CHAPTER 6

FAO LAND COVER MAPPING INITIATIVES

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ABSTRACT

The Food and Agriculture Organization of the United Nations (FAO), as part of its mandate, is conducting global assessment and monitoring of agricultural land, forest and fisheries resources, and assisting developing countries with their sustainable development and management. During the 1970s, FAO became one of the earliest operational users of satellite remote sensing data for land cover mapping and change monitoring in developing countries. Since the mid-1990s, the FAO land cover mapping activities have been expanded to include development of an advanced land cover mapping methodology appropriate for application at global and regional levels, and global harmonization of land cover classification. These tasks are now being completed and transformed into operational activities.

INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO), as part of its mandate, is conducting global assessment and monitoring of agricultural land, forest and fisheries resources, and assisting developing countries with their sustainable development and management. During the 1970s, FAO became one of the earliest operational users of satellite remote sensing data for land cover mapping and change monitoring in developing countries. Since the mid-1990s, the FAO land cover mapping activities have been expanded to include development of an advanced land cover mapping methodology appropriate for application at global and regional levels, and global harmonization of land cover classification. These tasks are now being completed and transformed into operational activities.

FAO needs timely and reliable information on land cover and its changes at global, regional and country levels to support implementation of the UN Millennium Development Goals, UNCED Agenda 21, WSSD Plan of Implementation, international environmental conventions on climate change, biodiversity, and desertification, and its programmes, projects and other activities. These include:

- FAO initiatives related to the Global Terrestrial Observing System (GTOS), which is managed by FAO, and its panel, the Global Observation of Forest and Land Cover Dynamics (GOFC/GOLD);
- FAO inputs to the GEOSS, IGOS, and, in particular, the Integrated Global Observations of the Land (IGOL), which is the IGOS new application theme;
- FAO Global Information and Early Warning System on Food Security, and the FAO ARTEMIS project's inputs to the sub-regional food security early warning systems in Africa;
- FAO Global Forest Resources Assessment project, which is implemented in 5-year intervals. The next assessment will be referenced to the year 2010 (FRA 2010);
- FAO LADA project for global assessment of land degradation in drylands;
- FAO projects for development of regional land cover databases to support environmental protection and rehabilitation (Africover and Asiacover projects);
- FAO projects for development of country-level land cover databases to support sustainable land use planning and agro-ecological zoning, including the assessment of aquaculture potential, in developing countries;
- FAO projects for natural disasters preparedness and mitigation, such as the monitoring of agricultural drought and desert locust recession areas in Africa, assessment of wildfires risk, and delineation of flood zones;
- FAO projects for detection of illicit drugs plantations and illegal logging;

- FAO projects aiming to enhance societal benefits of rural development, including improvement of fresh water supply, irrigation and road infrastructures, and delineation of habitats amenable to vector-borne diseases.

LAND COVER INFORMATION REQUIREMENTS AT GLOBAL AND REGIONAL LEVELS

FAO has been involved, in the framework of its participation in the implementation of the U.N. Millennium Development Goals, international environmental conventions, GTOS-GOFC/GOLD, IGOS/IGOL, FRA and LADA global programmes, and a variety of regional projects such as Africover, Asiacover and ARTEMIS, in a wide range of activities that require information on land cover and its dynamics at the global and regional levels. Considering its mandate, the main focus of these activities has been on the following applications:

Monitoring the impacts of climate change with particular attention on food security in developing countries

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 have 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.

Monitoring land cover dynamics is essential for the assessment of land degradation in drylands

(FAO-LADA global project) and timely development of adaptation strategies. Dryland areas have become more vulnerable to degradation because of the combination of climate warming and population increase. The expansion of agricultural cultivation in former grazing areas of drylands has exacerbated land degradation and led to food insecurity. In addition to LADA project, FAO implemented number of projects for identification of the areas with land degradation risk, and projects for agro-ecological zoning at the global, regional and country levels. (FAO, 2002; Fischer et al, 2002).

