributed on CDs, were integrated in the EEA Terrestrial Environment Information System (TERRIS) database.

B. Land Cover and Indicators of Environmental Quality

Satellite remote sensing has become the most powerful enabling technology for monitoring environmental quality at a country, regional and global levels. By virtue of its unique capability of providing repetitive, synoptic coverage of large areas, recorded in distinct spectral bands in the visible, near-IR, thermal-IR, and microwave parts of electromagnetic spectrum, it allows objective characterization of environmental quality and monitoring its changes. Satellite communication provides the connectivity for near-real time transfer of this information to processing centers and end users.

The state of environmental quality determines its life carrying capacity. Considering the continuing increase of population in developing countries, intensification of land use, degradation of land, pollution of fresh-water resources, and higher frequency and intensity of natural disasters worldwide, the protection of environmental quality is one of the essential requirements for the survival of mankind.

There are number of initiatives for monitoring the environmental quality at a country and international levels. The UNEP is issuing periodic global assessments of the state of the environment and developed guidelines for harmonization of environmental assessment based on a set of indicators. There are many criteria for the selection of environmental indicators, but the following ones are the most important (Kalensky & Latham, 1998):

- Environmental indicators should be measurable at reasonable cost and in required intervals.
- Their relationship to specific environmental conditions, which they are representing, should be easy to understand, measure, and interpret.
- A national set of environmental indicators should provide a comprehensive description of environmental conditions and their dynamics for the whole country.
- They should enable an international comparison of environmental conditions and their changes.

When selecting the environmental indicators, it should be remembered that the assessment of environmental quality is not just a technological task but it has a socio-economic dimension, closely related to rural poverty, food insecurity, and gender inequality. Furthermore, the selection of indicators of environmental quality will be influenced by the observation methodology.

Land cover is generally accepted as one of the most representative indicators of environmental quality. It can be interpreted from satellite remote sensing data and fulfills the above four criteria for the selection of environmental indicators. It reflects both, the natural and anthropogenic drivers of environmental change, such as the climate variability and change, natural disasters, and land use. Systematic monitoring of land cover enables assessment of the impact of climate change on land and fresh-water resources, changes in wetlands, lake areas and coastal zones. Information on land cover changes has also become one of the most important inputs to greenhouse gas accounting and terrestrial carbon management, assessment of bio-diversity, and land degradation/desertification.

In order to accelerate harmonization among international land cover mapping projects, FAO and UNEP, with funding support by the Italian government, established the Global Land Cover Network (GLCN) with the following mandate:

- Networking, to establish effective linkages and cooperation with major land cover databases;
- Normative and methodological, aiming at upgrading and harmonization of land cover mapping and monitoring methodologies;
- Serving as the international clearinghouse for information related to land cover mapping and monitoring activities at global and regional levels. This task involves the development and management of GLCN meta-database providing information on international land cover mapping and monitoring projects;
- Capacity building for land cover mapping and monitoring in developing countries.

<u>Reference</u>

Kalensky, Z.D. & Latham, J.S. 1998.: "The Establishment of Environmental Information Systems (EIS) in Developing Countries." Canadian Institute of Geomatics, Geomatica, Vol.52, No.4, Pp.474-480.

C. Land Cover and Ecosystems Conditions

Sound reporting on ecosystems requires the availability of reliable information identifying their type, location, extent and condition. The information should be available at periodic intervals to allow the monitoring of changes in ecosystems' conditions. Analysis of land cover data obtained by satellite remote sensing provides such information. Land cover reflects the characteristics of natural and managed ecosystems. The land cover types of natural ecosystems have been formed through interactions among the main environmental physical factors, the climate, soils, water and topography. The land cover types of managed ecosystems have been transformed from their natural state by the impact of land use. They reflect the socio-economic conditions, such as the population density and its dynamics, political stability, level of economic development, poverty and its geographic distribution, land tenure systems, agriculture policy and agronomic production systems, management of forest and rangelands, environmental protection, etc.

Global inventory and periodic monitoring of ecosystems are required for the assessment of net productivity of land, the state and fluctuation of fresh-water resources, and the identification and quantification of sinks and sources of greenhouse gasses. While the first two requirements are needed for determination of the carrying capacity of land, the third requirement is needed for forecasting the extent of climate variability and change.

