DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
Statistics Division

Working Document

Land Degradation and Land Use/Cover Data Sources

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CONTENTS

1 INTRODUCTION

The United Nations Statistics Division (UNSD) collects environmental data from the countries biennially with the help of the Questionnaire on environment statistics (http://unstats.un.org/unsd/environment/questionnaire2004.htm). The "Land" section of the questionnaire asks for national data on land use/land cover and land degradation. This report examines the global availability of country level land degradation and land use/cover data that could be used to complement questionnaire responses and to assist the UNSD in data validation. Any judgments related to the usability of existing data sources are made from that point of view. The report is made publicly available, since it can serve as a useful synopsis for other purposes.

Chapter 2 of this report provides first a short overview of the most important land degradation data sources (emphasis on soil degradation) and then presents each of them in more detail. Chapter 3 follows the same structure for land use/cover data. Each chapter also includes references to related internet pages and reports providing the data. Chapter 4 discusses the current use of remote sensing in land degradation and land cover/use assessments. Chapter 5 summarizes the findings of the paper.

2 LAND/SOIL DEGRADATION DATA

2.1 Overview of the main sources

The Global Assessment of Human Induced Soil Degradation (GLASOD) (1990) by the International Soil Reference and Information Centre (ISRIC), currently World Soil Information (www.isric.org), is the first world-wide assessment of soil degradation and is currently the only uniform global source of land degradation data (FAO 2000). After GLASOD there have been some regional studies, such as "the Assessment of the Status of Human-induced Soil Degradation in South and South East Asia" (ASSOD) (van Lynden and Oldeman 1997, also on www.isric.org), "Degradation of the drylands of Asia" (Kharin et al. 1999), "Digital Geo-referenced database of soil-degradation in Russia" (Stolbovoi and Fischer 1997, http://www.iiasa.ac.at/Publications/Catalog/PUB_AUTHOR_Stolbovoi,V.html) and "Soil degradation in Central and Eastern Europe" (van Lynden 2000, http://www.isric.nl/Docs/SOVEUR_Rep2000_05.PDF). Some regional results of GLASOD have also been published. Furthermore, the World Atlas of Desertification (Middleton and Thomas 1997) includes some readily available country level data on desertification. The Land Degradation Assessment in Drylands project (LADA) will provide more land degradation data in the future.

In addition to these global and regional studies, there are several studies for individual countries (e.g. for South Africa, Zimbabwe, Russia, Brazil, Colombia) available. The joint programme of the Land Use and Land Cover Change Project (LUCC) and the Global

Observation of Forest Cover Project (GOFC) produced a synthesis of the existing data on the main areas affected by land cover change during the last twenty years. The study also provides information on the main areas of degraded land in the drylands and hyper-arid zones of the world. The results of the study and the descriptions of country level data used are presented in Lepers (2003) and on the Internet at http://www.geo.ucl.ac.be/LUCC/lucc.html (check also Annex I of this report). The project is a part of the Millennium Ecosystem Assessment.

2.2 GLASOD

The GLASOD project produced a world map of soil degradation at an average scale of 1:10M. The map was originally produced for the 1992 United Nations Conference on Environment and Development (UNCED). Following the conference, the map was digitized and stored in GIS format with attribute database and supplementary statistics on the extent and degree of degradation. GLASOD was based on expert assessments and input from more than 250 soil and environmental scientists.

GLASOD characterized the actual status of soil degradation by mapping the degree to which the soil was degraded, the percentage of the mapped area affected, the apparent rapidity of the soil degradation process estimated over the past five to 10 years and the kind of physical human intervention that was causing soil degradation (Oldeman et al. 1991). Areas affected by human-induced soil degradation were defined as regions where "the balance between the attacking forces of climate and the natural resistance of the terrain against these forces has been broken by human intervention, resulting in a decreased current and/or future capacity of soil to support life" (Oldeman et al. 1991). According to the GLASOD guidelines (Oldeman 1988) this definition excludes soil degradation occurrences "that have occurred in the past as a result of geologic events or under past climatic conditions, such as the rising of mountain chains, volcanic eruptions, the melting of glaciers, rising and subsiding of ocean levels, etc.", i.e. degradation that is not caused by human beings. Soil degradation severity (low, medium, high and very high) is calculated in GLASOD by combining the degree of degradation (light, moderate, strong, extreme) with its relative extent (per cent of a mapping unit affected: 0-5%, 6-10%, 11-25%, 26-50%, and >50%). The degree of degradation is defined in terms of reductions in land productivity (FAO 2000). A total of 12 degradation types are recognized and mapped, e.g. water erosion (loss of topsoil and terrain deformation), wind erosion (loss of topsoil, terrain deformation, overblowing) and salinization. For more details about methodology or definitions consult Oldeman et al. (1991) or FAO (2000).

The results of GLASOD have been widely cited and the study is one of the core studies in soil degradation research. The study has certain limitations such as its small scale, which restricts the use of the data for national breakdowns, (see e.g. ISRIC homepages, www.isric.org) and its age. Being based on expert judgment, the study may be subjective as well. So far, GLASOD is the best source of global soil degradation data.

A digital version of GLASOD maps is available through ISRIC (www.isric.org). Country level GLASOD data (not including subtypes of degradation) is provided by FAO. For more details see chapter 2.9.

2.3 ASSOD

2.3.1 General information about the dataset

The Assessment of the Status of Human-Induced Soil Degradation in South and South East Asia (ASSOD) (1997), which is also made by ISRIC, is a follow-up activity of GLASOD. The same methodology, slightly refined, was used on a more detailed scale (1:5M) for South and Southeast Asia. The study provides data for 17 countries and includes data on several degradation types including water and wind erosion and their subtypes (e.g. loss of topsoil and terrain deformation, million hectares) and the dominant subtypes of chemical deterioration (including salinization). Compared to GLASOD, the ASSOD study is more detailed and thus also more accurate. A comparison of the studies is presented in van Lynden and Oldeman (1997). The ASSOD report, including the data, is available on the Internet (http://lime.isric.nl/Docs/ASSODEndReport.pdf).

In the ASSOD study the degree of soil degradation is expressed in all degradation subtypes in qualitative terms *as an impact on productivity* (negligible, light, moderate, strong, extreme impact). Classification is based on estimation of the *changes* in productivity and also takes the level of management into consideration. *Changes in productivity* are expressed in relative terms, i.e. the current average productivity compared to the average productivity in the non-degraded situation (or non-improved, where applicable) and in relation to inputs. More details of the definitions can be found in van Lynden and Oldeman (1997).

Similar to the GLASOD study, ASSOD covers only human-induced soil degradation. This differs somewhat from the definition used in the UNSD questionnaire. In practice, experts had some difficulties distinguishing human-induced degradation from natural degradation when conducting research for ASSOD. How these difficulties impacted the estimates is not clear. Furthermore, some degradation types reported in ASSOD, such as wind and water erosion or their subtypes, may be overlapping and cannot be added up. Therefore, aggregated figures do not accurately represent the total area affected by erosion.

2.3.2 Data on soil erosion

In ASSOD, both water erosion and wind erosion are divided into two subtypes: loss of topsoil and terrain deformation. The importance of off-site effects is also estimated. A loss of topsoil by sheet erosion/surface wash or by wind action is defined as “a decrease in depth of the topsoil layer (A horizon) due to more or less uniform removal of soil material by run-

off water/by wind." Terrain deformation caused by water is defined as "an irregular displacement of soil material (by linear erosion or mass movements) causing clearly visible scars in the terrain." Terrain deformation by wind is "an irregular displacement of soil material by wind action, causing deflation hollows, hummocks and dunes."