Climate change models for the reduction of impacts of the most important greenhouse gas, carbon dioxide (CO_2), need reliable information on land cover classes, which are its natural sinks and sources. Vegetation cover, in particular forests, is the carbon sink due to photosynthesis, as well as the source of atmospheric carbon due to respiration, forest fires and decay. FAO estimates that global forests store two-thirds of terrestrial carbon, nearly one trillion tons. Yet deforestation of tropical forest continues at an alarming rate, with South America having the largest net loss of forest, 4.3 million hectares annually between 2000 and 2005, followed by Africa with 4.0 millions hectares. (FAO, 2005).

The FAO Forestry Department has been conducting periodic assessments of global forest resources since its establishment in1946. Their objective is to provide reliable and globally consistent information on the state of tropical forest cover and the rates of its change. Since 2000, the global forest assessment has been carried out in 5-year intervals. It is based on a combination of country reports and analysis of high resolution remote sensing data in 117 sampling areas, each representing one Landsat TM/ETM+ scene, randomly distributed over the world tropical forest. (FAO, 2001 & 2005).

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 the G8 countries, 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 collection and assessment of scientific, technical and socio-economic information relevant to the understanding of climate change, its potential impacts, and options for adaptation and mitigation. FAO provides information related to the impact of climate change on agricultural land and food production to IPCC.

Preparedness for natural disasters at global and regional levels

Climate change and frequency of natural disasters, such as tropical storms, agricultural drought, wildfires, floods, and large-scale pest infestations, are closely linked. 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 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, planning of preparedness and mitigation of impacts. Land cover mapping is one of the key activities of natural disaster preparedness. It provides the reference data layer for disaster preparedness database and monitoring land cover changes facilitates up-dating of disaster preparedness plan.

Information on land cover and its dynamics is an important component in monitoring the environmental conditions in Africa and West Asia by the FAO ARTEMIS project, which started its operation in the mid-1980s. Its objectives are twofold: to provide an early warning on agriculture drought and monitor desert locust ecological conditions in its recession areas. The assessment and monitoring of land cover conditions are based on the decadal Normalized Difference Vegetation Index (NDVI) produced from the NOAA-AVHRR, SPOT-Vegetation, and Terra/Aqua MODIS multispectral image data that are recorded daily during the agricultural season. Monitoring of rainfall is based on the Meteosat thermal-IR data, recorded at hourly intervals and processed into 10-day and monthly products. The ARTEMIS products are integrated in dedicated GIS workstation with agro-meteorological and other relevant data, analyzed and used for: (a) location-specific assessment of food security risk by the FAO Global Information and Early Warning System on Food Security, and (b) identification of potential desert locust breeding sites by the FAO Desert Locust Plague Prevention Programme. (Hielkema, 2000).

Protection of environmental quality and biodiversity

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 fibre, and impacts of climate change accompanied by increasing frequency and intensity of natural disasters. Reliable and timely information on land cover and its changes 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 systematic assessment of ecosystems conditions at the global level, and included land cover on its list of ten highest priority data gaps.

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 a 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. Land cover provides the location-specific baseline data to which other biophysical and socio-economic data are linked. 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 of primary rain forest are in the Amazon Basin, Myanmar, and Indonesia. The fragmentation of forest is usually followed by its conversion to agricultural use. Land cover monitoring by Earth resources satellites enables early detection of illegal forest clearing and provides time-specific documentation of its extent and location. (FAO, 2001).

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 and man-made disasters, and land use impacts. Systematic monitoring of land cover enables an assessment of the impact of climate change on land and fresh-water resources, including land degradation and desertification, changes in forest cover, wetlands, surface water bodies 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. The aim of the FAO/UNEP Global Land Cover Network, described earlier, is to accelerate harmonization among international land cover mapping projects in order to increase the global availability of land cover information.