The following examples illustrate the importance of multi-level and multi-temporal land cover information for the accurate characterization of the ecosystems' biophysical properties and their changes, modeling the greenhouse gasses cycle, and forecasting its impact on climate variability. The type of forest (boreal, temperate, tropical rain forest, etc.), its composition, age, health, and structure determine the rate of carbon sequestration and storage capacity. The frequency and extent of forest fires, size of logging activities, and reforestation rate affect the amount of carbon released to the atmosphere. Similarly, the knowledge of the area size, characteristics and dynamics of northern wetland ecosystems, which are one of the largest natural sources of atmospheric methane, is essential to quantification of its atmospheric concentration.

An important recent initiative, coordinated by UNEP, was the Millennium Ecosystem Assessment (MA), undertaken in 2001-2004. It studied the links between ecosystem services/benefits, their health, and people's well-being. Its many examples include the effects of swidden agriculture on deforestation in Southeast Asia and Amazon Basin, and illegal logging and fuelwood extraction on deforestation in Africa. In Sistelo, Portugal, a government afforestation program on common property land (*baldio*) reduced land available for pastoralism and accelerated the rural-urban migration. Although the MA analysis was based on collation of the existing knowledge, it documented the power of systematic assessment of land cover changes by the Earth observation satellites for monitoring the ecosystems and early detection of their disturbances at a global level.

Land cover monitoring has an important role in the early detection of the effects of climate change on ecosystems. Furthermore, the integration of land cover data with other relevant bio-physical and socio-economic geospatial data in GIS database enables the assessment of climate change impacts on ecosystems services and forecasting their trends. Examples include early identification of areas with scarcity of fresh water supply, land degradation and desertification, increasing frequency of wild fires in grasslands and forests, and melting permafrost in northern ecosystems affecting their natural habitats.

Protection of natural ecosystems, their biodiversity and integrity, and the sustainable use of managed ecosystems, have become the top priority tasks of this century. Their fulfillment will not be easy, considering the increasing population pressures, growing demands for food and fiber, and impacts of climate change accompanied by increasing frequency of natural disasters. Reliable and timely information on land cover and its changes at a global level, provides the essential inputs to effective ecosystems protection. Yet, the recent report "Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition" (The Heinz Center, 2006), concluded that there is a lack of land cover data with parameters required for assessment of ecosystems conditions, and included land cover on its list of ten highest priority data gaps.

Reference

The Heinz Center, May 2006: "Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition." A Report of the Heinz Center's State of the Nation's Ecosystems Project. Washington, D.C., U.S.A.

D. Land Cover and Hazard Identification and Forecasting

Increasing frequency and intensity of disasters caused by natural and man-made hazards have prompted the introduction of a number of disaster risk reduction initiatives in recent years. These include the UN declaration of the 1990s as the International Decade for Natural Disaster Reduction, the 1994 World Conference on Natural Disaster Reduction in Yokohama, Japan, the 2000 UN International Strategy for Disaster Reduction (UN/ISDR), and the 2005 World Conference on Disaster Reduction in Kobe, Hyogo, Japan. Disasters represent a growing concern because of continuing global population growth, widespread poverty and food insecurity in developing countries, and the onset of global environmental changes, such as land degradation/desertification and loss of biodiversity caused by a combination of climate change and land use pressures.

In order to increase the global preparedness for disasters, the United Nations organized an International Conference on Early Warning Systems in Potsdam, Germany, in 1998. It recommended the more effective use of information technologies by the national and regional early warning systems in the risk assessment strategies and planning of preparedness for geological hazards, including earthquakes and landslides; hydrometeorological hazards, including floods, tropical storms, agricultural droughts and wild fires; biological hazards, including large scale pest infestations; and technological hazards, including pollution of inland water bodies and coastal zones, and acid rain.

The state of the environment and disasters are closely linked. Environmental degradation can affect biological, hydrometeorological, and some geological hazards. There is now international acknowledgement that efforts to reduce disaster risks must be systematically integrated into policies for sustainable development, environmental management and land use planning. Sustainable development, poverty reduction, food security, and disaster risk reduction are mutually supportive objectives, and are the inherent components of good governance.

