EARTHWATCH

GLOBAL ENVIRONMENT MONITORING SYSTEM

GEMS
REPORT SERIES
NO. 25

NAIROBI
MARCH 1994

Report of the UNEP/FAO Expert Meeting on Harmonizing Land Cover and Land Use Classifications

Geneva, 23-25 November 1993

UNEP
United Nations
Environment Programme

Food and
Agriculture Organization
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REPORT OF UNEP/FAO EXPERT MEETING ON HARMONIZING LAND COVER AND LAND USE CLASSIFICATIONS

23-25 November 1993, Geneva

1 SUMMARY

There is major interest in and need for better information on land cover and land use and on the interrelations between them (see 4.2.1 : Land use and land cover), at global, (sub-) regional, national and local levels, both within and across disciplines. Many actors are already involved in harmonizing land cover and land use data collection and classifications (see 2 : Rationale). UNEP and FAO organized this expert meeting to catalyze further coordinated action towards such harmonization efforts.

Introductory presentations were given on general, globally applicable principles related to classifications, including a draft land use classification prepared for the meeting through a UNEP/FAO consultancy contract, followed by national presentations on activities, interests and needs related to classifications at national level. Four groups of cross-cutting issues emerged from these discussions which were dealt with in more detail, after which suggestions for follow-up action were formulated.

The four cross-cutting issues were: (i) users and applications; (ii) land use and land cover, including change; (iii) data sources, collection and spatial frameworks; and (iv) basis for definitions and classifications.

Without following the exact sequence of discussions during the meeting, the points listed below reflect the main aspects which emerged:

1. Most participants saw clearly the need to harmonize land use and land cover classification mechanisms; both within and between countries; both within and between applications; and from national to regional to global scales. Reference systems for land cover and land use could be developed separately but in parallel to ensure comparison. An attribute definition approach should be considered as a possible alternative for a bridge system. Through a large set of well defined attributes, the users could "design" individual classifications themselves for their own purposes.

2. Participants also recognized the need to continue using existing systems which have resulted from research and development investments in them, from their specific adaptations to specific user requirements, and from their wide user base. Accordingly, it would be extremely difficult to develop a single classification system for all users at any level. This issue was highlighted clearly in many of the national presentations.

   Participants endorsed a common approach to this problem; firstly to develop a glossary for land cover and land use attribute definitions; and secondly to build international bridge (translating) protocols between existing land cover and land use classifications, recognizing that such protocols will work better on some classifications than on others.

Participants expect two benefits from this approach. First, by experiencing the benefits of synergism between different classifications, an international bridge (or translator) will eventually become accepted as the de facto standard classification. Second, designers of new classification systems will ensure compatibility with the bridge (or translator) and use agreed definitions. Specifically, bridges will:

i) provide international comparability and correlation between existing classifications;

ii) encourage users and creators of new classification systems to build in comparability; and

iii) be used more and more as standard protocols in their own right.

3. The draft UNEP/FAO Land Use Classification System presented to the meeting (ref. Annex V) was recognized as a possible land use classification targeted at agricultural applications, especially in FAO, but was not considered as a suitable prototype for an international bridge (translator) to link classifications for other sectors, or other existing land use classifications. In fact, it was not intended for the latter.

4. Three major follow-up actions were suggested:

(i) Joint UNEP/FAO/UNESCO/ICSU/WCMC/... Facilitating Committee on Land Cover and Land Use Classification Harmonization, to ensure that approaches and methodologies develop in parallel and that all actors are aware on ongoing activities. Two Working Groups were recommended: one on land use and one on land cover (link with the WCMC, UNEP/GEMS+HEM, IGBP vegetation group and FAO Forest/cover assessment activities).

(ii) Further develop prototype international bridge reference systems (translators) and a glossary for land cover and land use attribute definitions, tapping inter alia ITE's, ITC's and WCMC/UNEP-HEM's experience. Whether land use and land cover should be dealt with in an integral manner was for now kept open.

(iii) Case study with Eurostat and CORINE to field test several land use classifications and data collection approaches. Existing systems would be tested, representing both bridge and target systems, both hierarchical and attribute approaches, and statistical survey approaches.

2 RATIONALE

There is major interest in and need for better information on land cover and land use and on the interrelations between them (see eg. 4.2.1 : land use and land cover). At many levels, the characteristics and changes in land cover and land use have important implications for climate, bio-geo-chemistry, hydrology, ecological complexity, diversity and abundance of species, land degradation, and agriculture. Most land cover change is driven by human use, while land use practices themselves also have direct effects on environmental processes.

At global and regional level, land cover and land use data are needed for global change research and modelling, for macro economic studies, for assessments of the state of the Earth's environment, for decisions on international resource allocation and the like.

At regional and national level, better information is needed to model policy scenarios, and to forecast impacts on the environment of policies and decisions.

For land evaluation and land use and agricultural planning at national and local level, soil/terrain and climate information structures are quite sufficient. However, there is no agreed system to describe production systems. A first step is to describe land cover and land use in a systematic way, which will also feed into the regional and global level reporting and research activities.

National statistics, also aggregated for regional and global applications on agriculture, fisheries, forestry etc., are often not consistent, and multiple land use is usually ignored. Harmonized definitions and classifications will increase the value of land cover and land use statistics.

Existing land cover and land use data tend to be sectoral in nature and are therefore not suitable to deal with all these issues. Primary data sources, sampling structures, classifications, nomenclature, and data formats differ; many data are based on estimates and interpolations; and data sets are often static (no indication of changes or variation). As a result, area estimates of land cover and land use often vary seriously.

Most scientists recommend using remote sensing data, validated by ground truthing. This means that much land use data will be inferred from land cover information and is an important reason why reference systems for land cover and land use must be developed in parallel.

There are many initiatives underway to harmonize land cover and land use data collection and classifications. Institutions involved are (for acronyms see Annex I): NASA (Pathfinder, EOS-MODIS,...), NOAA, USGS EROS Data Center, Global Land Cover Characterization Database (GLCCD), US EPA, USDA-FS, FAO (Inter-departmental Working Group on Land Use and Land Use Planning, Forest Assessment activities and KOTKAII dealing with forest definitions and classifications, GTOS), UNESCO (MAB and biosphere reserves related work, GTOS), UNEP (eg. involvement in FAO Forest Assessment work, draft Global Vegetation Classification proposal of WCMC-IGBP-UNEP/HEM,GTOS), IGBP (DIS Land Cover Working Group, Land Use and Global Change proposal, GCTE) IUFRO, ISRIC, IIASA, JRC- ESA (TREES), EU (Eurostat and CORINE), Austrian Institute of East and Southeast European Studies, CSIRO (Australia), ITE (U.K.), ITC (Netherlands), RIVM (Netherlands), ECU (Oxford University, U.K.), CRU (University of East Anglia, U.K.), and many more international, (sub-) regional and national institutions and programmes.

The enormous task of providing reliable and concise information on land cover and land use can be split up into three major groups of activities: (i) define harmonized umbrella reference systems; (ii) select and test efficient methods for data collection; (iii) identify the way to proceed in data collection; and (iv) operational land cover and land use data collection programmes.

An important first step is to come to internationally agreed reference mechanisms, so that all potential users can find their niche and link their activities to these systems. Once such systems are in place, actual compilations can be made for current land cover and land use. UNEP and FAO organized this expert meeting to catalyze further coordinated action towards harmonization of data collection and management and reference mechanisms.

3 STRUCTURE OF THE MEETING

Brief introductions were given by FAO and UNEP representatives (see also rationale above) followed by an initial round of general observations by the participants. The meeting then actually started with:

(i) the presentation of the draft land use classification, prepared under a UNEP/FAO consultancy contract, followed by:

(ii) background presentations on general principles related to data collection and classification; and

(iii) national presentations on activities, interests and needs related to data collection and classifications at national level (in chronological order: Japan, Philippines, U.K., Canada, Austria (Eastern Europe), Brazil, USA, India, EC).

From discussions on these presentations four groups of cross-cutting issues emerged, which were discussed in more detail during separate sessions:

(i) users and applications;

(ii) land use and land cover, including change;

(iii) data sources, collection and spatial frameworks; and

(iv) basis for definitions and classifications.

During a final session suggestions for follow-up activities were given.
For further details see the agenda of the meeting in Annex II. Background documents mailed to participants before the meeting and papers presented and/or distributed during the meeting are listed in Annex III; participants and their biodata are given in Annex IV.
In order to avoid repetition, the introductory presentations and subsequent discussions are included in reports on the four groups of cross-cutting issues that emerged from these introductory presentations and discussions.

4 BRIEF REPORT ON THE DISCUSSIONS (not verbatim, focus on issues that kept coming up)

4.1 Users and Applications

The discussion was intended to address first the need for, purposes, and form of harmonization mechanisms, and secondly to identify the needs of specific user groups. The meeting centered on the first issue, covering the user domain rather superficially.

There is a wide variety of users and specific applications, each with different information requirements and interests: in different applications information is needed on different attributes (each inventory to suit its own purpose); different applications require different degrees of detail; in different applications the same information may be interpreted differently (one may consider several land uses with the same "functional responses" and therefore decide that no differentiation between these land uses is needed, eg. for global modelling natural grass/grazing land may have the same function as managed grass/grazing land); in different applications emphasis may be on different aspects (one may primarily be interested in irrigated versus non-irrigated land use, regardless of the fact whether the land is used for recreation purposes, for agricultural production, for wood production etc.). User requirements therefore direct classifications, but on the other hand user requirements will change over time.

All this demonstrates the need for a flexible means of communication (translation) between existing and planned reference systems for describing and quantifying land use and land cover. This need is apparent at national, (sub-) regional and global levels, both within and across disciplines.

The concept of a bridging (translating) reference system was accepted as the basic tool to achieve this aim, which would provide a means of inter-comparison and form the basis for a common methodology (eg. while strengthening statistical bases). Such a bridging system should comprise a minimum set of attributes (measures, descriptions, categories, and translation tables to existing classification systems) describing the composition, condition or context of land cover and land use which, taken together, embrace the complete range of concepts of interest. The various users can choose those attributes they are interested in and add more specific ones if needed.

As a first step, unambiguous definitions need to be formulated for each attribute, both in the bridge system and in applied (target) systems. By cross-referencing attributes in any "target" system to the "bridge" system, it becomes possible to effect a translation between any two target systems (irrespective of whether hierarchical or non-hierarchical).

Even though existing data collection activities and existing reference systems (eg. at national levels) will not be changed, bridges as suggested above can be used to make such national data consistent with international schemes. In case new data collection efforts are set up or where no clear national systems exist yet, such internationally accepted (and therefore considered authoritative) bridging systems could provide a common framework to guide the development of data collection schemes and of national systems. While serving specific disciplinary or sectoral interests, these data schemes and systems would nevertheless retain a degree a inter-compatibility through their common structural origin, making them consistent with internationally agreed systems from the start.

To support such reference systems there is a need for flexible databases, using the agreed definitions to describe land use and land cover in an objective way.

Harmonization efforts should probably focus more on data/information collection and management then on classification structures. It is in fact a documentation issue (definitions, minimum set of common attributes servicing all interests, minimum data/information sets for specific applications, etc.). In the end the users can decide which attributes to use for their applications and classifications.