THE CURRENT STATUS OF GLOBAL AND REGIONAL LAND COVER MAPPING.

There is an increasing number of land cover mapping projects being implemented at global and regional levels in recent years. However, there has been little or no compatibility among them in terms of land cover nomenclature, definitions of land cover classes, map legends, image interpretation methodologies, accuracy criteria and cartographic specifications. Although these land cover maps are a valuable source of information, most of them were designed for a specific application and are difficult to compare and use in other applications that may require different land cover definitions and map legends. (Kalensky et al., 2003).

Examples of recently completed or ongoing global land cover mapping projects.

- **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 the MERIS remote sensing system on-board of the 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 the GLC-2000 mapping and vegetation index assessment. Land cover classification was based on LCCS. High resolution image data were used for validation of land cover 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 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** moderate resolution global land cover datasets, based on Landsat TM and ETM+ image data of 1990 and 2000 (± 3 years) respectively, are being produced by the MDA-EarthSat company. Thirteen land cover classes are based on modified USGS-Anderson 1976 classification. Both datasets are co-registered and orthorectified to < 50m RMS error.

Examples of recently completed or ongoing regional (continental and sub-continental) land cover mapping projects

- **FAO Africover** land cover mapping project. (Kalensky, 1998). Its East African module, covering ten 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. Operational mapping has begun for West Africa, beginning with Senegal and Burkina Faso. Land cover mapping of Libya based on Africover specifications has been recently completed, funded by the Libyan government.
- **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. 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 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.

NEW PARADIGM FOR LAND COVER MAPPING

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).

A new paradigm for land cover mapping is clearly required that would provide information needed by these initiatives. In particular, 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 (e.g. topographic, soils, land degradation) 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 the establishment of links 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) and a software suite of innovative land cover mapping methodologies. (FAO & UNEP, 2002).

An Important component of GLCN-TC 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. An example is the Workshop on Harmonization of Forest and Land Cover Classifications for the Asia Pacific Region, which will take place in Dehra Dun, India, in December 2006. Its purpose is to promote and demonstrate harmonization of land cover and forest classification among Asian countries, based on LCCS.

The Global Land Cover Network (GLCN)

The Global Land Cover Network initiative is the result of a joint effort by the FAO and UNEP to respond to the need of international community for the availability of reliable and harmonized land cover information at a global level. This initiative is based on the recommendations of the Agenda 21 for coordinated, systematic, and harmonized collection and assessment of data on land cover and environmental conditions. The GLCN was developed in collaboration with the U.S.-led Geographic Information for Sustainable Development (GISD) global partnership, which aims to increase the use of Earth observation data and geographic information technologies in sustainable development projects focusing on food security, sustainable agriculture, natural resources management, disasters mitigation, and poverty alleviation. Its development benefited from the experience obtained during implementation of the Italian funded East African module of the FAO Africover project. The project produced and extensively tested the innovative methodologies for land cover classification and mapping, and led to development of the Land Cover Classification System, which is being used by growing number of national and international organizations. It.introduced a new, LCCS-based approach towards global harmonization of land cover nomenclature.

The GLCN overall objective is to provide direction, methodology and guidance for harmonization of land cover mapping and monitoring projects at national, regional and global levels in order to achieve compatibility among their products through the promotion of LCCS as the new standard classification system.

In order to fulfill the above objective, the GLCN Topic Centre was established to serve as an international clearinghouse for information on land cover mapping and monitoring projects (http://www.glcn.org/). Its configuration is in Fig. 1. The GLCN-TC conducts the following four types of activities:

- Methodology development -.includes certification of existing land cover databases for their compliance with GLCN technical specifications. It also includes a continuing development of GLCN methodology based on changing requirements on land cover products by their end users;
- Networking - establish effective linkages and cooperation with major land cover

databases and international, governmental and commercial organizations involved in land cover mapping and monitoring activities. The main aim is to increase the benefits from regional and global land cover mapping and monitoring initiatives to developing countries;

- Capacity building - includes provision of advisory services and organization of training courses on GLCN land cover mapping and monitoring methodology for technical staff and appraisal workshops for decision-makers. Its aim is to strengthen the national capacities for land cover mapping and monitoring in developing countries;

- Serving as an international clearinghouse - for information related to land cover mapping and monitoring activities. This task involves development and management of GLCN meta-database providing information on major land cover mapping and monitoring projects.