2.3.3 Data on salinization

Salinization/alkalinization is defined as a net increase of the salt content of the (top)soil leading to a productivity decline (mill. ha). Salinization is one of the subtypes of chemical deterioration. More details can be found in van Lynden and Oldeman (1997).

2.4 SOVEUR

2.4.1 General information about the dataset

The "Soil degradation assessment in Central and Eastern Europe" (carried out in 1997-2000 as a part of "the Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe" project (SOVEUR), conducted by ISRIC and FAO, used a slightly modified GLASOD methodology that focused on diffuse pollution. The study also includes data on water and wind erosion and salinization. Several other types of human-induced degradation are also examined. The status of degradation is evaluated both in terms of the type and intensity of the process (degree) as well as the impact of degradation on various soil functions (scale: negligible, light, moderate, strong, extreme). The impact of degradation is assessed as a combination of the change in productivity (current average productivity compared to the average productivity in the non-degraded or non-improved situation) and the level of management (high, medium, low).

The development of the database was based on 1:2.5 M scale physiographic map and on experts' estimates. The results of the study, which includes data on 13 countries are published in van Lynden (2000) (http://www.isric.nl/Docs/SOVEUR_Rep2000_05.PDF). The results of the whole SOVEUR project are available on CD-ROM (no. 10 in FAO's Land and Water Media Series).

SOVEUR provides more information on the overlapping degradation types (compared to ASSOD), and makes it possible to add up different (sub)types of water and wind erosion. This has to be done using the more detailed original SOVEUR data, not data presented in the SOVEUR publication.

2.4.2 Data on soil erosion

Water and wind erosions are divided into three classes: loss of topsoil, terrain deformation and off-site effects. SOVEUR definitions are similar to the ASSOD definitions. More detailed descriptions can be found in Van Lynden (1997, also on ISRIC web-page).

2.4.3 Data on salinization

Salinization/alkalinization is one form of chemical deterioration. It is described as "a net increase of the salt content of the (top) soil leading to a productivity decline". It can be further divided into inland salinization, intrusion of seawater and alkalinization (Van Lynden 1997, also on ISRIC web-page). The data in the report are not that detailed.

2.5 The CEReS studies for Asia and Northern Africa

The Center for Environmental Remote Sensing (CEReS) examined degradation of drylands of Asia (Kharin et al. 1999) and Northern Africa (Kharin et al. 2004) using e.g. satellite imagery. Both studies are regional and the publications do not provide any new country level information (even if the regional data are relatively detailed), but they provide some country level data based on other studies[1]. The digital data for the degradation map of Asia ("Desertification Map of the Drylands of Asia") produced by CEReS is available online (http://www.cr.chiba-u.jp/database.html). The map distinguishes land degradation (vegetation degradation, water erosion, wind erosion, salinization of irrigated soil, waterlogging of rangeland, and salinization of dried up sea floor) in different land use types (forest, rangeland, agriculture, etc.). The degree of degradation is defined using three degree scales (slight, moderate and severe/very severe). The scale of the map is 1:10 000 000 and the satellite imagery data is from years 1992-1994. The assessment of degradation covers only the drylands and semi-drylands of Asia and excludes also certain areas like bogs, bare land and stones, mountains, moving sand and extra-arid lands. CEReS also provides several land cover datasets (e.g. AARS Asia 30-second Land Cover Data Set with Ground Truth Information, AARS Global 4-minute Land Cover Data Set with Ground Truth Information, Global Land Cover Ground Truth (GLCGT) Database). Land cover datasets provide data on several different land cover classes such as forest types, grass crops, bare ground, water, built-up areas and wetlands. Further analyses are needed before degradation or land cover data produced by CEReS can be used for UNSD purposes.

[1] The data are from several different years and estimates of accuracy or methodologies of these studies are not provided.

2.6 IIASA study for Russia

The International Institute for Applied Systems Analysis (IIASA) created a geo-referenced database for the former USSR. Some results concerning soil degradation in Russia are published in the IIASA Interim Report (Stolbovoi and Fischer 1997). The report is also available Online (http://www.iiasa.ac.at/Publications/Documents/IR-97-084.pdf)[2]. The report includes data on the total area affected by soil degradation and area affected by 12 different degradation types (water erosion, wind erosion, water and wind erosion, terrain deformation, compaction, underfloods, secondary salinisation, desertification, disturbances of soil organic horizon due to cuttings, disturbances of soil organic horizon due to fires, surface corrosion and thermokarst). The report does not include detailed descriptions of the definitions used. Desertification is defined as "the expansion of desert area as a result of natural and anthropogenic factors", and is not in line with the definition used by UNCCD (http://www.unccd.int/convention/text/leaflet.php). Soil degradation attributes have been compiled following the ASSOD guidelines. Throughout the database various data sources were used including the updated FAO Soil Map of Russia, the Map of Soil Water and Wind Erosion in Russia, and the Map of Soil Salinization of Russia. Source maps for the whole database are from the time period of 1992-95. Reliability of the results is not discussed in the report.

2.7 Study by H.E. Dregne and Nan-Ting Chou (1992) (published by Texas Tech. University)

The study by Dregne and Chou (1992) provides desertification data for most of the countries in the drylands of the world. Country level data is available from all continents, and separately for irrigated land, rainfed cropland and rangeland in each country. The report is available on the CIESIN Web site (http://www.ciesin.columbia.edu/docs/002-186/002-186.html).

The report does not describe in detail the methodology that was used for obtaining the country-level estimates, but does mention that "the information base upon which the estimates in this report were made is poor". For the various estimates, anecdotal accounts, research reports, travelers' descriptions, personal opinions and local experience have provided most of the evidence. Results are thus very subjective.

[2] In 1999 IIASA published also a Research Report with the same name.

2.8 Study on land degradation in South Asia by FAO, UNEP and UNDP (1994)

The FAO, UNDP and UNEP study on land degradation in South Asia was conducted in 1994 as a response to the request of the Economic and Social Council of the United Nations to undertake a study to assess the extent of land degradation problems in South Asia. The report was written by Anthony Young and was published in the FAO's World Soil Resources Reports series. The publication is available online (http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/V4360E/V4360E00.htm). Data is available for eight countries: Afghanistan, Bangladesh, Bhutan, India, Iran, Nepal, Pakistan and Sri Lanka.

The study had strict time limits and was therefore based entirely on existing publications and reports. Over 200 publications and reports were consulted. The major data source used was the data of the Global Assessment of Soil Degradation (GLASOD). Material assembled by the Asian Problem Soils Network and estimates by individual countries were also used. As the resources were extremely limited, the authors point out that the results should be regarded as provisional and subject to modification.

The report provides country level data e.g. on degradation in general, water erosion, wind erosion, soil fertility decline, salinization, waterlogging and lowering of the groundwater table. FAO data on deforestation is also included. Water erosion covers all soil erosion caused by water, including sheet and rill erosion and gullying. Human-induced intensification of landsliding caused by vegetation clearance for example is also included. Wind erosion is defined simply as a loss of soil by wind, occurring primarily in dry regions. Salinization refers to all types of soil degradation by the increase of salts in the soil, and covers the buildup of free salts and alkalization. Saline intrusion (the incursion of sea water into coastal soils caused by an excessive use of ground water) is also included. Land degradation in general is defined as a temporary or permanent lowering of the productive capacity of land (UNEP definition). It covers soil degradation, adverse human impacts on water resources, deforestation, and lowering of the productive capacity of rangelands. The GLASOD definition for the degree of degradation is used[3]. The degree of degradation is estimated in relation to changes in agricultural suitability, in relation to declined productivity and also in some cases in relation to biotic functions. The report also includes estimates of the per cent of agricultural land impacted by different types of degradation.