4.2 Land Use and Land Cover, Including Change

4.2.1 Land use and land cover

There was general agreement that reference systems for land use and land cover should be developed separately, while keeping close contact to ensure that approaches and methodologies develop in parallel because the two are often closely linked. Land cover can coincide with land use, but one cover may have several uses and vice versa. All this has serious implications for both land use and land cover classifications.

In many current applications land cover and land use are not clearly distinguished, with descriptions and definitions being written partly in terms of land cover, partly in terms of land use. This is less so in agricultural applications, but certainly in forest(ry) applications and in livestock/grazing studies. Also, often natural and managed ecosystems are mixed up. Many forest or grazing uses, for instance, take place in "natural" ecosystems which are then described in terms of cover while implying a use. There is very frequently a relationship between land use and land cover, and one may often, but not always, be inferred from the other. They are different concepts though. One describes the physical attributes of the land, and the other a pattern of human activities undertaken within a social and economic context. For mapping purposes mixing of land use and land cover terminology is no real problem, but for reference systems more work is needed on this (which cover could eg. be linked to which use(s)). Use and cover need to be well defined and properly distinguished, so that, among other things, defined uses can be "rated" in terms of suitability for defined land units, uses can be analyzed in terms of economics or environmental impact, or to determine whether the current status of the land is due to present or previous use.

Thirdly, there is a more "political" aspect to consider. For instance in the USA and Canada, land use is an "emotive" term with connotations of federal and state control: all official classifications therefore use land cover terminology only. Also farmers (eg. in the Philippines) are reluctant to provide information on land use because of possible tax implications or because eg. their land use is not in line with land use allocation policies (same in many other countries). The term land cover is more neutral.

Flexible systems, focussing on well defined attributes, may solve (part of) the problems. Different users can then interpret the well described information for their own purposes and classifications.

4.2.2 Change detection

Change in cover can be detected more easily then change in use. The question is: what is needed in addition to monitoring changes in cover in order to know how/if use changed. Remote sensing is a good tool for monitoring change in cover, but additional ground checks are necessary to know how/why the change occurred.

In addition, certain changes in use will (eventually) result in a cover change which may have beneficial or detrimental effects. Rather then waiting for changes in cover to be detected, changes in use may be channeled into different directions at an earlier stage, to avoid detrimental effects of cover change.

Changes in cover can result from sudden (eg. fires) events or cyclic processes (crop rotations, shifting cultivation rotations, forest production rotations), or they can be transformations and successional changes. The question remains: when is something a real change (a change in output) and when is it part of a cycle.

While the detection of change seems to be more an issue of methodology then of classification per se, land use classification systems must be able to accommodate change detection without massive amounts of additional work in monitoring and field data collection. Rigid hierarchical classification systems make change detection difficult: in contrast, change is easier to detect while applying flexible systems based on easily observed and measured attributes.

4.3 Data Sources, Collection and Spatial Frameworks

Data collection ideally involves both the use of remote sensing, statistical surveys, and mapping (all data collection tools with their own characteristics). The level of data accuracy is to be considered (for instance questionnaire results may be biased). While using remote sensing (certainly for global and large regional inventories) political aspects should be kept in mind (monitoring from space is often interpreted as "spying with the intention of controlling").

Sample sizes are to be such that they are representative, both considering the scale being worked at (basic mapping unit) and the subject (larger sample units are sufficient for forest surveys than eg. for grassland). Concerning remote sensing : for different scales different media can be selected. The choice of spatial resolution is not complicated. However, it is difficult to decide what information can be obtained through remote sensing and what additional information would need to be collected to get the full picture. Concerning classifications: they are in principle scale independent, scale mainly being an operational issue. A particular hierarchical level in a classification, however, is bound to certain ranges of scale. Eg. detailed attributes can usually not be mapped in course scaled maps. Whichever data source, sampling system or data storage structure is used, there are classification issues to be considered. While categorizing data one needs to know how the data will be collected and well defined terminology should be used.

In general, data collection for the sake of data collection should be avoided and collection of (a minimum of) data for a specific use/analysis should be promoted. Data users should become more explicit on, and could be assisted in deciding, what they actually need (as a minimum) and which sampling frames would be most suitable to achieve their requirements. When terminology is well defined one can also re-use administrative data and eg. develop a multiple use system where one data system can be used for different purposes. In other words: sampling frames, databases and reference systems, though separate aspects, are closely linked. Also the importance of documentation, metadata, archiving, and data management was acknowledged, since the long term viability of any land cover and land use data is dependent on these activities.

Ideally, all land cover and land use data should be georeferenced, using a commonly agreed reference framework, such as geographical coordinates (latitude/longitude) or a global grid system such as UTM. This will simplify the integration of different datasets and will facilitate the use of GIS for analysis and modelling (eg. to detect changes, assess trends and to analyse environmental and socio-economic impacts).

The ITC/FAO/AUW Land Use Database, briefly presented during the meeting, was considered as a very good effort to structure data collection and organize data storage into an easily accessible database which could serve many users. Other comments made could be summarized as follows : the database seems quite specifically designed for agricultural applications and would require drastic changes in current national data collection efforts (it often does not coincide with existing national statistical surveys, certainly once going into detail). Extensive inputs and training will be necessary to operate the database, before agricultural extension workers will have the capacity and capability to work with it. Probably most important: considerable training efforts will be necessary before such databases could actually be put into context and be used for analysis, policy formulation etc. (both by extension workers and eg. by policy and decision makers).

4.4 Basis for Definitions and Classifications

Most aspects discussed during this session also emerged in earlier sections (and are reported there so avoiding repetition). One aspect remains: multiple versus single use.

It was agreed that land use classifications should avoid the inclusion of categories comprising multiple land uses. This had been a strongly stated principle in the outline land use classification presented to the meeting (ref. Annex V). Several relevant issues were flagged in this context:

Many uses are not restricted to one major category or eg. only to natural ecosystems or managed ecosystems. For instance, tourism/recreation occurs both in urban areas, in natural and in managed ecosystems; forest production occurs both in "natural" and in managed ecosystems; biodiversity conservation relates to both natural and managed ecosystems; national parks may be used for conservation purposes only, but also for tourism, agriculture, (cultural) landscape protection etc. It depends on the specific interest of users which subdivision would be preferred.

Secondly, valuable information could be lost if multiple use would not be catered for. For instance, in many countries very different uses are combined in the same plots. The different uses would be part of several high level categories in the presented classification, so these multiple uses would have to be split up. Such multiple uses often provide very interesting information and may eg. provide clues on environmental impacts and sustainable development aspects. After all, it is the combination which makes it a 'strong' use (eg. sustainable, degradation preventive, etc.).

No real solution could be agreed on for multiple versus single use. While entering a reference system one should preferably have several options. This means terminology for attributes must be well defined at all levels (down to the very detailed level). The specific users could then group the various attributes (in a hierarchical system if so preferred) for their specific requirements.

4.5 Future Programming and Cooperation - Suggested Follow-up

The meeting formulated the following recommendations for follow-up action:

4.5.1 Joint UNEP/FAO/UNESCO/ICSU/WCMC/... Facilitating Committee on Land Cover and Land Use Classification Harmonization.

It was recommended that reference systems for land cover and land use should be developed separately, while at the same time keeping close contact to make sure that approaches and methodologies develop in parallel because eg. much land use information will be inferred from land cover data (see section 4.2). The best way to proceed would therefore be to set up a small joint facilitating committee which can ensure that:

(i) the two systems being developed keep in touch, and

(ii) that all actors working on these issues are informed and aware of work being carried out in this field, so that existing programmes can link up and contribute.

Under this umbrella facilitating committee two working groups could be set up:

(i) a Land Use Working Group, in which FAO and UNEP will cooperate with as many relevant other institutions as possible (see also 4.5.2 below), and

(ii) a Land Cover Working Group, in which the recently started work of WCMC, UNEP/GEMS+HEM and IGBP on a global vegetation classification would be incorporated, again cooperating with as many relevant institutions as possible (eg. IUFRO, FAO etc.).

UNEP will arrange contacts with the global vegetation group to work out modalities, also requesting this group to consider broadening the scope of their work from vegetation only to cover in general (eg. including settlement issues through cooperation with HABITAT). UNEP and FAO will also contact others (UNESCO, ICSU etc.) to discuss participation in the umbrella committee and to facilitate feedback from the various regions.

4.5.2 Further develop a prototype international bridge reference system

Through a project with ITE in the U.K. a follow-up desk study could be carried out, considering the following activities:

(i) Further identify user groups and liaise with them what their specific minimum requirements are.

(ii) Collect and analyze major existing classifications and databases on land use (the most relevant ones are already collected, but more material from the Northern American continent needs to be included, as well as examples of developing country classifications); selecting both classifications which aim to be a common system for all users and target classifications for certain applications (e.g. the draft land use classification presented by UNEP and FAO during the meeting and the ITC/FAO/AUW Land Use Database also briefly presented during the meeting, both focussing on agriculture).

(iii) Based on these two activities develop a proposal for an international bridge reference system for describing and quantifying land use at (sub-) national, regional and global levels, both within and across disciplines. Through such a system it would become possible to effect a translation between any target system to another by cross referencing categories to the bridge reference system.

(iv) At the same time it would be necessary to attempt to compile existing and formulate new definitions for each category (or attribute), both in "target" and in the "bridge" system.

UNEP and FAO will liaise with ITE to formulate a project and work out modalities.

4.5.3 Case study with Eurostat and CORINE to field test several land use classifications and data collection approaches.

A project could be formulated to compare several existing classifications, databases and statistical survey methods in the field. Such an exercise would provide a useful illustration of the pro's and con's of the various classifications and databases and of the applicability of such approaches for statisticians who actually coordinate data collection.

One or several countries could be selected where a good area frame is existing. The draft land use classification presented by UNEP and FAO (that is, a revised version based on the discussions in the meeting), the EC CORINE Land Cover classification, the ITC/FAO/AUW Land Use Database, the draft bridge system to be developed by ITE and the FAO and Eurostat statistical survey classifications and approaches could be tested and compared. This selection of systems would represent a bridge and a target system, an hierarchical and an attribute approach, closely linked to statistical survey approaches.

UNEP and FAO will contact Eurostat to formulate a project. In addition other operational data collection programmes will be contacted and linked up with.