GLCN Land Cover Classification System (LCCS)

The LCCS innovative design is based on the following unique concept: rather than using pre-defined classes, the LCCS uses universally valid pre-defined set of independent diagnostic attributes, or classifiers. This presumes that any land cover class, regardless of its type and geographic location, can be identified by a pre-defined set of classifiers. The number of selected classifiers determines the level at which the land cover is classified. Thus, the larger number of classifiers is needed for a more detailed classification of land cover and *vice versa*. Furthermore, the classifiers provide a more comprehensive insight into the characteristics of land cover types than would be possible than through standard class names. The LCCS thus facilitates a multiple use of land cover database by allowing users to select the classification levels best suited to their respective applications.

The LCCS output is a comprehensive land cover characterization with a clear definition of class boundaries, without overlaps. The universality of LCCS is based on its following four characteristics:

- Independent of map scale;
- Independent of data source and data collection methodology;
- Independent of geographic location;

- Independent of application.

The above LCCS characteristics, combined with its capability to translate the existing land cover classifications into the LCCS-compatible land cover datasets, make the LCCS an optimal land cover classification standard for large-area projects. This is particularly important considering that an increasing number of regional and global land cover mapping and monitoring projects urgently need a universally applicable land cover classification system for objective international comparisons of land cover state and its changes. A growing number of international projects are already using the LCCS as their classification standard and a number of countries have translated their existing land cover legends to align with the LCCS system (e.g. South Africa and New Zealand). To illustrate the global usefulness of the databases generated by the Africover project, over 3000 request for data, representing over 800 different organisations have registered and downloaded data from the Africover website since January 2003.

Another unique approach to land cover classification adopted by LCCS was driven by pragmatic, operational considerations. Instead of attempting to use the same, large set of pre-selected classifiers compatible with land cover of large areas, such as the whole continents, it divided the classifiers into eight groups corresponding to eight major land cover classes representing the global land cover diversity. This has greatly reduced the number of classifiers needed for precise definition of any land cover class regardless of its location and thus significantly simplified the classification procedure. However, it required designing the LCCS implementation in two phases: the initial *Dichotomous Classification Phase* and the follow-up *Modular-Hierarchical Classification Phase*.

The *dichotomous phase* uses the following three classification criteria: presence of vegetation, edaphic condition and artificiality of land cover. It consists of three classification levels and results in eight major land cover classes in the third level (Table 1). These classes are then further classified during the *modular-hierarchical phase*, based on eight sets of pre-defined classifiers. Each of the eight major land cover classes defined during the dichotomous phase has its own distinct set of classifiers, tailored to the type of land cover class. An example of classifiers for land cover class “natural and

First level	Second level	Third level
PRIMARILY VEGETATED	TERRESTRIAL	MANAGED TERRESTRIAL AREAS
		NATURAL and SEMI-NATURAL TERRESTRIAL VEGETATION
	AQUATIC or REGULARLY FLOODED	CULTIVATED AQUATIC AREAS
		NATURAL and SEMI-NATURAL AQUATIC VEGETATION
PRIMARILY NON-VEGETATED	TERRESTRIAL	ARTIFICIAL SURFACES
		BARE LAND
	AQUATIC or REGULARLY FLOODED	ARTIFICIAL WATER BODIES
		NATURAL WATER BODIES, SNOW and ICE

Table 1. LCCS dichotomous classification phase.