[3] Unlike in GLASOD "degree of degradation" and "severity of degradation" have the same meaning.

2.9 FAO

2.9.1 Data on salinization

AQUASTAT

FAO's AQUASTAT database (http://www.fao.org/ag/agl/aglw/aquastat/main/index.stm) provides country specific information on the area salinized by irrigation (ha). Data is available for dozens of countries. There is no information on the credibility of the data or on the exact year of data. Furthermore, no time series are provided.

World Soil Resources Report 90

FAO's World Soil Resources Report 90 (WSRR90) (FAO 2000) (www.fao.org/ag/agl/agll/terrastat/), based on the work of A.J. Bot, F.O. Nachtergaele and A.Young, includes country specific information on salinity and sodicity as soil constraints. Data are available for 160 countries. Data does not include time series. Salinity/sodicity is defined as a "presence of free soluble salts (km^2)", not as an increase in salt concentration as defined in the UNSD questionnaire. Estimates are based on the "Digital Soil Map of the World" (FAO and UNESCO 1995). The digital map is based on older data, which is most likely from the years 1970-1980. Presented estimates largely exclude secondary salinization caused by poor management of irrigation schemes.

2.9.2 Data on land/soil degradation in general

The "World Soil Resources Report 90" (FAO 2000) includes country specific data also on land degradation severity. Data used are GLASOD data from the late 1980s to the early 1990s and are available for 160 countries. In addition to the WSRR90 report, the Terrastat database draws from the GLASOD study and includes degradation data. WSRR90 classifies the severity of degradation into four classes: light, moderate, severe and very severe (the original GLASOD survey calls these classes low, medium, high and very high). In other aspects, classifications are identical with the original GLASOD data. For more details see the description of the GLASOD data above, Oldeman et al. (1991) or FAO (2000). WSRR90 has some inaccuracies in data on Africa and should not be used for country level queries (the total area of a country is in some cases smaller than the area affected by degradation). The GLASOD data in general can be used only as a reference point at country level.

In addition to the data presented in the "World Soil Resources Report 90" and on the related Web site, FAO has carried out another more detailed study of the GLASOD results. The results for Africa are presented on the FAO Web site (http://www.fao.org/landandwater/agll/glasod/glasodmaps.jsp) and more results are available on the Terrastat CD-ROM. The results presented on the Web site and CD ROM take the extent of

degradation into account in a more detailed way and therefore present figures different from the estimates available in WSRR90. FAO's Web site informs readers that the reliability of the data is still very low, especially in small countries. The reliability problem arises from the small scale used in GLASOD.

Degradation data concerning Arab states are available in a document produced by FAO and by the Population Information Network of the United Nations Population Division (POPIN) (Marcoux 1996, http://www.un.org/popin/fao/arabstat.htm). The data are based on GLASOD data and therefore have the same accuracy problems.

2.10 UNCCD/National reports

United Nations Convention to Combat Desertification obliges countries to report on the measures which they have taken for the implementation of the Convention. Some reports provided by countries also include exact data on the current status of degradation. All country reports are on the Internet (http://www.unccd.int/cop/reports/menu.php). In the Convention, desertification is defined as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities". Land degradation is defined as a "reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil, and long-term loss of natural vegetation" (The United Nations Convention to Combat Desertification (1994), http://www.unccd.int/convention/text/convention.php? annexNo=-1).

2.11 World Atlas of Desertification (UNEP)

The World Atlas of Desertification (Middleton and Thomas 1997) includes maps of desertification and some data in tabular form. Map layers are available at UNEP. The Atlas is based on GLASOD and ASSOD, and therefore has the same problems as those studies.

2.12 IGBP/IHDP LUCC and GOLD/GOFC project for Millennium Ecosystem Assessment: Synthesis on the main areas of land-cover and land-use change

The project is a joint effort of the International Geosphere-Biosphere Programme/ International Human Dimensions Programme's Land-Use and Land-Cover Change core

project (IGBP/IHDP LUCC) and the Global Terrestrial Observing System's Panel on Global Observations of Land Dynamics/Forest Cover project (GOLD/GOFC) and is part of the Millennium Ecosystem Assessment. The project provides a synthesis of the existing data on the main areas affected by land-cover change during the last twenty years and also includes an overview of the studies of land degradation in the drylands and hyper-arid zones of the world (for studies and details see Lepers (2003), LUCC Web Site http://www.geo.ucl.ac.be/LUCC/lucc.html and Annex I). The results of the project are presented in maps. As the project provides a synthesis of existing data, detailed country level degradation data are not made available. Country level data must be requested from each individual country or from those research institutes which carried out the studies.

2.13 Ongoing activities

2.13.1 LADA

The Land Degradation Assessment in Drylands (LADA) (http://lada.virtualcentre.org/pagedisplay/display.asp?section=ladahome) is an international UN initiative executed by FAO and supported by the Global Environment Facility (GEF), UNEP, the Secretariat and the Global Mechanism of the UNCCD and FAO. The project aims at developing and testing an effective methodology to assess causes, status and impact of land degradation in drylands. So far, the study has produced, amongst other things, several pilot studies (http://www.fao.org/ag/agl/agll/lada/pilot.stm). A report by Van Lynden and Kuhlmann (2002) for the LADA project reviews different degradation assessment methodologies. Major outputs of the project will include a standardized methodological framework for the assessment of degradation status, risk and causes, a baseline map of dryland degradation at subregional scale based on the collection and collation of existing maps and databases with incorporation of new data where possible, a global assessment of actual dryland degradation and degradation hazards, and a detailed assessment of land degradation at national level focusing on areas at great risk and areas where degradation has been reversed (FAO 2002). Part of the LADA project is the Global Land Degradation Assessment (GLADA), which aims at assessing land degradation by measuring changes in biomass production through remote sensing. A first test phase is currently under way for an area in China (van Lynden 2004).

2.13.2 WOCAT

The World Overview of Conservation Approaches and Technologies (WOCAT) (http://www.wocat.net) was established with the aim to facilitate local and international exchange of experience. It documents and evaluates soil and water conservation case studies worldwide, and has developed an internationally recognized standardized methodology for documentation and evaluation of individual soil and water conservation technologies and

approaches (van Lynden 2004). Data is collected using questionnaires, one of them being a mapping questionnaire (http://www.wocat.net/QUEST/mape.pdf). The mapping questionnaire follows a method similar to GLASOD and ASSOD.

2.13.3 National Aeronautics and Space Administration's (NASA) Land Cover Land Use Change Program

NASA's Land Cover Land Use Change Program (LCLUC) (http://lcluc.gsfc.nasa.gov/index.asp) is examining several topics including land cover conversion, land use intensification, and land degradation in arid and semi-arid environments. The project aims to define, develop, and evaluate improved remote sensing measurement techniques and data integration methods for characterizing land degradation. In the case of land cover conversion, the primary NASA interest is to identify the current distribution of land cover types, and to track their conversion to other types. The LCLUC program has a particular interest in the impacts of land cover and land use change on biogeochemical cycles and the hydrological cycle (http://lcluc.gsfc.nasa.gov/strategy/priorities/index.asp).