ANNEX I LIST OF ACRONYMS USED

AUW	Agricultural University Wageningen, Netherlands
AVHRR	Advanced Very High Resolution Radiometer
CORINE	Coordination of Information on the Environment, EC
CRU	The Climate Research Unit, University of East Anglia, U.K.
CSERGE	Centre for Social and Economic Research on the Global Environment
CSIRO	Commonwealth Scientific & Industrial Research Organization
DENR	Department of Environment and Natural Resources, Philippines
DIS	Data and Information System, IGBP
EC	European Community
ECU	Environmental Change Unit, Oxford University
EOS-MODIS	Earth Observing System - Moderate Resolution Imaging Spectrometer
EROS	Earth Resources Observing Satellite
FAO	Food and Agriculture Organization of the UN
GCTE	Global Change and Terrestrial Ecosystems
GIS	Geographic Information System
GRID	Global Resource Information Database
GTOS	Global Terrestrial Observing System
HDP	Human Dimensions of Global Environmental Change Programme
IGBP	International Geosphere-Biosphere Programme
IIASA	International Institute for Applied Systems Analysis
INPE	Instituto Nacional de Pesquisas Espacials, Brazil
ISRIC	International Soil Reference and Information Centre
ITC	International Institute for Aerospace Survey and Earth Sciences
ITE	Institute of Terrestrial Ecology, U.K.
IUFRO	International Union of Forestry Research Organizations
JRC-ESA TREES	Joint Research Centre and European Space Agency Tropical Ecosystem Environment Observations by Satellite Project
LANDSAT-TM	Land Remote Sensing Satellite - Thematic Mapper
MAB	Man and Biosphere Programme of UNESCO
MEF	Ministry of Environment and Forests, India
NALC	North American Landscape Characterization
NAMRIA	National Mapping and Resource Information Authority, Philippines
NASA	National Aeronautics and Space Administration, USA
NIES	National Institute for Environmental Studies, Japan
NOAA	National Oceanic and Atmospheric Administration, USA
RIVM	National Institute of Public Health and Environmental Protection, NL
SPOT	Système pour l'Observation de la Terre
U.K.	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
US EPA	United States Environmental Protection Agency
USDA-FS	United States Department of Agriculture - Forest Service
USGS	United States Geological Survey

ANNEX II AGENDA FOR THE UNEP/FAO EXPERT MEETING ON HARMONIZING LAND COVER & LAND USE CLASSIFICATIONS, 23-25 November 1993, Geneva

Tuesday 23 November

10.20-11.00 Opening of the meeting

Objectives of the meeting
Initial round of discussion

11.30-13.00 Introductory Presentations - 1

Anthony Young (FAO/UNEP Consultant): Land use and land cover: principles, glossary and an outline classification

14.15-17.30 Introductory Presentations - 2

Tom Loveland (EROS Data Center - IGBP/Land Cover Group): Development of a global land cover data base

Rik Leemans (RIVM): The IMAGE II model, focussing on links between land cover and land use and classification implications

Kees de Bie (ITC): The Land Use Database; an ecosystem approach

Gyde Lund (USDA Forest Service): Thoughts on land cover and land use classification harmonization (presented on Wednesday)

Wednesday 24 November

09.00-13.00 National presentations

Yoshifumi Yasuoka, NIES, Japan
Ricardo Bina, NAMRIA/DENR, Phillipines
Barry Wyatt, ITE, U.K.
Ian Marshall, Environment Canada
Peter Jordan, Austria (Eastern European Studies)
Dalton Valeriano, INPE, Brazil
Denice Shaw, US-EPA, USA
Dipak Sharma, MEF, India
Jean Louis Weber, CORINE, EC

14.15-17.30 Cross-cutting issues - 1

1 Users and applications

Agriculture, forest resources, vegetation mapping, global models, biodiversity, carbon sinks, economic forecasts, statistical outputs, modelling; implications for classifications

2 Land cover and land use, incl. change

Relation between cover and use; types of change; change within and between sampling units; changes within and between classes; resampling strategies for efficient change detection

Thursday 25 November

9.00-13.00 Cross-cutting issues - 2

3 Data sources and collection, spatial frameworks

Sampling frames; harmonization with other national sampling frames; georeferencing; link with remote sensing; integration/standardization

4 Basis for definitions and classification; rational for having a classification

Multiple use versus mixed use; time; scale; land use and land units to coincide or not; environmental factors as classifiers; definitions

14.00-15.00 Future programming and cooperation - suggested follow-up

ANNEX III LIST OF BACKGROUND DOCUMENTS MAILED TO PARTICIPANTS BEFORE THE MEETING AND OF PAPERS PRESENTED AND/OR DISTRIBUTED DURING THE MEETING

Land Use and Land Cover: Principles, Glossary and an Outline Classification, Interim Report -2nd draft. A. Young, FAO/UNEP Consultant (Oct. 1993).

Land Use and Land Cover Classification: a discussion paper. A. Young, FAO/UNEP Consultant (Oct. 1993).

A Strategy for Development of a Global Land Cover Characteristics Data Base. Thomas Loveland, USGS-EROS Data Centre (Oct. 1993).

Thoughts on land cover and land use classification harmonization. Gyde Lund, USDA-FS (Nov. 1993).

The Land Use Database; An Ecosystem Approach. C. de Bie and J. van Leeuwen, ITC/FAO/AUW (Version 1.0, Sept. 1993).

Land cover assessment and monitoring for Cambodia, Lao P.D.R. (and Nepal), UNEP/GRID-Bangkok (Oct. 1993).

Land Use and Land Cover Classification for Environmental Monitoring by Using Remote Sensing - Case studies in Japan. Yoshifumi Yasuoka, NIES, Japan and UNEP/GRID-Focal Point (Oct. 1993).

Examples of Land Cover and Land Use Classification Schemes in the Philippines. Ricardo Bina, NAMRIA, Philippines (Oct. 1993).

IUFRO International Guidelines for Forest Monitoring - Draft. Risto Päivinen, Gyde Lund and Simo Poso (Eds.) (Oct. 1993).

ANNEX IV ADDRESSES OF PARTICIPANTS IN THE UNEP/FAO EXPERT MEETING ON HARMONIZING LAND COVER AND LAND USE CLASSIFICATIONS, 23-25 November 1993, Geneva

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23-25 November 1993, Geneva

Mr. Kees de BIE - Netherlands

Mr. de Bie obtained his MSc from the Agricultural University, Wageningen, the Netherlands in 1982, with emphasis on tropical crop husbandry, and soil fertility and plant nutrition. From 1983-89 he worked on an FAO Fertilizer Programme in Pakistan as an associate expert on fertilizer/plant nutrition and as data processing specialist respectively. From 1990-91 he worked as an FAO fertilizer use and soil fertility agronomist in Ethiopia, and since July 1991 to date he is lecturer in the Department of Land Resource and Urban Sciences of the International Institute for Aerospace Survey and Earth Sciences (ITC) in Enschede, the Netherlands.

Mr. Ricardo T. BINA - Phillipines

Deputy Administrator for Remote Sensing, Mapping and Information Management at the National Mapping and Resource Information Authority (NAMRIA), Manila, Philippines. He has his basic training in botany and ecology, followed by graduate studies in natural resources management, marine ecology, geography and special training on remote sensing and geographic information systems. His professional experience (1976 to present) comprises: research and management of projects on applications of satellite remote sensing data to land cover mapping, forest resources mapping and inventory, coastal resources mapping; involvement in environmental impact assessment and natural resources development projects; development of GIS applications for area development projects.

Mr. Thomas Sly van BUREN - USA

Mr. van Buren is responsible for GIS database administration at the Advanced Computer Applications Project, International Institute for Applied Systems Analysis Laxenburg, Austria. He graduated from the Massachusetts Institute of Technology, Department of Urban Studies and Planning, in 1991 with a Master in City Planning degree. He wrote his thesis on the integration of rural town geographical information systems. He graduated from The American University, School for International Service 1986. Mr. van Buren served with the United States Peace Corps 1986-1988 in the Republic of Niger, West Africa.

Mr. Declan CONWAY - UK

Mr. Conway obtained an MSC in Natural Resource Management in 1989 and has recently completed a Ph.D at the Climatic Research Unit, University of East Anglia. His work has involved developing large-scale hydrologic models of the river basins that comprise the Nile Basin. He is currently engaged in implementing a model of the Blue Nile Basin in the IMAGE 2.0 integrated model being developed at RIVM in the Netherlands.

Mr. Christophe DUHAMEL - France

Mr. Duhamel obtained a BSc degree in geography in 1982; an MSc degree in Quantitative Geography in 1983 (both at the Université des Sciences de Lille); and a postgraduate degree in thematic and statistical cartography in 1985 (Université de Paris). In 1985-86 he was Geographer at the Ministry of Development Cooperation in Paris (Cabinet of the Minister). From 1988 to December 1990 he was a geographer at the Ministry of Agriculture in Maputo, Mozambique where he participated in setting up a new Department of Statistics. Since July 1991 Mr. Duhamel works as a geographer at EUROSTAT, the Statistical Office of the European Communities where he participates in the development of the Remote Sensing Programme and coordinates a working group on land use statistics.

Mr. Vincent VAN ENGELEN - Netherlands

Mr. Van Engelen obtained an MSc in Physical Geography from the State University Utrecht in the Netherlands in 1975. From 1976-79 he was involved in soil surveys and training in Niger and Burkina Faso (through FAO); from 1982-87 he was soil surveyor/editor at the Kenya Soil Survey; and since 1988 Mr. Van Engelen works at ISRIC as project manager of the SOTER project (World Soil and Terrain Digital Database) and as GIS specialist. He was involved from the beginning in the development of the database for SOTER and in training in the use of SOTER.

Mr. David W. HEATH - UK

Mr. Heath obtained a B.A. in Philosophy, Politics and Economics in 1960, a Post graduate diploma in Mathematics in 1966 and an MSc in Statistics in 1969. During his long career he worked inter alia as Assistant Statistician in the Ministry of Health (1960 - 62, UK); as an economist at T. Sainsbury Ltd (1962 - 67); at the Home Grown Cereals Authority, involved in economic analysis and market intelligence, later as Deputy General Manager (1967 - 74); and since 1974 to date as a European civil servant in EUROSTAT, the Statistical Office of the European Communities : four years on agricultural structure statistics, five years on computer management, 4 years on analysis of foreign trade statistics and technical cooperation with developing countries, one year on industrial statistics, four years on agriculture and environment statistics with current grade A2 (Director).

Mr. Klaus JANZ - Sweden

Mr. Janz is Senior Forestry Officer in Forest Resources Division of FAO. He is responsible for overall coordination of the Organization's Forest Resources Assessment Programme. He studied Forestry in Freiburg, Germany. After this he served for twenty years in the National Forest Survey of Sweden, where he started as field crew leader and participated in the annual review of field instructions, specialized in calculations of yield potential on province and national levels, was responsible for user contacts and finally associate professor and prefect with overall responsibility for the Swedish National Forest Survey. He then became head of the forecasting and statistic unit of the Swedish Nation Board of Forestry. Main activities were related to the supply side of national timber balances, national forest and forest industries statistics and international cooperation.

Mr. Peter JORDAN - Austria

Mr. Jordan studied geography, cartography and ethnology at the University of Vienna. He wrote a doctoral thesis on "The problem of international standardization of cartographic symbols" with a focus on symbols in land use maps. Since 1977 Mr. Jordan is cooperating in the Atlas of the Danubian Countries, published by the Austrian Institute of East and Southeast European Studies in Vienna; since 1980 he is deputy, since 1989 head of its Geographical Department. He is editor-in-chief of the Atlas of Eastern and Southeastern Europe, published as a map series since 1989. He wrote several scientific publications on semantics of land use maps, atlas cartography, regional geography of East-Central, Eastern and Southeastern Europe.