	Classifiers			
4	Life form of main layer (e.g. woody, herbaceous)	Vegetation cover of main layer	Vegetation height	Spatial distribution (macropattern)
5	Leaf type (e.g. broadleved, needleleaved, aphyllous)		Leaf phenology (e.g. evergreen, deciduous, mixed)	
6	Vertical stratification second/third layer	Vegetation cover second/third layer	Vegetation height second/third layer	

Table 2. Set of classifiers and their hierarchical arrangement corresponding to the dichotomous class Natural and Semi-Natural Terrestrial Vegetation.

semi-natural terrestrial vegetation" is in Table 2. These *classifiers* are arranged in a fixed hierarchical structure, which has to be followed during classification procedure. Each set of *classifiers* also includes two types of additional, optional classification attributes, the *environmental attributes* and the *specific technical attributes*, which are used when further, more detailed description of characteristics of land cover classes is required.

The advantages of the Land Cover Classification System are manifold. It is a highly flexible system in which each land cover class is mutually exclusive and clearly defined, thus providing internal consistency. These characteristics are independent of the classification level. The classification can be stopped at any desired level and will result in clearly defined land cover class corresponding to that level. Any land cover type can be readily accommodated. The system is truly hierarchical and applicable at a variety of mapping scales and in any geographic location. It can be used as a reference standard system because it is based on diagnostic criteria that allow correlation with existing classifications and legends. The LCCS, which represents a paradigm shift in land cover classification, thus contributes towards harmonization and standardization of land cover classification and mapping. (Di Gregorio and Jansen, 2000; Di Gregorio, 2005).

International Standardization of the LCCS.

Through a cooperative agreement with the International Organization for Standardization Technical Committee 211 on Geographic Information, the UNFAO is developing a joint UN-FAO/ISO standard on classification systems in general and the LCCS in particular. The standardization effort is in four parts. The first is a general standard that addresses all classification systems. This general standard can be used for land cover classification or to address completely different fields (e.g. oceanography). The second standard is a description of the LCCS system of defining classifiers (classification rules). The third part is a register of classifiers and the fourth part deals with classification legends developed to address land cover in particular regions. For example, the CORINE classification legend developed for European countries, can be expressed in terms of the LCCS classifiers and thus becomes compatible with LCCS legends developed for other regions. Such compatibility, based on LCCS as the underlying structure, enables merging of land cover classes and generation of statistics over broad areas from land cover data generated by different mapping methodologies.

Development of UN-FAO classification standards is based on standardized Universal Modelling Language (UML) and compatibility with other ISO geographic standards to ensure that there is broad commonality with the entire geographic information community. . This approach assists industry in providing tools that support the LCCS classification, dissemination of land cover information and its inclusion in spatial data infrastructure. (ISO 19135:2005; ISO WD 19144-1; ISO WD 19144-2.)

CONCLUSION

The socio-economic, climatic and environmental challenges facing 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 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 billion 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 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 the growing scarcity of natural resources and continuing environmental degradation in developing countries. Thus, the intensification of agricultural production has to be based on sustainable development and management of land and fresh-water resources to produce enough food for growing population.

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. 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), and agricultural policy (including forestry and fresh-water resources).

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 an 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, for their joint analysis and modeling. Furthermore, the United Nations Millennium Development Goals and international environmental conventions, have set new standards for the type, availability and quality of geospatial information required for their implementation. FAO and UNEP, with the support by the Italian Government, responded to this challenge through the establishment of GLCN-TC at the Istituto Agronomico per l'Oltremare in Florence, Italy. (FAO & UNEP, 2002). I should like to use this opportunity to invite your cooperation with its activities.

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ADDENDUM.

Participants of the North American Land Cover Summit (Washington, D.C., 20-22 September 2006) agreed that the GLCN-Land Cover Classification System (LCCS) should be considered as the classification standard for the future North American land cover mapping products.