3 LAND USE AND LAND COVER DATA

3.1 Overview of the main databases

One of the main sources for country level data on agricultural land and forests and other wooded land is FAO[4]. Other important data sources are the GLC2000 database, which has been produced by the Joint Research Centre's Global Vegetation Monitoring Unit in collaboration with a network of partners around the world; databases produced by the University of Maryland, University of Boston and NASA; and the Global Land Cover Characterization (GLCC) database, which has been developed by the U.S. Geological Survey (USGS), the University of Nebraska-Lincoln (UNL), and the European Commission's Joint Research Centre (JRC). Furthermore, the Global Lakes and Wetlands Database project (GLWD) by the University of Kassel/World Wildlife Fund and the Pan-European Land Cover Monitoring project (PELCOM) provide some useful data for UNSD.

GIS analyses are needed for most of these databases before data can be used for UNSD purposes. Some databases do provide analyzed country level data. The World Resources Institutes' Earth Trends information portal (http://earthtrends.wri.org) provides GLCC data and some Global Land Cover Facility data in a readily-available analyzed form. In addition, useful data for UNSD purposes are provided by FAO and by the Joint Research Centre (in Mayaux et al. 2003).

[4] Some FAO datasets, as well as some other global land use datasets, are presented in George and Nachtergaele (2002).

3.2 FAO databases

3.2.1 Agricultural land

FAO's FAOSTAT database (http://faostat.fao.org/default.jsp?language=EN) provides data on agricultural land, arable land, land under permanent crops and land under permanent pasture for most of the countries in the world. Data are available for several years and the newest data are for the year 2002. Data is collected from countries using questionnaires. Definitions for different land use categories are available Online at http://www.fao.org/waicent/faostat/agricult/landuse-e.htm. Arable land is defined to include land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Land under permanent crops includes land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest. This category includes, for example, land under fruit trees, nut trees and vines, but excludes land under trees grown for wood or timber. Land under permanent pasture includes land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild.

3.2.2 Forest and other wooded land

FAO's FORIS database provides country level data on the area covered by forest and other wooded land (http://www.fao.org/forestry/site/fra/en). Data is based on the global Forest Resources Assessment (FRA) conducted by FAO (and UNECE). Data on forests are also provided in the FAOSTAT database (until 1994).

FRA 2000, which is the most recent forest resources assessment, was primarily based on information provided and validated by the countries, but it was supplemented by state of the art technology to verify and analyze the information. This included a remote sensing survey of forest resources in tropical countries.

In the FRA, a homogeneous set of definitions are used globally. For definitions used in FRA 2000 consult the FAO publication "FRA 2000: Terms and definitions" (FAO 1998). The FRA 2005 is currently in progress and the definitions have been modified. For detailed FRA 2005 definitions see the FRA Web site (www.fao.org/forestry/site/ 13637/en).

3.2.3 Waters

FAO (FORIS) provides data on inland waters ("Area occupied by major rivers, lakes and reservoirs") for most countries in the world (http://www.fao.org/forestry/foris/

webview/forestry2/index.jsp?siteId=101&sitetreeId=1191&langId=1&geoId=0, Global tables, Global table 5.).

3.3 Global Land Cover Characterization (GLCC) database

The GLCC database (http://edcdaac.usgs.gov/glcc/globdoc2_0.asp) is developed by the U.S. Geological Survey's (USGS) Earth Resources Observation System Data Center, the University of Nebraska-Lincoln (UNL), and the European Commission's Joint Research Centre (JRC). Funding for the project has been provided by the USGS, NASA, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Forest Service, and the United Nations Environment Programme. The database includes information for example on built-up areas, waters, barren or sparsely vegetated areas, grasslands, open shrublands, and different categories of croplands and forests.

The database is based on Advanced Very High Resolution Radiometer (AVHRR) imagery (April 1992 through March 1993), which has 1 km resolution. In addition to satellite images, digital elevation models and maps of soil and land cover have been used. Masks have been used to screen out built-up areas, water bodies and barren areas. The overall accuracy of GLCC data is estimated to be 60-80% (estimate is obtained by comparing the results of the GLCC with higher-resolution satellite imagery) and should be considered as estimates rather than an exact interpretation of the earth's surface.

Analyzed GLCC data is available on the World Resources Institute's (WRI) data portal (http://earthtrends.wri.org/) for most of the countries in the world. WRI uses the International Geosphere Biosphere Programme (IGBP) land cover scheme (for legend see Annex II or http://edcdaac.usgs.gov/glcc/globdoc2_0.asp). Urban and built-up areas are defined simply as areas covered by buildings and other man-made structures. Barren and sparsely vegetated areas are defined as lands of exposed soil, sand, rocks, or snow, which never have more than 10% vegetated cover during any time of the year. Open shrublands are lands with woody vegetation less than two meters tall and with shrub canopy cover between 10-60%. The shrub foliage can be either evergreen or deciduous. Grasslands are lands with herbaceous types of cover. Tree and shrub cover is less than 10%. Water bodies include oceans, seas, lakes, reservoirs and rivers. Other legends used in GLCC are presented in Annex III.

3.4 Global Land Cover 2000 (GLC 2000) database

The Global Land Cover 2000 database (http://www-gvm.jrc.it/glc2000/), produced by the European Commission's Joint Research Centre, provides land use and land cover data. The GLC 2000 database has been produced in collaboration with over 30 research teams around the world, including FAO, UNEP/GRID and CIESIN. The database has been chosen as a core dataset for the Millennium Ecosystems Assessment.

The GLC 2000 approach is based on satellite images (1 km resolution). It also uses a bottom-up approach to global mapping where each defined region has been mapped by local experts. Each partner used the Land Cover Classification System (LCCS) developed by FAO. The GLC 2000 database provides data for several areas including forests, cultivated and managed areas, bare areas, water bodies and urban and built-up areas. The data is mainly from the year 2000. The global dataset available on the Internet is a pre-validation version.

The GLC 2000 database's global legend and a detailed description of it can be found at http://www-gvm.jrc.it/glc2000/legend.htm. The data is in binary and ESRI GRID formats and, thus, some GIS analyses are needed. Some already-analyzed country level data are available for Africa (in the report by Mayaux et al. 2003) and include information e.g. on the area of bare soil and grasslands (http://www-gvm.jrc.it/glc2000/Products/africa/GLC2000_africa3.pdf).

3.5 Moderate Resolution Imaging Spectroradiometer (MODIS) MOD12 Land Cover and Land Cover Dynamics Products (University of Boston, NASA)

University of Boston has developed Land Cover and Land Cover Dynamics products for NASA's Earth Observing System (EOS) Moderate resolution Imaging Spectroradiometer (MODIS) land science team. Products are continuously updated and developed, and details are available on the University of Boston Web site at http://geography.bu.edu/landcover/index.html and the NASA-USGS Web site at http://edcdaac.usgs.gov/modis/dataproducts.asp.