Mr. Odell LARSON - USA

Mr. Larson is responsible for technical aspects of formulation, implementation, monitoring and backstopping of FAO agricultural statistics projects, to achieve development of long-term integrated programmes of national systems of food and agricultural statistics. He also has responsibility for the preparation of programmes for the decennial World Census of Agriculture which includes standard concepts and definitions, methodology, tabulations and publications. ESS organizes and conducts training centers, workshops and seminars in agricultural census, surveys, and related data processing. Previous experience: Chief of Statistical Analysis Service, Statistics Division, FAO, Rome; five years as Assistant Division Chief, Agriculture Division, U.S. Bureau of the Census, and 30 years with the National Agricultural Statistics Service U.S. Department of Agriculture, as Agricultural Statistician, International Programs Officer, Statistician in Charge (2 States, California and Wyoming) and Chief, Data Collection Branch.

Mr. Rik LEEMANS - Netherlands

Mr. Leemans is a senior scientist at the Global Change Department of the dutch National Institute of Public Health and Environmental Protection. He also serves as task-leader of the "global modelling activity" of the IGBP-GCTE programme, is a lead-author of the IPCC assessments, and is member of several (inter)national committees concerned with various aspects of global change. His early studies at Uppsala University (Sweden) emphasized the successional dynamics and structure of boreal forests. He then held a position at the Biosphere Project of the International Institute of Applied System Analyses (IIASA, Austria). Here he developed a simulation model for the circumpolar boreal forest biome and used it to assess the impacts of climate change on these ecosystems. Since then his research has excelled into modelling global vegetation patterns. In his current position he is responsible for the research concerning the impacts of global change on eco- and agrosystems. His main research involves biodiversity, land cover and C-cycle modelling, and global environmental data bases. These activities are part of the further development of the IMAGE, a model which explicitly incorporates the influence of changing land cover patterns by humans on transient greenhouse gas emission from the terrestrial biosphere. His research is an official contribution to the GCTE project of IGBP.

Mr. Thomas R. LOVELAND - USA

Mr. Loveland is a remote sensing scientist for the U.S. Geological Survey's EROS Data Center (EDC) in Sioux Falls, SD and leads the USGS global land cover characterization research program. He has been engaged in remote sensing research programs at EDC for nearly 15 years. His research has dealt with large area land cover mapping and vegetation monitoring in the Arctic, Africa, and the United States. Mr. Loveland is currently co-chair of the Land Cover Working Group of the International Geosphere-Biosphere Program, and serves on advisory panels for several U.S. land cover applications programs. Previously, Mr. Loveland served in GIS and remote sensing applications and management positions with state governments in South Dakota and Arizona. He has a BS and MS in Geography from South Dakota State University.

Mr. H. Gyde LUND - USA

Mr. Lund is a research forester on the Forest Inventory, Economics and Recreation Research Staff, USDA Forest Service in Washington, DC, with over 30 years in the inventory and monitoring field. His present job includes serving as international resource assessment liaison in the field of information needs assessment, resource inventory coordination, and technology assessment. He has worked in National Forest Systems and State and Private Forestry in the USDA Forest Service and with the USDA Bureau of Land Management. He has served as consultant to FAO and the U.S. Agency for International Development on inventory techniques in developing countries. Mr. Lund is a charter member of the International Society of Tropical Foresters and a fellow of the Society of American Foresters. He is Leader of the International Union of Forestry Resource Organizations (IUFRO) Subject Group S 4.02.00 (Forest Resource Inventory and Monitoring). He has authored nearly 100 papers on resource assessments and has helped organize over 20 national and international conferences on resource inventory and monitoring. He holds a Bachelor of Science degree in General Forest Management form Utah State University and a Master of Science degree in remote sensing from the University of Washington.

Ms. Miriam SCHOMAKER - Netherlands

Ms. Schomaker got her MSc in Landscape Ecology and Land Evaluation from the Department of Physical Geography and Soil Science of the University of Amsterdam (Apr. '84; including a post-graduate diploma in Geomorphological Image Interpretation at ITC). She was research assistant in an Arid and Semi Arid Lands (ASAL) Programme in NW Kenya (part-time 1982-85). She conducted soil/landscape surveys in the Gubbio Basin, Italy (for the Archaeological Department of Cambridge University, UK, July-Dec. '84) and in the Pisa Valley for the Toscana Provincial Planning Agency, Italy, (July - Dec. '85). She then worked as an associate landscape science/hydrology specialist in an Integrated Watershed Management Project in East Java, Indonesia (Febr. '86 - July '88). After Indonesia she joined UNEP in Nairobi as an Associate Programme Officer in the Soils Unit and Desertification Control Office (Oct. 88 - Aug. '91), after which she became Special Assistant of the Assistant Executive Director/Environment Programme (Sept. '91 - Jan. '93). Since Febr. '93 she works in GEMS as a Programme Officer on Renewable Resources related activities.

Mr. Dalton VALERIANO - Brazil

Mr. Valeriano is a biologist/ecologist, graduated from the Federal University of Rio de Janeiro in 1978. He obtained an additional degree in Remote Sensing from the Brazilian National Institute for Space Research (INPE) in 1984, and is presently working on his PhD in Geography at the University of California at Santa Barbara. Since 1982, Mr. Valeriano is a researcher at INPE's Remote Sensing Department, working on areas of land cover mapping using LANDSAT data and vegetation classification and mapping using remote sensing. He is currently working with radar data for biophysical characterization of forest covers.

Mr. Barry K. WYATT - UK

Mr. Wyatt heads the Environmental Information Center (EIC) of the UK Institute of Terrestrial Ecology. EIC serves as custodian of the Institute's extensive data holdings on terrestrial ecology and rural land use. The Center has a staff of 25, with interests in the biogeography of species distributions (a database of 76 000 records describing British species is held by EIC), remote sensing of land cover and vegetation dynamics (we have just completed a national digital land cover map by supervised classification of multi-temporal TM imagery) and Geographical Information Systems. Dr. Wyatt recently undertook, on behalf of the UK Department of the Environment, a systematic inter-comparison of a 20 extant national and international systems for the description and classification of land use and land cover, which has led to proposals for a common land classification system, designed to provide a bridge between the sectoral variants.

Mr. Yoshifumi YASUOKA - Japan

Mr. Yasuoka is Chief, Information Processing and Analysis Section in the Social and Environmental Systems Division of the National Institute for Environmental Studies and is concurrently appointed to Professor for a Graduate Course in Socio-economic Planning, University of Tsukuba. His research background relates to Remote Sensing and Image Processing and he has a Ph.D in mathematical engineering. He worked as a Research Scientist in the Division of Environmental Information of the National Institute for Environmental Studies (NIES) (1974-1985); as Section Chief in the System Analysis and Planning Division (NIES) (1985-1990); and as Section Chief in the Division of Social and Environmental Systems Division (NIES) (1990-1991). He was Chairman of the Tokyo Chapter, Geoscience and Remote Sensing Section at the Institute of Electrical and Electronic Engineering (International Society) (1989-1990) and Secretary General of the Remote Sensing Society of Japan (1990-1991).

Mr. Anthony YOUNG - UK

Mr. Young (MA, PhD, SD) is currently an Independent Consultant, Visiting Fellow, University of East Anglia, Norwich, UK, (1992-1993). From 1983-91 he was Principal Scientist at the International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya. From 1968-82 he was Professor of Environmental Sciences, University of East Anglia, Norwich, UK. He is author of Slopes (1971), Tropical Soils and Soil Survey (1976), soil Survey and Land Evaluation (1981), Agroforestry for Soil Conservation (1989); contributor to FAO Framework for Land Evaluation and subsequent Guidelines; and 140 scientific publications.

ANNEX V TOWARDS INTERNATIONAL CLASSIFICATION SYSTEMS FOR LAND USE AND LAND COVER

A preliminary proposal
prepared for UNEP and FAO

March 1994

FOREWORD

This document results from a need felt in FAO to identify systems of land use and land cover classification which could be adopted throughout the Organisation for internal data exchange, for the publication of all statistics and data relating to these matters, for purposes of farm and land use planning, for other development purposes, and for studies on global change. As a result studies were commissioned: Remmelzwaal (1989), Adamec (1992), and Mücher, Stomph, and Fresco (1991 and 1993).

Also in UNEP a crucial need was felt for globally standardised information on land use and land cover for assessment, monitoring and reporting purposes at a global level. Standardized land use and land cover information is needed for assessments and monitoring of for instance dryland degradation, forests, freshwater, land based sources of pollution in oceans and coastal areas, greenhouse gas fluxes, integrated environment-development issues, etc. In 1993 UNEP provided funds for a UNEP/FAO consultancy by Prof. Anthony Young. It resulted in a first draft proposal, which was used as an input to the UNEP funded UNEP/FAO expert meeting held in Geneva in November 1993, and which was up-dated afterwards by the consultant.

The present document is a slightly modified version which is being circulated for information and discussion. This does not imply agreement with every statement contained in the report by all parties so far involved in the discussions. See also the report of the meeting itself.

It is realised that for proposals to be generally accepted, they must result from a collaborative process involving as many interested people and institutions as possible. The intention is to try and achieve this through an informal networking approach.

It will probably not be possible to achieve one world-wide system of classification, at least not for many years, therefore the immediate aim will be to develop a means to "translate" existing systems into a common format. To do this, common definitions will be proposed for relevant attributes describing the composition, condition or context of land use and land cover.

At present it is not clear whether land use classifications and land cover classifications should be developed by separate groups, or together. It is hoped that time and circumstances will indicate which is most appropriate in the nearer future.

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Chapter 1

THE NEED FOR LAND USE AND LAND COVER CLASSIFICATION

Introduction and objective

There are no internationally recognized systems for the classification of land use and land cover. The available data on world land use and cover do not currently permit a comprehensive assessment on uniform basis. There is no completely satisfactory means by which land use data at country level, compiled according to detailed national classification systems, can be converted to a common global basis. Much data on land use is collected by sector, for agriculture, forestry, conservation, etc., with no standard basis for comparison.

The objective of this report is to provide a first step in the development of internationally-recognized classifications for land use and land cover. These can be regarded as bridging classifications, in that they provide a means of comparison of data from different sources. Such bridges, or links, are needed first, between sector data, compiled for agriculture, forestry, etc., and secondly between different national classification systems.

The report arises out of the recommendations of a UNEP/FAO meeting on harmonizing land cover and land use classifications (Schomaker, 1993). Presentations were given on globally applicable principles relating to classification, including a review of previous work and a draft land use classification. Issues arising were discussed, and guidelines suggested. The discussions and recommendations of the meeting, have been utilized in the preparation of the land use classification which is presented in this report.

Data requirements and applications

The resources offered by the land and the use which is made of these resources are a central concern for the welfare of the world's population. In the development of methods to compare land resources with land use, the initial task was the survey of land resources, for example soil survey and forest resources assessment. A fundamental advance was made by the establishment of an internationally-recognized system for soil classification (FAO-UNESCO, 1974, 1988).