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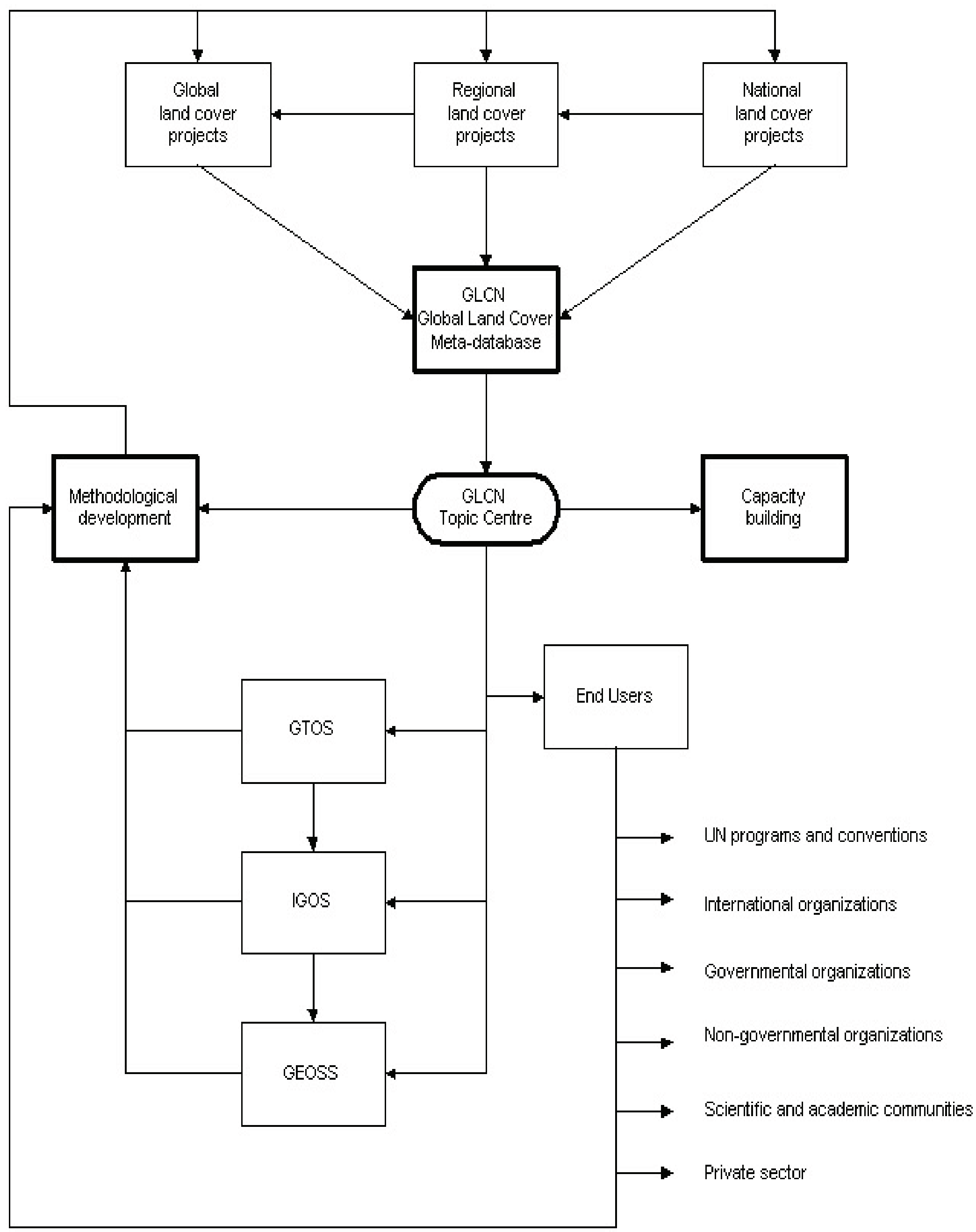

Figure 1. Configuration of GLCN-TC linkages and feedbacks