The MOD12Q1 Land Cover Science Data product provides a suite of land cover classifications with the primary classification in the International Geosphere-Biosphere Programme (IGBP) scheme. Other classification schemes are also used (e.g. IGBP scheme refined by the University of Maryland. For details see Hansen et al. 2000). The IGBP land cover scheme is one of the schemes used in the GLCC database and it is presented in Annex II (see also GLCC Web site, http://edcdaac.usgs.gov/glcc/globdoc2_0.asp). The IGBP legend includes classes for croplands, water bodies, barren or sparsely vegetated areas, permanent wetlands, different types of forest and more. For all schemes used in the MOD12Q1 product see http://geography.bu.edu/landcover/userguidelc/lc.html. Each of the classification schemes used is accompanied by assessments of its quality or confidence. MOD12Q1 product data (unofficial data) are available on the University of Boston Web site (http://duckwater.bu.edu/lc/). Official data can be ordered from the NASA-USGS Web site (http://edcdaac.usgs.gov/modis/dataproducts.asp). The newest version of the MOD12Q1 product uses satellite imagery from the year 2001.

The MODIS Land Cover Dynamics Product (MOD12Q2) will provide information on land cover change vectors. The product is not yet operational.

3.6 Global Land Cover Facility (GLCF)

The Global Land Cover Facility (University of Maryland, NASA) provides satellite imagery and products derived from satellite imagery (http://glcf.umiacs.umd.edu/data/). Country level data from the GLCF's Vegetation Continuous Fields project (VCF) is available on WRI's Web site (processed by the University of Maryland). For other datasets further analyses are needed.

The MODIS VCF provides proportional estimates of vegetation cover. Resolution of the satellite imagery used is 500 m. The currently available version of VCF contains only the per cent tree cover layer. Four different classes are available: area of forest with canopy cover >10%, >25%, >50% and >75%. For example, the area of forest with canopy cover >10% indicates the total area within a country that is determined via satellite data to have 10% or greater canopy cover. Other layers (e.g. proportion of herbaceous vegetation or bare ground and different leaf types) will be released in the future. The VCF data are available on the Global Land Cover Facility (GLCF) Web site (http://glcf.umiacs.umd.edu/data/modis/vcf/) and on the World Resources Institute's website (www.wri.org offers analyzed data for year 2000 and for most of the countries in the world).The data will be updated periodically and will be made available on WRI and at the University of Maryland (UMd) Global Land Cover Facility (GLCF) data site. In addition to the VCF project, GLCF also has the AVHRR Continuous Fields Tree Cover project (http://glcf.umiacs.umd.edu/data/treecover/), which provides similar tree cover data. The VCF data is refined and more detailed than the data of its predecessor.

AVHRR Global Land Cover Classification (http://glcf.umiacs.umd.edu/data/landcover/) (Hansen et al. 1998, for details see e.g. Hansen et al. 2000) provides data (based on satellite imagery of 1 km, 8 km and 1 degree spatial resolution) on waters, different types of forests and woodlands, wooded grassland/shrubland, closed and open shrubland, grassland, croplands, bare ground and urban and built-up land for all continents. The database is based on satellite imagery from the years 1981-1994. The length of record has provided the ability to test the stability of classification algorithms.

Global Land Cover Facility has also produced the MODIS Vegetation Cover Conversion (VCC) product (http://glcf.umiacs.umd.edu/data/modis/vcc/) which aims to detect areas of rapid land cover conversion (e.g. tropical deforestation). The product is not intended to be a real estimate for land cover change. Change is expected to be identified, but not necessarily its exact amount. Results are available only to some individual areas and the product is at the moment minimally validated.

3.7 NASA Goddard Institute for Space Studies (GISS) datasets

NASA Goddard Institute for Space Studies (GISS) has created a dataset, "Global Distribution of Cultivation Intensity at 1°×1° Resolution", which distinguishes five levels of cultivation (http://www.giss.nasa.gov/data/landuse/cultint.html). The database is based on

satellite imagery and on the existing maps of vegetation. Classes are defined according to relative extent of cultivated areas to natural vegetated areas.

The GISS dataset, "Global Distribution of Vegetation at 1°×1° Resolution" (http://www.giss.nasa.gov/data/landuse/vegeem.html), distinguishes 32 vegetation types including several types of forest, cultivated land and grasslands. If combined with the "Cultivation Intensity dataset" the database may be used to calculate land cover.

GISS also produced the dataset "Global Distribution of Wetland Ecosystems at 1°×1° Resolution". It distinguishes five classes: forested bog, nonforested bog, forested swamp, nonforested swamp and alluvial formations. In combination with other GISS databases it can be used to calculate wetland areas.

3.8 Global Lakes and Wetlands Database (GLWD) (University of Kassel and World Wildlife Fund)

The Global Lakes and Wetlands Database (GLWD) provides data on large lakes and reservoirs, smaller water bodies and wetlands (see Lehner and Döll 2004[5]). Level one of the database provides data on 3067 largest lakes ($\geq$ 50 km^2) and 654 largest reservoirs (storage capacity $\geq$ 0.5 km^3) worldwide. Level two contains shoreline polygons of approximately 250,000 smaller lakes, reservoirs and rivers (surface area $\geq$ 0.1 km^2). Level three includes all water bodies of level 1 and 2, and different wetland types.

GLWD is based on a variety of existing maps, data and information from different years. The main data sources applied include several lakes and reservoirs databases, hydrography layers, WCMC's global wetlands map and also the GLCC database. For more details see Lehner and Döll (2004). In a validation GLWD proved to represent a comprehensive database of global lakes $\geq$ 1 km^2 and to provide a good representation of the maximum global wetland area (Lehner and Döll 2004). Data (in ArcView format, 1:1 million to 1:3 million resolution) are available on the World Wildlife Fund's Web site (http://www.wwfus.org/science/data/globallakes.cfm). Some country level data are available in Lehner and Döll (2004).

3.9 Corine Land Cover Database (European Environment Agency)

The European Environment Agency (EEA) (http://www.eea.eu.int/) has country specific information e.g., on built-up and related areas, open land, agricultural land, forests, wetlands, and water bodies in the Corine land cover database. The classification is very detailed. Built-up and related areas include for example continuous urban fabric,

[5] Lehner and Döll (2004) also provide an overview of the existing global and regional datasets on lakes, reservoirs and wetlands.

discontinuous urban fabric, industrial units, port areas and airports. Open land includes bare rocks, sparsely vegetated areas, beaches, dunes, etc. Data is available for 24 European countries, most of whom are members of the EU (countries outside the EU include Bulgaria, Croatia and Romania). There are no time series on the Internet. Not all data are freely available to all users, but area statistics (in Excel form) are available for free.

3.10 Pan-European Land Use and Land Cover Monitoring project (PELCOM)

The Pan-European Land Use and Land Cover Monitoring project (PELCOM) (http://www.geo-informatie.nl/projects/pelcom/public/index.htm, Müchner (2000), Müchner et al. (2000)) aimed to develop a consistent methodology to derive land cover information on a European scale from Earth Observation data for environmental monitoring. A major achievement was the establishment of a database that provides land cover data for the whole of Europe. PELCOM provides data on the area of coniferous, deciduous and mixed forests, grassland, rainfed and irrigated arable land, permanent crops, shrubland, barren land, ice and snow, wetlands, inland waters, sea and urban areas. Detailed definitions of different classes are available on the PELCOM Web site. Some further analyses are needed before UNSD should use the data.