Subsequently, methods of land evaluation were developed, in which the requirements of proposed new uses of land were compared with the surveyed properties of the land, in order to assess the suitability of different areas of land for each kind of use (FAO, 1976, 1984a, 1984b, 1985a, 1991). This approach was applied at national and district scales in numerous development planning projects, and at international scale in an assessment of the population-carrying capacity of the world's land resources (FAO/UNFPA/IIASA, 1982; FAO, 1984c). More recently, land evaluation methods have been placed in a wider context through preparation of a set of guidelines on land use planning (FAO, 1994).

Concurrently with these measures directed at improvements in land use, there has been a growing concern for preservation of the earth's natural resources and avoidance of land degradation. This has led to attempts to monitor changes in world land resources, as a basis for policy at international and national levels (UNEP, biennially; World Resources Institute, biennially). These efforts have been greatly assisted by the development of remote sensing methods based on earth resources satellites, leading to a vast increase in available data.

Compared with this progress in the survey and analysis of land resources, the study of land use and land cover has received less attention. Many of the statistics are collected by sector, separately for agriculture, forestry, and conservation. Areas of international concern which are directly dependent on land use data include:

- pressures for the extension of area under arable use, with problems associated with its extension onto land which it is only marginally suitable for this purpose;

- the environmental consequences of clearance of the world's forest cover;

- the expansion of settlement onto agricultural land;

- the problem of land degradation, arising from inappropriate use and management practices;

- the need to match different kinds of use to land for which it is best suited, in order to achieve sustainable productivity;

- the need of countries party to the Framework Convention on Climate Change to provide reliable estimates of greenhouse fluxes from rural land uses.

The need for improved land use data was repeatedly recognized in the report of the 1992 *United Nations Conference on Environment and Development (Agenda 21)*, eg.:

"Governments...should promote the improvement, further development and widespread application of planning and management tools that facilitate an integrated and sustainable approach to land and resources. To do this, they should: (a) Adopt improved systems for the interpretation and integrated analysis of data on land use and land resources" (UNCED, 1992, Section II, p.23, para. 10.8).

Land use and land cover information are needed at three levels of scale: international, national, and local.

At the **international level** some current applications include:

- The first *World Agricultural Census* related to the year 1930, and was coordinated by the International Institute of Agriculture, FAO's predecessor organisation. FAO inherited this function, and except for an interruption during the Second World War, Censuses have been carried out every ten years. At the present time active preparations are under way for the Census for the year AD 2000.

- The recently-completed *Forest resources assessment 1990* (FAO, 1993), and plans for the next assessment in the year 2000;

- Other monitoring, assessment and reporting activities of the UN system-wide Earthwatch eg. related to natural resources, pollution, climate change etc., often coordinated through the *Global Environment Monitoring System (GEMS)* in UNEP;

- The work of FAO's Inter-Departmental Working Group on Climate Change, which seeks to anticipate how human-induced climatic changes may affect production, food security and natural resources (FAO, 1992);

- A series of internationally-conducted research programmes conducted by the International Geosphere-Biosphere Programme (IGBP), notably that on *Relating land use and global land-cover change* (IGBP, 1993).

- A *Land use database*, being prepared by a joint working group coordinated by FAO, which provides standardized methods for the collection of detailed data on land use attributes (de Bie and van Leeuwen, 1994).

- Current projects for the survey of land cover and monitoring of its changes at international and regional levels, for example by FAO for Africa, for Europe (European Communities, 1993), and several projects on a world scale.

At the national level, many countries are now monitoring land use and land cover change, as a basis for policy guidelines and action. Some countries of the developed world have land use surveys dating back 50 years or more. Data for less-developed countries is often less complete and reliable. However, many countries are now conducting land use surveys, out of concern for the development of improved systems of use, resource conservation, and the avoidance of land degradation.

At the local (or district) level, data on present land use are fundamental to the planning of future improvements in use. This is illustrated by the work of the FAO Investment Centre, which makes use of data on land use and cover, including applications of remote sensing (FAO, 1990; Lantieri and Gastellu-Etchegorry, 1993). In forestry, a former focus upon wood production has given place to multiple-purpose forest management (FAO, 1985b).

The need for a common classification

There is a need to harmonize land use and cover classification systems as between:

- different national classification systems;

- sector classifications (surveys for agriculture, forestry, conservation, etc.);

- classifications for use at global, national and local scales.

In relation to land use planning, the concept of land use is inherent in the FAO Framework for Land Evaluation (1976), and the Agro-Ecological Zones Methodology ((1978). These concepts began to be further developed from 1986.

Separate classifications are needed for land use and land cover. They can be referred to as bridging classifications with respect to their role in providing bridges, or links, between national systems and between different scales; or general-purpose classifications in that they serve the needs of land use analysis as a whole, as compared with the special-purpose classifications employed by different sectors. The term **international classification** is employed here as a means to include both these functions.

It is not intended that the systems set out in this Report should replace national or sector classifications. These will continue to be required to meet special-purpose needs.

There is an analogy with the development of an international system of soil classification. Initially, many countries employed national classification systems based on different criteria. The first step in achieving compatibility was to develop a common system for soil profile description, now largely standardized worldwide. The second was the development, and subsequent revision, of an international system for soil classification. This allowed the mapping of soils on world scale, and provided a powerful means for technology transfer (FAO-UNESCO, 1974, 1988). It has by no means displaced national classification systems, but many now provide conversion tables between their national and the international systems.

Specifically, the international classifications, for land use and land cover, will have the following functions:

1. To provide compatibility and comparability between different classifications - national, by sector, and at different scales: the bridging function.

2. To encourage institutions responsible for the development of classification systems to incorporate comparability with the international systems.

3. To provide tools for land use decision making at all levels

4. To serve as a basis for land use and land cover monitoring at an international level, together with associated analysis and research.

5. In course of time, and with further development of the international classifications, these may come to be used as standard classifications in their own right.

Chapter 2

TYPES AND SOURCES OF DATA

Types of data

Data on land use and cover are obtained from four types of survey:

- **Census data:** These are based on questionnaires addressed directly to the land user, or collected by enumerators. Coverage may be total or by means of an area sampling frame. This method permits direct survey of land use. It provides statistical data but not detailed maps. Example include the *World Census of Agriculture* and its contributory national censuses.

- **Remote sensing:** Data are obtained from satellite or aerial imagery, with control by ground observation of sample areas. This is primarily a source of data on land cover; land use must be inferred from cover and by other means. It provides detailed maps but not, directly, statistical data.

- **Ground observation:** Data are collected by direct observation on the ground, either of all land or by means of area sampling. Visual observation can be supplemented by enquiry to land users. Observation can be of land use and/or land cover.

- **Administrative data:** This method covers the re-use of legal, institutional and administrative data, for example on designated conservation areas, forest reserves, or areas licensed for growing of specific crops. It is of particular value for areas under conservation. There is the danger that the designated use may not correspond to the actual use, e.g. through illegal incursion.

The most reliable information, both on land use and land cover, are obtained by combining data of more than one kind.

International sources of data

Many current data sources include a mixture of land use and land cover information. At international level, major sources of data include the following:

FAO Production Yearbook (FAO, annually), *UNEP Environmental Data Report* (UNEP, biennially) and the *World Resources* reports (World Resources Institute, biennially). In the FAO Production Yearbook, Table 1 gives 'Land use/land cover' as five classes, Table 2 gives irrigated areas, and Tables 15-87 give areas under specific crops. The FAO statistics are now available on diskette as *Agrostat* (FAO, annually), giving 30-year runs by country of all main statistics.

World Census of Agriculture (FAO, 1985-89, 1986). Based on guidance and coordination of national censuses. Conducted as a ten-year cycle, e.g. 'World Census of Agriculture 2000' is based on national censuses conducted between 1996 and 2005. This is the major source of international statistics on agricultural land use.

For the European Union, data on the agricultural sector are consolidated in a *Statistical yearbook* (Eurostat, annually).

Forest Resources Assessment (FAO, 1993). Conducted every 10 years, as an integrated operation. It is a survey of forest cover, not forestry as a land use. The 1990 assessment for Europe also has land use, recorded as multiple uses (UN-ECE, 1990).

United Nations list of national parks and protected areas (IUCN, 1990) and associated documents (WCMC, 1992). Gives areas under designated conservation status.

For land cover data based on remote sensing, a number of international surveys are currently in progress, including:

- International Geosphere-Biosphere Programme (IGBP) data information system;
- European Union survey of tropical forest cover;
- National Aeronautics and Space Administration (NASA) Landsat Pathfinder project, on tropical forest cover;
- FAO land cover map of Africa (to include development of a standard land cover classification for Africa).
- The European Union CORINE land cover project.

For land use by settlement, or land cover by built-on land, there is no world source. FAO Statistics Section requests such data, but currently holds it for only 24 countries.

Some countries have land use, land cover, or combined use and cover data, either as maps or statistics. Many countries are seeking to expand such data, and to monitor change over time.

In summary, the major data sources, for agricultural land use, forest land cover, and designated conservation areas, contain data of different kinds, and are not spatially coordinated, whilst there is no comparable source for areas under settlement. Hence, there are at present no standardized surveys and data sources at international level, either of land use or land cover.

Data reliability

It is generally recognized that much information on land use is relatively unreliable, as compared with the standards expected in statistical data. This is particularly the case with less-developed countries. The UNCED conference noted that "the gap in the availability, quality...and standardization of data between the developed and the developing world has been increasing, seriously impairing the capacities of countries to make informed decisions concerning environment and development" (UNCED, 1992).

In preparing this report, some exploratory studies were carried out, in which data on land use and cover from different sources were compared. For a sample of 20 tropical countries, two clearly-recognized classes were examined: for land use, that of land under temporary crops, and for land cover, that of forest cover. In many cases, estimates differed by more than 50 percent, and in some by over 100 percent. An external study, partly on environmental data but including land use, found data discrepancies of the same order (Rodenburg, 1993). Inaccuracies of this order represent a serious obstacle to future planning.

Chapter 3

THE LAND USE CLASSIFICATION: PRINCIPLES AND STRUCTURE

Introduction

In the course of preparatory work for the proposals presented here, many previous systems were examined. The more recent of these are shown in Table 1. As would be expected, they differ in matters of detail, and with respect to classes considered important at a high level of classification. There are also more fundamental differences. There is often a mixture of elements of land use and land cover, and classes are frequently not fully defined. The purposes of use, such as crop production, are not consistently distinguished from the operations carried out to achieve these purposes.

It is true that many classes of use are widely recognized, and common to all or most systems. Even so, it became apparent that for a system intended to act as a bridge between national classifications, it would not be sufficient simply to construct a compromise system. A set of principles are needed, together with a logical structure.

Principles

More than 20 principles have been proposed as relevant to land use classification, some of which are conflicting[1]. The following have been taken as a basis for the present system.

1. *The classification must be based only on land use, not on land cover.*

Some kinds of use are closely linked with cover, and land cover will frequently be employed as a diagnostic means for determining use (see Chapter 7). However, there are also many cases where cover and use are independent, and the use of both in the same classification system has been a source of confusion. Table 1 lists some recent existing classifications.

2. *The classification must be comprehensive, covering all land uses. Features related to land use as a whole should be given priority over special interests.*

This is a basic to the present proposal. The classification should include all forms of land use, including agriculture, forestry, conservation, settlement, and land not

presently used for any purpose. Sector interests should receive due attention, but coverage of all types of use on the same basis should have priority over these.