The development of a disaster preparedness plan consists of the following activities:

- Broad delineation of hazard zones according to their vulnerability to specific disasters;
- Land cover mapping of hazard zones;
- Establishing a disaster preparedness database with land cover as its reference data layer;

- Monitoring land cover and land use changes in hazard zones;
- Developing predictive models for risk of specific disasters;
- Establishing a disaster early warning system;
- Systematic reduction of disaster risk through effective application of best practices and lessons learned;
- Preparedness for effective response and recovery.

Land cover mapping is thus one of the key activities of disaster preparedness. It provides the reference data layer for disaster preparedness database, and monitoring land cover changes enables the fine-tuning and up-to-dating of disaster preparedness plan.

The FAO food security early warning system is based on monitoring land cover conditions and rainfall by the Advanced Real Time Environmental Monitoring Information System (ARTEMIS) in Africa and West Asia. Its objectives are twofold: to provide early warning of agriculture drought, and monitoring desert locust ecological conditions in its recession areas. The monitoring of land cover conditions is based on decadal Normalized Difference Vegetation Index (NDVI) produced from NOAA-AVHRR, SPOT-Vegetation, and Terra/Aqua MODIS multispectral image data that are recorded daily during vegetation season. Monitoring of rainfall is based on Meteosat thermal-IR data, recorded at hourly intervals and processed into 10-day and monthly products. The ARTEMIS products are integrated with agro-meteorological and other relevant data in dedicated GIS workstation, analyzed and used for location-specific assessment of food security risk. (Hielkema, 2000).

Reference

Hielkema, J.U. 2000. “FAO Spatial Information Applications in Early Warning for Food Security – The ARTEMIS System.” FAO-SDRN Internal Report.

E. Land Cover and Climate Change

Climate change is considered one of the most serious threats to sustainable development and management of natural resources. It affects all climatic zones but has the most devastating effects in the arid and semi-arid zones, such as the Sahelian region of Africa. The increasing frequency, intensity and duration of droughts has disastrous effects on agriculture and pastoralism, on which the livelihood of majority of population in these zones depend. Although the consequences of climate change are the most serious in drylands, the tropical and sub-tropical humid zones experience higher frequency and intensity of tropical storms and floods, coastal zones are exposed to raising sea level, temperate zones to higher occurrence of wildfires, eutrophication of lakes and drying of wetlands, and northern zones to melting permafrost. As the communities in the worst affected regions in developing countries struggle to adapt to changed environmental conditions resulting from climate change, their traditional way of life becomes unsustainable and leads to worsening famine, impoverishment and migration of people from their traditional habitats.

The need to improve the preparedness for and adaptation to the impacts of climate change has been receiving an increasing attention from national governments, inter-governmental bodies including G8, and United Nations. All recognized that it is an ecological, developmental and socio-economical challenge. The WMO and UNEP jointly established an Intergovernmental

Panel on Climate Change (IPCC) for the assessment of scientific, technical and socio-economic information relevant to the understanding of climate change, its potential impacts, and options for adaptation and mitigation.

In 1992, the UN Framework Convention on Climate Change (UNFCCC) was adopted. Its overall objective is "…*stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."* The Kyoto Protocol to UNFCCC, which was ratified in 2004, commits industrialized countries to reduce emissions of six greenhouse gasses by at least 5% below 1990 levels between 2008 and 2012.

The importance of the availability of reliable information on current land cover, its past changes and trends for mitigation of the impacts of climate change has been recognized and incorporated in the planning and modeling activities. There are two types of such activities:

- Proactive activities, which aim to reduce the climate change impacts. These activities primarily concern reduction of the atmospheric concentration of greenhouse gases through identification, protection and strengthening of their natural sinks;
- Mitigation and adaptation activities are based on knowledge of land cover changes that have already occurred as a consequence of climate change. Monitoring land cover changes and their quantification enables objective assessment of climate change impacts and development of effective mitigation and adaptation measures.

Climate change models supporting the development of measures for the reduction of impacts of two most important greenhouse gasses, the carbon dioxide (CO_2) and methane (CH_4), are based on characterization of land cover classes, which are their natural sinks and sources.