The PELCOM database is created with NOAA-AVHRR satellite data (1 km resolution) and ancillary information (e.g. the Digital Chart of the World and the Corine database). AVHRR data used for the current database is from the years 1996-1997. The database is updated frequently. Müchner et al. (2000) carried out an extensive accuracy assessment of the database. The accuracy of the land cover class "arable land" was estimated to exceed 75%, while the accuracy of highly fragmented classes such as "grassland" did not exceed 50%. The total average accuracy was estimated to be 69.2%, which was, according to the authors, good considering the mixed pixel and geo-referencing problems of AVHRR data.

3.11 Africover, Global Land Cover Network (GLCN) and Land Cover Classification System (LCCS)

FAO's Africover project (www.africover.org) was established to develop a digital geo-referenced database on land cover in Africa. It currently covers 10 countries in eastern Africa and provides detailed data for seven countries. The dataset is, to a large extent, based on satellite imagery. The year of the data varies somewhat between countries, but in all countries it is relatively new. The oldest satellite imagery data is from 1994. The scale of the datasets is either 1: 100 000 or 1: 200 000. Data can be ordered through the Africover Web site.

The Africover land cover classes have been formed using the FAO/UNEP international standard Land Cover Classification System (LCCS). LCCS enables the use of very detailed

legends, which can include e.g. several different types of forests, cultivated areas, water bodies, urban and associated areas, etc. LCCS is also used in the GLC 2000 database and it is now adopted by FAO and UNEP as the standard land cover classification system (Africover Web site). The LCCS approach means that instead of pre-defining the classes, it pre-defines the classification criteria that uniquely identify the classes (http://www.africover.org/LCCS.htm). The approach is based on the presumption that any land cover class, regardless of its type and geographic location, can be defined by a set of pre-selected independent diagnostic attributes, the classifiers. The number of classifiers used determines the level at which the land cover is classified and a larger number of classifiers is needed when more detailed classification of land cover is required (http://www.africover.org/LCCS.htm). The LCCS is the only universally applicable classification system in operational use at present. FAO/UNEP has submitted the LCCS for approval to become an ISO standard. Through the Global Land Cover Network (GLCN) project, FAO and UNEP aim to expand the scale of the project from regional (Africa) to global. Detailed information about the LCCS classification system is presented on the Africover Web site (http://www.africover.org/LCCS.htm) and on the GLC 2000 Web site (http://www-gvm.jrc.it/glc2000/legend.htm).

3.12 Other databases

The Center for Environmental Remote Sensing also provides land cover data. For more details see chapter 2.5 or the CEReS Web site (http://www.cr.chiba-u.jp/database.html). The Global Map (http://www.iscgm.org/index.html) database provides some land cover and land use data as well. Country-level data is currently relatively small. Mapping of Agricultural Production Systems (Agro-MAPS) http://www.fao.org/landandwater/agll/agromaps/), a collaborative initiative by FAO, IFPRI (International Food Policy Research Institute) and SAGE (Center for Sustainability and the Global Environment), aims to produce a global dataset on selected agricultural statistics. The major aim is to fill some critical data gaps related e.g. to land degradation and food security. The database currently includes for example data on area harvested. The Miombo Project Web site (e.g. http://www.creaf.uab.es/miramon/mmr/examples/ miombo/docs/index.htm) provides land cover and vegetation data for Africa (e.g. Matthew's GISS Global Vegetation and Land-use data, GLCC data and UNESCO data).

4 USE OF REMOTE SENSING

In most of the soil degradation studies that are currently available expert assessment/opinion has been the main method used. GLASOD, ASSOD and SOVEUR were all based on such a method. Remote sensing, field monitoring, observation of productivity changes and land users' opinion and modeling are other methods that can also be used in land degradation assessments (FAO 2001, Van Lynden and Kuhlmann 2002). Remote sensing has the greatest comparative advantage when the scale is small, because it can provide data for a large area

at one time (Van Lynden and Kuhlmann 2002), and it is, in principle, an ideal methodology for regional or global degradation assessments. The main problem with the method is that the data should not be used as such, but should be accompanied by adequate ground data in order to obtain reliable estimates. This is one of the reasons why remote sensing is most often used for degradation assessments of relatively small areas. Land degradation is also a complex issue and degradation processes differ greatly. A suitable method for assessment in one situation may not be suitable in another situation. Remote sensing has been used in several local degradation studies and also in the regional study conducted by Kharin et al. (1999). Currently, there are also some ongoing research projects (e.g. in ESA and CIESIN) that aim at using remote sensing to observe treaty implementation.

In land cover and land use mapping satellite imagery is a very important data source. The GLC 2000 database is using satellite images as the major data source. The main data set used is the VEGA 2000 data set, which is composed of satellite data. The Global Land Cover Facility databases and the University of Boston/NASA databases are all based on satellite imagery interpretation, as well as the GLCC database. In the composition of the GLCC, other data sources used include digital elevation data and country or regional-level vegetation and land cover maps. The main sources of data for the Africover database are satellite images. The interpretation chain also includes field checking. Furthermore, EEA's Corine land cover database is based on satellite image interpretation, and remote sensing has also been used in some parts of FAO's Forest Resources Assessment.

5 SUMMARY OF FINDINGS

Although land and soil degradation is a severe problem in many countries, there is little reliable data available on a regional or global level. The GLASOD survey, which was completed in the early 1990s, is basically the only global survey available at the moment. GLASOD is one of the core studies in soil degradation research, but using its country level results is difficult. The study was never meant to be country-specific, and, due to its small scale, the data are not accurate, particularly for smaller countries. The ASSOD study is more detailed and, because of that, provides better country level estimates. The SOVEUR study provides some country level data as well. However, ASSOD and SOVEUR have very limited country scopes. The ASSOD study also has some overlaps between the subtypes of degradation, which causes problems for using the data for UNSD purposes. ASSOD, GLASOD and SOVEUR also measure human-induced degradation, not degradation in general, which is the focus in the UNSD questionnaire. The actual impact of this difference on the estimates is unclear. The studies also measure soil degradation, not land degradation, which is a wider concept[6]. In addition to the core studies, GLASOD, ASSOD and SOVEUR, there are other studies (such as the IIASA study by Stolbovoi and Fischer (1997)) which provide country level data on degradation as well. The CEReS study (Kharin et al. 1999)

[6] In the United Nations Convention to Combat Desertification (1994) (UNCCD) "land" is defined to mean "the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system". Soil degradation is, thus, only one aspect of land degradation.

provides some secondary country level data for several Asian countries, but also provides regional satellite images based data. It is expected that the LADA project (see e.g. http://lada.virtualcentre.org/pagedisplay/display.asp?section=ladahome) will improve the situation in the future and deliver standardized data at least for the countries most concerned with land degradation.

Compared to the availability of degradation data, land use/land cover data availability is generally much better. The FAO databases provide country level data on agricultural land and forests for most countries, and the GLC 2000, MOD12 (University of Boston/NASA), GLCF, GLCC, and CEReS databases also provide data on several other land use and land cover categories. The World Resources Institute provides some of these data in an analyzed form. In addition, there are several other databases such as Africover or Corine land cover databases that provide data for smaller regions. For UNSD purposes, the most useful land cover databases are, in addition to FAO databases, the MOD12Q1 and GLC 2000 databases. The GLC 2000 database uses a flexible LCCS classification system that was developed by FAO and UNEP and adopted by the same organizations as the standard land cover classification system. LCCS is now proposed to become an ISO standard. MOD12Q1 is a continuously updated database and provides data that is relatively suitable for UNSD purposes. The data collecting methodologies of these databases differ from each other. The FAO data are, to a large extent, based on country reporting and therefore include local knowledge. All reporting countries also use, at least in principle, the same definitions. Databases such as MOD12 and GLC 2000 are, on the other hand, based on remote sensing. This greatly increases the objectivity and comparability of the data, but decreases the utilization of the knowledge of local conditions.