---

[1]Sources on which the following account is based include Adamec (1992), de Bie (1993, 1994), Eurostat (1992, 1994), Mücher (1992), Mücher et al. (1993), Sims (1992, 1993), Sombroek (1993), Stomph and Fresco (1991) and van Gils et al. (1993).

Table 1

Recent land use and land cover classifications

Page references are to the tabular presentation of the classification in the source reference.

General classifications:

Anderson et al. (1976) p.8	Land cover, and land use inferred from land cover; the revised US Geological Survey classification.
Kostrowicki (1983) pp.17-21	Land use.
Remmelzwaal (1989) pp.8-12	Land use.
Stomph and Fresco (1991) p.60	Land use.
Van Gils et al. (1991) p.166	Land use *and* land cover, the ITC classifications; each with 'related land uses/related land covers'.
Adamec (1992) pp.4-14	Land use.
Directorate-General... (1992) p.10, and (1993) pp.23-28	Land cover. The CORINE system, for Europe.
IRSA (1992) pp.1-6	Land cover. The CRONOS system, for Europe.
Mücher et al. (1993) pp.13-20	Land use.
ITC (1993) Computer printout	Land use, the current ITC classification. Also production attributes of land use types.
Sims (1993) pp.10-12	Land use. Also lists six other classifications.
De Bie (1993)	Land use.
Sombroek (1993)	Land use.
Economic Commission for Europe (1993) pp.3-5	Land use, with relation to cover.
De Bie and Van Leeuwen (1994)	Attributes for description of land use systems

Sectoral classifications:

FAO (1986b) pp.32, 36, 40, 45	Land use, agricultural holdings; 1990 World Census of Agriculture.
FAO (1990) pp.4-7	Forest land cover, 1990 Forest Resources Assessment.
UN-ECE/FAO (1990)	Land use, forestry.
IUCN (1990) pp.10-14	Land use, conservation.
White (1983) p.46	Land cover, vegetation, the UNESCO classification.

3. *At each level of classification, the set of uses should be mutually exclusive. They should exclude mixed and transitional classes.*

This applies to the land use types defined in the classification. On the ground, multiple use is frequently important, and on maps, composite mapping units will often be necessary (see Chapter 7).

4. *The classification should be independent of scale, both the scale of data collection and the scale of presentation of results.*

5. *The classification should be independent of the method of observation. It should be based on one common terminology, linked with methods and terminologies of observation by predefined rules.*

These principles require that data obtained from different sources (questionnaire, remote sensing, etc.), and from surveys at different scales, should be capable of inclusion in the same basic classification. Means will be needed for relating data from different sources (see Chapter 7).

6. *The classification should have a logical and scientifically sound foundation.*

In the proposed system this is provided first, by keeping clear the distinction between purpose of the use, and means employed to achieve this purpose, that is, between functional and biophysical land use.

7. *The classification should be as pragmatic and easy to understand as possible.*

Obscure terminology, or definitions which run counter to intuition, will not be accepted by the desired wide range of users. In places there is conflict between Principles 6 and 7, some departures from strict logic being necessary so that classes correspond to those which are widely recognized.

Structure of the classification

The proposed classification is intended as a first approximation to an international system, and is restricted to land uses described in a generalized manner. It is intended to give a uniform standard covering all types of use, which will serve as a basis for subsequent development in more detail.

Level I: degree of modification of the ecosystem

The first basis employed in this classification is the degree of change of the natural land conditions. This refers to the progression from undisturbed natural ecosystems, not used or protected by conservation; through ecosystems managed for biologically-based production, as in agricultural land uses; to forms of settlement in which the ecosystem has been completely replaced by man-made structures.

In generalized terms, this spectrum corresponds also to increased input of human effort in managing the land, that is, intensity of use. Non-use, for example, requires less input than active management for conservation, and forestry generally requires lower inputs per unit area than most kinds of agricultural crop production.

This criterion is employed as the basis for the highest level of classification, Level I, a which all land uses are grouped into three highly-generalized classes:

- uses dependent on natural ecosystems;
- uses based on production from managed ecosystems;
- uses related to settlement (or "artificial ecosystems").

In addition, the same rule is applied to give a logical order for the listing of classes at lower levels of the classification. For example, forestry based on management of natural forests is listed before forest plantations, extensive grazing from natural pastures before livestock production from improved grasslands.

Level II: functional land use - purpose of the use

The basis for describing classes at Levels II and III may be introduced by two basic questions which are asked about land use:

- What is this area of land used for; what is the purpose of it use, what is the end product ?
- How is the land managed, in order to achieve this purpose?

The first question asks whether the land is used for the production of crops, livestock, wood, or fish, and if so, of what kind? Or are the aims to conserve biological resources, to serve the needs of tourism or recreation, or to provide space for housing or other kinds of settlement? At level II use is classified on the basis of purpose.

Level III: biophysical land use - sequence of land management operations

The second question above is about the operations carried out on the land as part of its management. Has the natural vegetation been cleared and replaced? If used for crop production, for which crops, and are they grown as single stands or intercropping? If used for timber, are the trees selectively cut or clear-felled in one year? If conservation is the purpose, what degree of public access is permitted?
These are aspects related to biophysical land use. This is the basis of classification employed at Level III.

PRELIMINARY PROPOSAL FOR AN INTERNATIONAL CLASSIFICATION OF LAND USE

The proposed classification is shown in Table 2 and Figure 1 (page 29). To justify all decisions taken would be a lengthy process but notes giving reasons for some of them, referenced by numbers as (1), (2)..., are given on page 27.

Definitions of classes are given in order of their occurrence; an alphabetical index of definitions is given on page 45.

Levels of the classification

There are three levels in the classification, referred to as Levels I-III. Each level consists of a set of defined classes, the *land use types*. At all levels, the coverage of land uses is comprehensive; that is, a listing of the areas under land use types at any level for a surveyed region should be equal to the land area of the region. In addition, one *land use phase* is recognized, that of irrigated land use, which can be applied to many land use types.

Each level of the classification is defined by a specific type of criterion:

Level I	Degree of modification of the ecosystem
Level II	Functional land use - purpose of the use
Level III	Biophysical land use - sequence of land management operations

Level I: Degree of modification of the ecosystem

All land uses are divided with respect to degree of modification of the ecosystem. There are three classes:

Uses based on natural ecosystems

Uses based on managed ecosystems

Settlement and related uses

This is a very broad and generalized grouping. It provides a logical basis for the order of listing of classes at Level II. The Level I land use types may be utilized as an index of the degree of human impact upon ecosystems, for example for monitoring changes at national level.

Table 2

An international classification of land use: first approximation.

At each level, the listing is in approximate order of increasing modification of the ecosystem.

Level I Degree of modification of the ecosystem	Level II Functional land use	Level III Biophysical land use
USES BASED ON NATURAL ECOSYSTEMS		
	NOT USED	
	CONSERVATION	
	TOTAL CONSERVATION	
	PARTIAL CONSERVATION	
	COLLECTION	
		COLLECTION OF PLANT PRODUCTS
		COLLECTION AND ANIMAL PRODUCTS
		COLLECTION OF PLANT AND ANIMAL PRODUCTS
USES BASED ON MANAGED ECOSYSTEMS		
	PRODUCTION AND MULTIPURPOSE FORESTRY	
		MANAGEMENT OF NATURAL FORESTS
		MANAGEMENT OF PLANTED FORESTS
	AGRICULTURAL PRODUCTION	
	LIVESTOCK PRODUCTION	
		NOMADIC GRAZING
		EXTENSIVE GRAZING
		INTENSIVE LIVESTOCK PRODUCTION
		CONFINED LIVESTOCK PRODUCTION
	CROP PRODUCTION	
		SHIFTING CULTIVATION
		SEDENTARY CULTIVATION, PERMANENT CROPPING
		SEDENTARY CULTIVATION, TEMPORARY CROPPING
		WETLAND CULTIVATION
		COVERED CROP PRODUCTION
	PODUCTION OF FISH AND RELATED PRODUCTS	
		FISHING
		AQUACULTURE
SETTLEMENT AND RELATED USES		
	RECREATION	
	MINERAL EXTRACTION	
		MINING
		QUARRYING
	SETTLEMENT	
	RESIDENTIAL SETTLEMENT	
	COMMERCIAL ACTIVITIES	
	INDUSTRIAL ACTIVITIES	
	SETTLEMENT INFRASTRUCTURE	
	USES RESTRICTED BY SECURITY	
Land use phase:	IRRIGATED LAND USE	

Uses based on natural ecosystems

Land uses based on natural or semi-natural ecosystems which have not been fundamentally changed by human activities, and from which there is no substantial production, other than by collection. The vegetation has not been cleared.

Level I includes semi-natural ecosystems, modified to a limited degree by past or present management. There may be conservation of the ecosystem. There may be use for use for recreation, provided that conservation is at least of equal importance and the ecosystem is not fundamentally changed. Conservation forestry based on natural forests is included. Water bodies that are used for conservation are included. Natural grasslands used for extensive grazing are excluded.

Uses based on managed ecosystems

Land uses, the major purpose of which is production based on biomass. The natural vegetation may be cleared, either permanently (e.g. in plantation forestry, sedentary agricultural crop production) or temporarily (e.g. in production forestry based on natural forests, or shifting cultivation). Where the natural ecosystem remains, there is substantial impact upon it from human activities for purposes of production (e.g. grazing, fishing).

Grazing on natural grasslands or rangelands is included. Fish production is included. Conservation forestry is included where based on planted forests, but is excluded when based on natural forests.

Settlement and related uses

Covers systems of land use which are not fundamentally dependent upon biological production, or in which substantial parts of the land have been covered by buildings or other human structures.

Land used for mining and quarrying is included. Land used primarily for recreation is included, even where built structures occupy a proportion of the area (e.g. sports fields). Land managed primarily for nature conservation, with subsidiary recreation (e.g. wildlife parks) are excluded. Buildings that are for agricultural production (e.g. greenhouses, cattle sheds) are excluded.

Level II: Functional land use - purpose of the use

Divisions at this level are based on functional land use, that is, the purpose for which the land is used. The classes included under the Level I class of managed ecosystems are uses based on production from biomass. Classes are listed as nearly as possible in order of increasing modification of the ecosystem.

Because of the existence of certain widely-recognized subdivisions of purposes, certain classes consist of a main purpose with subdivisions, which could be regarded as 'Levels IIA and IIB'.

Ten main purposes are recognized, subdivided into 15 classes. The classes of functional land use are:

Not used
Conservation:
- Total conservation
- Partial conservation
Collection
Production and multipurpose forestry
Agricultural production:
- Livestock production
- Crop production
Production of fish and related products
Recreation
Mineral extraction
Settlement
Residential settlement
Commercial activities
Industrial activities
Settlement infrastructure
Uses restricted by security

Not used

Land which, within the current production cycle, is not used for production, nor actively managed for conservation. The land may be permanently unproductive ("barren land"), formerly productive ("abandoned land"), or potentially productive.