Vegetation cover, in particular forests, are the carbon sinks due to photosynthesis, as well as the sources of atmospheric carbon due to respiration, forest fires and decay. It is estimated that global forests store two-thirds of terrestrial carbon, nearly one trillion tons. The effectiveness of atmospheric carbon sequestration by forest depends on its level of photosynthesis that is, on its species composition and age. The rate of carbon sequestration by young forest is much higher than by mature forest. The mature forest stores a significant amount of carbon (approximately half a ton of carbon per cubic meter of wood) but its uptake of atmospheric carbon is minimal, because the photosynthesis and respiration are carbon neutral in mature forest. Globally, about half of the photosynthesis is occurring in the tropical rainforest. Yet, the decay of organic matter, and hence the release of carbon dioxide into atmosphere, is also high in humid tropical climate.

Another group of land cover classes, which are important for quantification of natural sinks and sources of greenhouse gasses are the northern wetlands. The northern wetland ecosystems are significant natural sources of atmospheric methane. Their mapping, classification and change monitoring is needed for modeling the methane cycle. Other land cover classes related to methane include rice paddies, open-pit coal mines, landfills, and wastewater treatment lagoons.

One of the main objectives of the IGBP Global Land Cover Mapping Project (Chapter A) was to provide reliable information on global land cover to climate change studies in order to enable more accurate assessment of natural sinks and sources of carbon dioxide and methane, and modeling their uptake, storage and release at a global level.

F. Land Cover and Biodiversity

The maintenance of biodiversity is a precondition for sustainable development. Biodiversity sustains human life through provision of food, purification of air and water, moderation of climate, components for medicines, and large number of other products. However, the fast growth of population and consumption has resulted in increasing rate of biodiversity loss. The importance of its protection was emphasized at the UN Conference on Environment and Development (UNCED, Rio de Janeiro, 1992), which adopted the Convention on Biological Diversity (CBD). The CBD provides a legal framework for the protection of global biodiversity, the sustainable use of biological resources, and the fair and equitable sharing of genetic resources. It has developed programs for the protection of biodiversity in specific ecosystems, such as forests, wetlands, drylands, agriculture, coastal, etc. The UN World Summit on Sustainable Development (WSSD, Johannesburg, 2002) called for significant reduction in the current rate of biodiversity loss by 2010. The WSSD was followed by the International Conference "Biodiversity: Science and Governance" (UNESCO, Paris, 2005), with the objective to strengthen the ongoing international effort of reversing the biodiversity loss and assuring its long-term conservation and sustainable use.

The availability of reliable and up-to-date land cover information is indispensable to effective biodiversity protection. It reflects the changing conditions of natural, anthropogenic and mixed ecosystems and their embedded biodiversity types. The land cover change provides an early warning about possible biodiversity change.

Land cover provides the location-specific baseline data to which other bio-physical and socio-economic data are linked. In the past, the land cover information was available only in the form of a single-time snapshot maps with rather limited land cover information content because of high cost and long time needed for their production. The advanced geo-information technologies of satellite remote sensing, GIS and GPS have fundamentally changed the methodology of land cover mapping, significantly shortened its production cycle and reduced cost. In particular, the repetitive coverage of the same area by the Earth observation satellites enables frequent monitoring of land cover changes with ground resolution ranging from about 1m to 1km anywhere in the world.

Mapping and monitoring of land cover for the assessment and protection of biodiversity also includes delineation of key habitats, specific to individual ecosystems and biological species. This task has to be preceded by the selection of habitat indicators, such as the type of land cover and its seasonal change, topography, minimum temperature and precipitation, etc. The GIS is used for processing of habitat polygons. The land cover map provides a backdrop on which the habitat polygons are overprinted.

Fragmentation of land cover is an important indicator of endangered biodiversity and often results in transformation of the whole ecosystem. Examples of extensive fragmentation of land cover caused by illegal logging and burning primary rain forest are in the Amazon Basin, Myanmar, and Indonesia. The fragmentation of forest land cover is usually followed by its conversion to agricultural use. Land cover monitoring by Earth resources satellites enables early detection of illegal logging activities, and their location and time-specific documentation.

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