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ANNEXES

Annex I

Degradation studies used in the LUCC/GOFC *Areas of rapid land cover change* – project (Lepers 2003; personal communication with Eric F. Lambin, Department of Geography, University of Louvain, Belgium).

Database	**Data source**	**Time period**	**Variables**
Africa			
A national review of land degradation in South Africa	Expert consultation	Period of completion: 1997-1998, collection of data over the last ten years	Combined degradation index based on the soil degradation and veld degradation indexes
Land degradation in Botswana	Expert opinion	1980-2000	Desertification mostly due to heavy grazing in the vicinity of rivers and consequent erosion
Land degradation in Zimbabwe	Actual monthly rainfall data and daily AVHRR GAC data	1982-1989	Rain-use efficiency (RUE) or the ratio of net primary production to precipitation. Reductions in RUE are indicative of degradation
Monitoring desertification in Namibia	National level desertification monitoring system based on data collected by different administrations in Namibia	1970-2001	Yearly desertification risk map based on a livestock pressure index (Ministry of Agriculture), a population pressure index (census data), a rainfall index (Namibian Weather Bureau) and a erosion risk index (AEZ project)
Land degradation in Sahel	Actual monthly rainfall data and daily AVHRR GAC data	1982-1990	Rain-use efficiency (RUE) or the ratio of net primary production to precipitation. Reductions in RUE are indicative of degradation

Database	Data source	Time period	Variables
Asia			
Desertification map of the drylands of Asia	Extensive literature review, application of low-resolution space images (NOAA/ AVHRR), thematic maps	Roughly 20-30 years up to 1992	Vegetation cover degradation, wind erosion, water erosion, soil salinisation, rangeland watterlogging
Assessment of the status of human-induced soil degradation in South and South-East Asia (ASSOD)	Development of national soil degradation databases by the national nodal institutions	1997, rate of degradation has been assessed over 5 to 10 years	Water erosion, wind erosion, physical and chemical deterioration. Soil degradation severity = f(extent of degradation, impact of degradation). Impact= f(level of production change, level of management)
Desertification/soil degradation map of Russian Federation	Literature review, expert opinion, field survey, remote sensing	Most data gathered after 1960s	Water erosion, formation of non-fixed and blown-out surfaces, salinization, soil alkalinisation
Digital Geo-referenced Database of soil degradation in Russia	Unpublished maps compiled for the State Committee on Land Resources and Land-Use Planning of Russia	Completed in 1997 but data derived from more than 10-years old inventories	Water erosion, wind erosion, physical and chemical deterioration
Desertification in China		published in 1988 and updated in 1996	Degradation severity mainly based on wind erosion
Australia			
Sheetwash and rill erosion over the Australian continent	Time series of remote sensing imagery (NOAA/NASA pathfinder GAC 8-km), daily rainfall, new digital maps of soil and terrain properties.	1981-1994	Water erosion: sheetwash and rill erosion (via the Revised Universal Soil Loss equation)
Wind erosion trends	Data on dust event type, wind speed, temperature and rainfall from the Bureau of Meteorology (Australia)	1986-1996	Accelerated Erosion Index = wind erosion due to the impact of land use activities

Database	Data source	Time period	Variables
North and Central America			
Change in annual soil erosion by wind and water in the United States	Aggregation at hydrologic unit level of data collected at more than 800,000 sample sites nationwide	1982-1992	Change in annual soil erosion by wind and water on cropland and CPR land based on the Universal soil loss equation and the wind erosion equation
Evaluation of the degradation of soils in Mexico	National level desertification monitoring system	1999	Water erosion, wind erosion, chemical (pollution, decline of fertility, salinisation, acidification, eutrofication) and physical deterioration (compaction, diminution of the water availability)
South America			
Status of desertification in the Patagonian region	Derived from NOAA AVHRR LAC images, Landsat MSS images, existing data and intensive field observation	1986-1992	Degradation of vegetative cover and soil (water erosion, wind erosion, soil crusting and compaction, salinisation, alkalinisation)
Map of desertification in Chili	National level desertification monitoring system	Data published in 1999, snapshot, not a dynamic diagnosis of desertification	Aridity regime (drough period length and xerophytism index), erosion, poverty, local desertification trend
Occurrence of desertification in Brazil	Carried out partly by the Center of Remote Sensing of IBAMA, radar images ?	1995	Methodology based on the capacity to use the soil (soil productivity)
Colombia	Model to identify areas where desertification is taking place	Information available up to the year 2000	Climatic index, biotic component, xerophilous vegetal cover, dry soils and their erosion, salinisation

Annex II

IGBP Land Cover Classification (by Belward 1996) (source: Global Land Cover Characteristics Database, http://edcdaac.usgs.gov/glcc/globdoc2_0.asp, original source: Belward, A.S.(ed.), 1996, The IGBP-DIS global 1 km land cover data set (DISCover)-proposal and implementation plans: IGBP-DIS Working Paper No. 13, Toulouse, France, 61 p.)

Value	Description
1	Evergreen Needleleaf Forest
2	Evergreen Broadleaf Forest
3	Deciduous Needleleaf Forest
4	Deciduous Broadleaf Forest
5	Mixed Forest
6	Closed Shrublands
7	Open Shrublands
8	Woody Savannas
9	Savannas
10	Grasslands
11	Permanent Wetlands
12	Croplands
13	Urban and Built-Up
14	Cropland/Natural Vegetation Mosaic
15	Snow and Ice
16	Barren or Sparsely Vegetated
17	Water Bodies
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Annex III

Global Ecosystems Legend (by Olson 1994a, 1994b). (Source: Global Land Cover Characteristics Database, http://edcdaac.usgs.gov/glcc/globdoc2_0.asp, original sources: Olson, J.S. (1994a), Global ecosystem framework-definitions: USGS EROS Data Center Internal Report, Sioux Falls, SD, 37 p., and Olson, J.S.(1994b), Global ecosystem framework-translation strategy: USGS EROS Data Center Internal Report, Sioux Falls, SD, 39 p.)

Value	Description
1	Urban
2	Low Sparse Grassland
3	Coniferous Forest
4	Deciduous Conifer Forest
5	Deciduous Broadleaf Forest
6	Evergreen Broadleaf Forests
7	Tall Grasses and Shrubs
8	Bare Desert
9	Upland Tundra
10	Irrigated Grassland
11	Semi Desert
12	Glacier Ice
13	Wooded Wet Swamp
14	Inland Water
15	Sea Water
16	Shrub Evergreen
17	Shrub Deciduous
18	Mixed Forest and Field
19	Evergreen Forest and Fields
20	Cool Rain Forest
21	Conifer Boreal Forest
22	Cool Conifer Forest
23	Cool Mixed Forest
24	Mixed Forest
25	Cool Broadleaf Forest
26	Deciduous Broadleaf Forest
27	Conifer Forest
28	Montane Tropical Forests
29	Seasonal Tropical Forest
30	Cool Crops and Towns
31	Crops and Town
32	Dry Tropical Woods
33	Tropical Rainforest
34	Tropical Degraded Forest
35	Corn and Beans Cropland