Inclusion of areas in this class indicates that an effort has been made to ascertain the use, and it has been found that there is no present use. It should not be employed to refer to land for which the use has not been determined; where any such land occurs in a surveyed area, it should be described as "use not determined" or "no data".

Conservation

Land on which the primary purpose of management is conservation and protection of the natural ecosystem and environment, including both biological and non-biological elements. Conservation may be based on any type of ecosystem. Includes conservation of water bodies, and conservation forestry. (1)

Subclasses of conservation:

Total conservation: Conservation is the only, or highly dominant, objective of the use. There may be scientific study. Where other objectives are permitted, these are only such as do not conflict with that of conservation.

Partial conservation: Conservation is the primary objective but there is controlled use for other purposes. There may be use for recreation, but in ways that do not have major impacts upon the natural ecosystem (e.g. hill walking, wildlife viewing).

Controlled shooting of wildlife as a form of recreation in game reserves is included. Human communities living by collection of natural products are excluded. Areas which some countries designate as "natural parks" but in which are substantially occupied by agriculture are excluded.

Collection

The collection of products from natural ecosystems. The ecosystems are not substantially altered through management, other than by possible controls on the quantity of products collected or the timing or methods of collection. There may be degradation of the ecosystem.

This type of use is transitional between the Level I classes of natural and managed ecosystems. Although a form of production, it is grouped under use of natural ecosystems on grounds that no operations are undertaken to modify the ecosystem (other than prevention of degradation by control of amounts collected).

Fishing is excluded from Collection. (2)

Production and multipurpose forestry

The management of ecosystems consisting predominantly of trees, for purposes which include the production of wood and associated products. There may be additional management objectives, including conservation. (3)

Agricultural production

Land use for which the primary objective is the production of agricultural products, including both primary and secondary products (crops and livestock).

Excludes production of forestry and fisheries products from agricultural holdings.

Subclasses of agricultural production:

Livestock production: Production of livestock and its products; secondary agricultural production. Covers livestock related activities carried out on grasslands, rangelands, and grasslands with trees or shrubs; grazing as a main use in open woodlands and livestock production in buildings. (4)(5)

Crop production: Agriculture directed at the production of field crops, orchard crops, and other products in the conventional sends of the word; primary agricultural production.

Excludes the growing of crops which are subsequently fed to livestock (fodder crops), on-farm or off-farm. Also excludes livestock production on permanent grasslands and grass-based pastures, both natural and planted. Includes crop production in buildings. (See definition of a land use on page 32)

Production of fish and related products

Land or water use for which the primary objective is the production of fisheries products, including fish, crustaceans, and aquatic plant products.

Recreation

Recreation and tourism. Includes sporting and competitive activities, and both rural and urban leisure areas. Includes activities carried out on both built-on land (e.g. covered sports facilities) and land largely under vegetation (e.g. sports fields). Excludes activities carried out in gardens of residences. (6)

Mineral extraction

The extraction of minerals, from underground or surface workings.

Settlement

Activities which take place in or on built-up areas, buildings, and other human structures (e.g. roads); together with land adjacent to such buildings, the use of which is directly linked to them.

Subdivisions of settlement:

> **Residential settlement**: Homes, flats/apartments, etc. Includes gardens where these are primarily for leisure. Excludes gardens which are primarily for agricultural production (e.g. 'home gardens', allotments).
>
> **Commercial activities:** Activities connected with shops (retail and wholesale), warehouses, and other commercial or trade activities. Excludes land used for transport and port facilities.
>
> **Industrial activities**: Activities carried out in factories and on land used for the production of industrial goods. Includes processing of agricultural products, other than on-farm preparation for storage or marketing.
>
> **Settlement infrastructure:** Activities pertaining to transport (by road, rail, canal, air, sea) and settlement services (water, electricity, etc.). Includes activities relating to port facilities.

Uses restricted by security

Land under military use or having security restrictions which do not permit the identification or mapping of use. Although classed under artificial ecosystems, this class may include areas of managed or natural ecosystems (e.g. military training land).

Level III: Biophysical land use - sequence of operations

The basis for classifying land use types becomes fundamentally different at Level III. Divisions are based on the functional land use, the sequence of operations carried out on the land. This provides the means of defining a number of recognized types of production system.

For those classes carried down from higher levels without subdivision, supplementary definitions are given, based on functional land use. Classes are listed as nearly as possible in order of increasing modification of the ecosystem. There are 27 classes:

Not used
Total conservation
Partial conservation
Collection of plant products
Collection of animal products
Collection of plant and animal products
Management of natural forests
Management of planted forests
Nomadic grazing
Extensive grazing
Intensive livestock production
Confined livestock production
Shifting cultivation
Sedentary cultivation: permanent cropping
Sedentary cultivation: temporary cropping
Wetland cultivation
Covered crop production
Fishing
Aquaculture
Recreation
Mining
Quarrying
Residential settlement
Commercial activities
Industrial activities
Settlement infrastructure
Uses restricted by security

Not used

No operations are applied to the land, and no active measures are taken for its conservation.

Total conservation

The use of the land for production is prohibited. Access by the public is strictly controlled, and may be only primarily for scientific study. Recreation, if permitted at all, is limited to viewing of the environment without disturbance to it, usually on foot and often with limitation of numbers. Includes nature reserves, wildlife refuge areas, etc.

Partial conservation

The range of operations comprising this use is variable, but includes control over access by the public and the forbidding of activities which substantially disrupt the natural ecosystem. Includes wildlife parks with public access. Includes conservation forestry based on natural ecosystems.

Collection of plant products

The collection of plant products from natural ecosystems, e.g. collection of firewood and domestic timber. There is little or no active management of the environment, although uncontrolled collection may lead to degradation.

Collection of animal products

The hunting or trapping of wildlife, usually for commercial purposes. Controlled shooting of wildlife in game reserves, where conservation is the primary aim, is excluded.

Collection of plant and animal products

Land use by communities living partly or wholly by collection from the natural environment (plant collection, animal hunting or trapping). Such areas may or may not be designated anthropological reserves; the activity takes precedence over the conservation status.

Management of natural forests

Forestry management operations carried out on natural or semi-natural forests. Specific operations vary according to the system of forest management, for example selective felling, enrichment planting, protection. They may include total felling at intervals in a rotation.

Management of planted forests

Forestry management operations which include clearance of the natural vegetation and planting of trees.

Nomadic grazing

Production systems in which the livestock are moved from one area of grazing and source of water to another, often over a wide area. Generally the owners or herders do not have formal title to the land being grazed.

Extensive grazing

Livestock production by grazing from pastures and rangelands which are natural or semi-natural. The pasture is not sown, and if improved, this is on an extensive basis. The pasture may be degraded. Supplementary feeding is absent or relatively unimportant. Includes grazing on grasslands, grasslands with trees or shrubs, and on open woodland where this is the primary use. (7)

Intensive livestock production

Livestock production by grazing pastures that have been planted or otherwise substantially improved. In addition to grazing there may be substantial use of supplementary feedstuffs, of on-farm or off-farm origin. Excludes confined livestock production.

Confined livestock production

Livestock production in which the livestock remain permanently, or for most of the time in covered buildings or enclosures. Includes stall-feeding of cattle, and much poultry production.

Shifting cultivation

Crop production in which the land is cultivated for from one to a few seasons before being allowed to revert to natural vegetation. Usually involves annual crops (cereals, roots), but may include some permanent crops. There may be limited production from the fallow (e.g. from fruit trees, continued harvesting of perennial crops). Excludes rotational systems in which the fallow is planted or intended for production (e.g. improved tree fallows). (8)

Sedentary cultivation: permanent cropping

Crop production on permanent agricultural holdings, based on the growing of crops which remain in the ground for five years or more. In most systems, the land is cleared and replanted at intervals in the cycle of use. However, also includes systems in which planting takes place selectively without clearance. Includes "home gardens" where these are based mainly on perennial crops. (5)(8)

Sedentary cultivation: temporary cropping

Crop production on permanent agricultural holdings, based on the growing of crops which remain in the ground for less than five years. In many cases, clearance and replanting is carried out annually. There is frequently tillage but not necessarily, since systems of zero tillage are included. The essential operation is that of regular replanting. (8)(9)

The words "sedentary cultivation" may be omitted from permanent and temporary cropping where the distinction from shifting cultivation is understood. Although defined in terms of land use operations, this class will in practice usually be mapped on the basis of type of crop, temporary or permanent. See crop lists in FAO (1986, pp.105-114), crop codes beginning with "1" are temporary, with "2" are permanent.

Wetland cultivation

Crop production in which the fields are flooded for part of the year. Flooding may be by retention of rainfall or by irrigation (see *irrigated land use*).

This land use type is separately identified in view of its large extent and importance. It refers mainly to wetland rice cultivation, but is applicable to wetland systems for other crops, e.g. jute. (8)

Covered crop production

Crop production within buildings (greenhouses, etc.). May include temporary or permanent crops. (8)

Fishing

The use of water bodies for fisheries primarily by collection. Management of the natural ecosystem is mainly by controls over methods of fishing and quantity of offtake, although such controls may be substantial. There may be degradation of the ecosystem by excessive offtake.

Includes fishing from rivers, lakes and lagoons. Artificial water bodies are also included, provided that these were constructed other than for the primary purpose of fishing. (2)

Aquaculture

The use of water bodies for *fisheries* with substantial management of the aquatic ecosystem. Includes both the creation of aquatic environments (e.g. fishponds) and the active management of existing environments to improve production (fish farming).

Recreation

Because of the many kinds of recreation, there are few operations held in common, and the class is defined largely in terms of purpose of use. In most systems there is some degree of control over access or type of use, but this is not a defining criterion.

Mining

Mineral extraction from underground workings. The area mapped as a form of land use will usually, but not necessarily be the surface area occupied by mine buildings, pit-head works, waste heaps, etc. Excludes opencast mineral extraction. (10)

Quarrying

Mineral extraction from surface workings. A superficial layer of the land is completely removed. There may or may not be restoration of the former ecosystem. As a form of land use, includes types of surface mineral extraction which are commonly called "mining", e.g. bauxite, opencast coal workings. Includes the extraction of soil or turf.

Former quarried land currently under management for restoration is classed as quarrying. Abandoned land not under such management is classed under its current use, or as not used.

Residential settlement, Commercial activities, Industrial activities, Settlement infrastructure.

The defining criterion in all classes of settlement is the fact that the activities take place in buildings or other artificial structures (e.g. roads, airfields). For purposes of analysis (for example economic, social, and environmental impact analysis), the subdivisions of settlement are differentiated in terms of operations. For common purposes of identification they are often separated on the basis of purpose.

Use restricted by security

Operations undertaken involve activities which require that access by the public is totally forbidden, or permitted only subject to security restrictions.

Land use phase: irrigated land use

The activity of providing water for crops is a highly important attribute of land use, but one which cuts across many classes. Rather than create an additional level by subdividing classes at Level III, it is included in the classification as a *land use phase* (comparable with the phases in the international soil classification).