36 Rice Paddy and Field
37 Hot Irrigated Cropland
38 Cool Irrigated Cropland
39 Cold Irrigated Cropland
40 Cool Grasses and Shrubs
41 Hot and Mild Grasses and Shrubs
42 Cold Grassland
43 Savanna (Woods)
44 Mire, Bog, Fen
45 Marsh Wetland
46 Mediterranean Scrub
47 Dry Woody Scrub
48 Dry Evergreen Woods
49 Volcanic Rock
50 Sand Desert
51 Semi Desert Shrubs
52 Semi Desert Sage
53 Barren Tundra
54 Cool Southern Hemisphere Mixed Forests
55 Cool Fields and Woods
56 Forest and Field
57 Cool Forest and Field
58 Fields and Woody Savanna
59 Succulent and Thorn Scrub
60 Small Leaf Mixed Woods
61 Deciduous and Mixed Boreal Forest
62 Narrow Conifers
63 Wooded Tundra
64 Heath Scrub
65 Coastal Wetland, NW
66 Coastal Wetland, NE
67 Coastal Wetland, SE
68 Coastal Wetland, SW
69 Polar and Alpine Desert
70 Glacier Rock
71 Salt Playas
72 Mangrove
73 Water and Island Fringe
74 Land, Water, and Shore (see Note 1)
75 Land and Water, Rivers (see Note 1)
76 Crop and Water Mixtures
77 Southern Hemisphere Conifers
78 Southern Hemisphere Mixed Forest
79 Wet Sclerophylic Forest

80	Coastline Fringe
81	Beaches and Dunes
82	Sparse Dunes and Ridges
83	Bare Coastal Dunes
84	Residual Dunes and Beaches
85	Compound Coastlines
86	Rocky Cliffs and Slopes
87	Sandy Grassland and Shrubs
88	Bamboo
89	Moist Eucalyptus
90	Rain Green Tropical Forest
91	Woody Savanna
92	Broadleaf Crops
93	Grass Crops
94	Crops, Grass, Shrubs
95	Evergreen Tree Crop
96	Deciduous Tree Crop
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

USGS Land Use/Land Cover System Legend (Anderson et al. 1976) (Modified Level 2). (Source: Global Land Cover Characteristics Database, http://edcdaac.usgs.gov/glcc/globdoc2_0.asp, original source: Anderson, J.R., Hardy, E.E., Roach J.T., and Witmer R.E. (1976), A land use and land cover classification system for use with remote sensor data: U.S. Geological Survey Professional Paper 964, 28 p.)

Value	Code	Description
1	100	Urban and Built-Up Land
2	211	Dryland Cropland and Pasture
3	212	Irrigated Cropland and Pasture
4	213	Mixed Dryland/Irrigated Cropland and Pasture
5	280	Cropland/Grassland Mosaic
6	290	Cropland/Woodland Mosaic
7	311	Grassland
8	321	Shrubland
9	330	Mixed Shrubland/Grassland
10	332	Savanna
11	411	Deciduous Broadleaf Forest
12	412	Deciduous Needleleaf Forest
13	421	Evergreen Broadleaf Forest
14	422	Evergreen Needleleaf Forest
15	430	Mixed Forest
16	500	Water Bodies
17	620	Herbaceous Wetland

18	610	Wooded Wetland
19	770	Barren or Sparsely Vegetated
20	820	Herbaceous Tundra
21	810	Wooded Tundra
22	850	Mixed Tundra
23	830	Bare Ground Tundra
24	900	Snow or Ice
99		Interrupted Areas (Goodes Homolosine Projection)
100		Missing Data

Simple Biosphere Model Legend (Sellers et al., 1986). (Source: Global Land Cover Characteristics Database, http://edcdaac.usgs.gov/glcc/globdoc2_0.asp, original source: Sellers, P.J., Mintz, Y., Sud, Y.C., and Dalcher A. (1986), A simple biosphere model (SiB) for use within general circulation models: Journal of Atmospheric Science , v. 43, p. 505-531.)

Value	**Description**
1	Evergreen Broadleaf Trees
2	Broadleaf Deciduous Trees
3	Deciduous and Evergreen Trees
4	Evergreen Needleleaf Trees
5	Deciduous Needleleaf Trees
6	Ground Cover with Trees and Shrubs
7	Groundcover Only
8	Broadleaf Shrubs with Perennial Ground Cover
9	Broadleaf Shrubs with Bare Soil
10	Groundcover with Dwarf Trees and Shrubs
11	Bare Soil
12	Agriculture or C3 Grassland
17	Persistent Wetland
18	Dry Coastal Complexes
19	Water
20	Ice Cap and Glacier
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Simple Biosphere 2 Model Legend (Sellers et al. 1996). (Source: Global Land Cover Characteristics Database, http://edcdaac.usgs.gov/glcc/globdoc2_0.asp, original source: Sellers, P.J., Randall, D.A., Collatz, G.J., Berry, J.A., Field, C.B., Dazlich, D.A., Zhang, C., Collelo, G.D., and Bounoua, L. (1996), A revised land surface parameterization (SiB2) for atmospheric GCMs - Part I-model formulation: Journal of Climate , v. 9, p. 676-705.)

Value	Description
1	Broadleaf Evergreen Trees
2	Broadleaf Deciduous Trees
3	Broadleaf and Needleleaf Trees
4	Needleleaf Evergreen Trees
5	Needleleaf Deciduous Trees
6	Short Vegetation/C4 Grassland
7	Shrubs with Bare Soil
8	Dwarf Trees and Shrubs
9	Agriculture or C3 Grassland
10	Water, Wetlands
11	Ice/Snow
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Biosphere Atmosphere Transfer Scheme Legend (Dickinson et al. 1986). (Source: Global Land Cover Characteristics Database, http://edcdaac.usgs.gov/glcc/globdoc2_0.asp, original source: Dickinson, R.E., Henderson-Sellers, A., Kennedy, P.J., and Wilson, M.F. (1986), Biosphere-atmosphere transfer scheme (BATS) for the NCAR community climate model: NCAR Technical Note NCAR/TN275+STR, Boulder, CO. 69 p.)

Value	Description
1	Crops, Mixed Farming
2	Short Grass
3	Evergreen Needleleaf Trees
4	Deciduous Needleleaf Tree
5	Deciduous Broadleaf Trees
6	Evergreen Broadleaf Trees
7	Tall Grass
8	Desert
9	Tundra
10	Irrigated Crops
11	Semidesert
12	Ice Caps and Glaciers
13	Bogs and Marshes
14	Inland Water
15	Ocean
16	Evergreen Shrubs

17	Deciduous Shrubs
18	Mixed Forest
19	Forest/Field Mosaic
20	Water and Land Mixtures
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Vegetation Lifeforms Legend (Running et al. 1995). (Source: Global Land Cover Characteristics Database, http://edcdaac.usgs.gov/glcc/globdoc2_0.asp, original source: Running, S.W., Loveland, T.R., Pierce, L.L., R.R. Nemani, and Hunt, E.R. (1995), A remote sensing based vegetation classification logic for global land cover analysis: Remote Sensing of Environment , v. 51, p. 3,948-3,952.)

Value	**Description**
1	Evergreen Needleleaf Vegetation
2	Evergreen Broadleaf Vegetation
3	Deciduous Needleleaf Vegetation
4	Dedicuous Broadleaf Vegetation
5	Annual Broadleaf Vegetation
6	Annual Grass Vegetation
7	Non-Vegetated Land
8	Water Bodies
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data