Irrigated land use

Land use under which the production or other benefits are largely or entirely dependent upon the transfer of water into the area of production, by surface transport or extraction from groundwater. Includes systems of water harvesting. Excludes *supplementary irrigation*. Excludes retention of rainfall by bunds, as in some wetland rice systems. (11)

Associated definitions:

Supplementary irrigation: Irrigation employed to improve yields, or as an insurance against dry periods. But production would be obtained in most years if the irrigation were not undertaken.

Rainfed land use: Land use other than *irrigated land use.*

The Irrigation phase can be applied to the basic classification either as a subdivision or a grouping. As a subdivision, this has the effect of an additional level, for example:

Sedentary cultivation, temporary cropping:
- irrigated temporary cropping;
- rainfed temporary cropping.

For the special purpose of irrigated land use planning, this attribute can be applied as a grouping at the highest level:

Irrigated land use:
- temporary cropping;
- intensive livestock production;
- etc.

Other land use phases could be established, to distinguish other phases to cover situations in which an attribute cuts across the classification. An example is agroforestry systems, which occur within crop production, intensive livestock production, forestry, and aquaculture.

Some potential subdivisions

Certain subdivisions which are widely recognized may be noted. These may be used in specific applications, statistical or mapping, but they are not a formal part of the current version of the basic classification.

Conservation An established basis for classification of conservation areas exists in the IUCN conservation management categories. Definitions are given in IUCN (1990). There are ten classes:

I	Scientific reserve/strict nature reserve
II	National park
III	Natural monument/natural landmark
IV	Nature conservation reserve/managed nature reserve/wildlife sanctuary
V	Protected landscape or seascape
VI	Resource reserve
VII	Anthropological reserve/natural biotic area
VIII	Multiple use management area/managed resource area
IX	Biosphere reserves
X	World heritage sites (natural).

These classes, however, are not mutually exclusive, and sites are frequently placed in two or more classes.

Conservation and protection forestry may be subdivided into:

> **Conservation forestry**: Forestry in which the primary objective is the conservation of the biological resources of the forest, including both plant and animal resources.
>
> **Protection forestry**: Forestry in which the primary objective is the protection of non-biological resources, e.g. against erosion, land slides.

The commonly-employed subdivision into forestry based on broad leaved and coniferous forests can be accepted within the structure of the classification in that the respective products and management operations differ. Divisions based on forest cover (dense, closed, open), however, should not be included in land use classification, since these are based on land cover.

Nomadic grazing may be subdivided into total and partial nomadism.

> **Total nomadism**: Nomadism in which there is no permanent land holding which is owned or grazed annually.
>
> **Partial nomadism**: Nomadism in which livestock spend part of the year on one permanent holding.

All classes of **livestock production** may be subdivided according to predominant **livestock groups**: cattle, sheep and goats, camels, wildlife, poultry, etc.

Shifting cultivation may be subdivided on the basis of the cultivation factor, R:

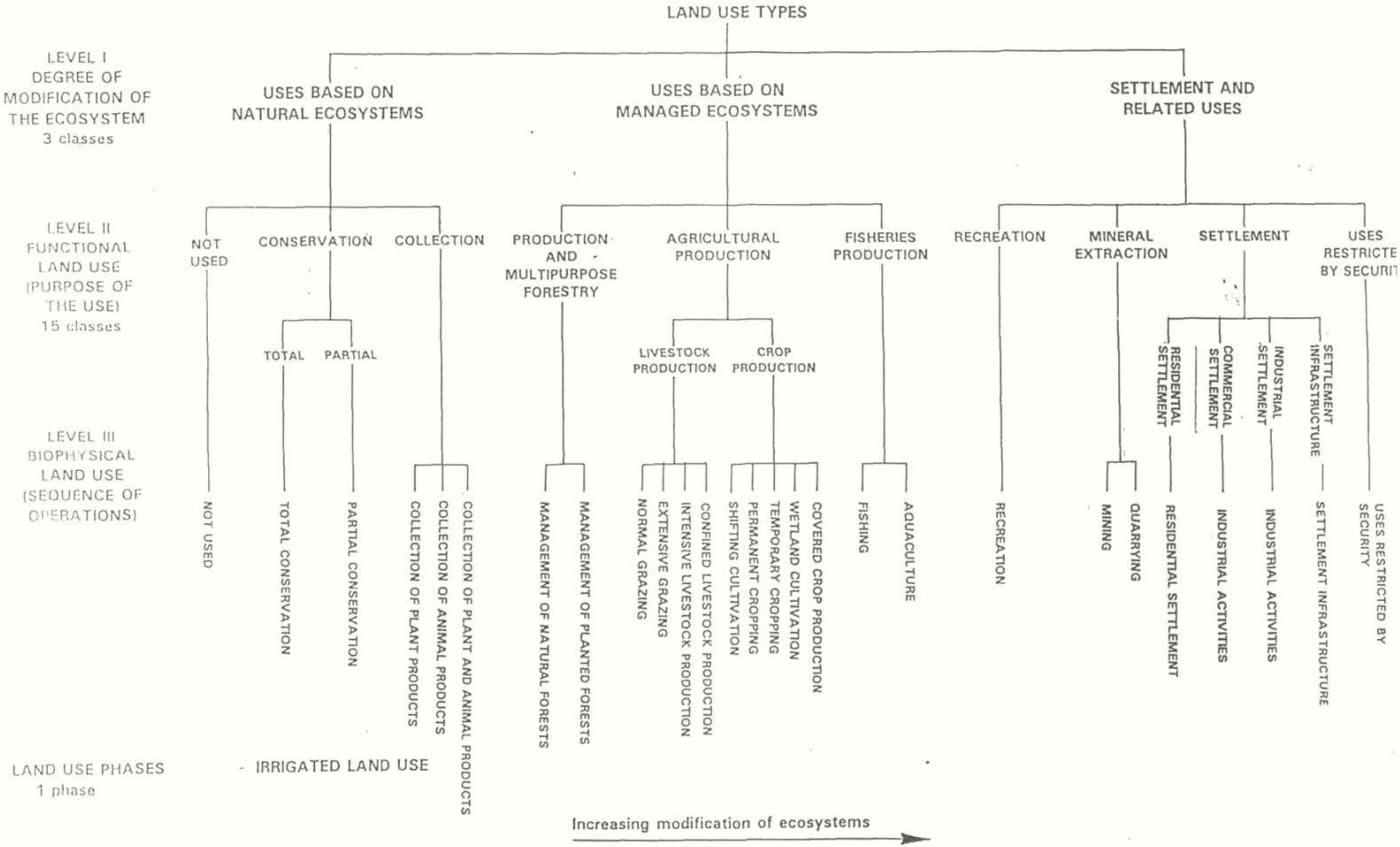
> **Cultivation factor**: Years under cropping divided by years in the total cropping-plus-fallow cycle, expressed as a percentage.
>
> - shifting cultivation: long fallow: $R < 33\%$
> - shifting cultivation: short fallow: R 33-66%

Agriculture, crop production All classes of crop production may be divided into:

- crop groups;
- individual crops.

The **crop groups** recommended are those employed for FAO statistical purposes (FAO, 1986, pp.107-114).

FIRST APPROXIMATION



Notes on the classification

(1) Conservation forestry

The class of Production and multipurpose forestry includes conservation and protection forestry based on planted forests, but not conservation forestry based on natural forests. The latter is included under Conservation, on grounds that conservation is the purpose, irrespective of whether it is applied to a forest or non-forest ecosystem.

(2) Fishing

Fishing could alternatively be grouped under collection from natural ecosystems. It is placed under managed ecosystems in order to group together both classes of fisheries production; this may be justified because, for land-based fishing, there is frequently substantial management of the ecosystem through control of offtake.

(3) Production and multipurpose forestry

In accordance with current forestry practice, a separate class of "forestry production" is not distinguished, on grounds that forestry management is so frequently multipurpose.

(4) Livestock production

It has been suggested that secondary agricultural production, or livestock production, should not be considered a form of land use. The arguments are that the direct land use consists of grass production; that livestock move between one area of land to another; and that the growing of fodder crops (including temporary grass) is classed as crop production. This suggestion is rejected on grounds that livestock production is recognized as a form of land use in nearly all existing classifications. In practice, it is diagnosed largely from the land cover of permanent grassland. Furthermore, one of the major uses of land use classification is in land use planning, or farm planning, in both of which all possible uses of land have to be considered in selecting that which is considered as the "best", or optimum use. (See also the concept of land use on page 30).

(5) Order of listing of classes

The listing of Livestock production before Crop production, and of Permanent cropping before Temporary cropping, although in reverse order to that of common practice, is done on the principle of degree of modification of the ecosystem.

(6) Recreation

Whilst many kinds of recreation take place on open spaces and are dependent on plant growth (e.g. sports fields), it was recommended in discussion that it should be grouped with

Settlement, on grounds that the human impact is usually considerable, and that the use is clearly separate from "agriculture" in the broad sense.

(7) Extensive grazing

Extensive grazing is sometimes called "ranching", but this term is not employed, as it has been applied with different meanings.

(8) Treatment of crop area data

Areas of land under individual crops are a highly important element of land use statistics. For three classes at Level III, shifting cultivation, wetland cultivation, and covered crop production, the crop areas should be added to those under temporary cropping. In the case of *wetland cultivation* (using the example of rice), data presentation must make clear whether "temporary crops" include or exclude wetland rice.

(9) Horticulture

Whilst many national systems include a class of horticulture, this is difficult to define in a way which is internationally acceptable. The criterion of production on small, intensively managed, holdings is not applicable to field-scale cultivation of vegetable crops, and range of crops covered differs between countries. Horticulture is therefore omitted from the present classification. Crop groups of vegetable crops, fruit crops, etc., can be employed as subdivisions.

(10) Mining

Underground mineral workings are not covered by land use survey or classification (other than special-purpose surveys).

(11) Irrigated land use

Some countries at present include land with retention of rain by bunds as irrigated land; if the present definition of irrigated land use is adopted, such land should be excluded. This example illustrates how a recognized classification could provide guidance in the standardization of international statistics.

Chapter 5

CONCEPTS AND TERMINOLOGY

Many of the basic concepts related to land use are incorporated in definitions of terms used. The definitions given in this and the following sections are based on those agreed by the FAO *Interdepartmental working group on land use planning*, supplemented by other sources.

Land

For many years a widely-used definition has been accepted under which the term land refers not only to soil, but to all natural resources that form the basis of land use, including climate, water resources, vegetation and fauna. This definition is as follows:

> **Land** An area of the earth's solid surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above or below this area, including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on the present and future uses of the land by man.

A problem arises in the treatment of inland water bodies. In official statistics, many countries exclude large water bodies which form part of their national territory, such as major lakes, from their land area. However, smaller water bodies are included, and also large reservoirs, since it is unusual for countries to change their official land area. Hence inland water bodies, other than those which countries exclude from their land area, are included within land.

The following definitions, taken from the *FAO Production Yearbook*, provide the areal basis for land use statistics:

> **Total area** The total area of a country, as specified by the UN Statistical Office.
>
> **Land area** Total area, minus area under major inland water bodies.

Land use and land cover

The distinction between land use and land cover is fundamental. Failure to distinguish between these concepts has led to much confusion in previous classifications.

Land use is based on function, the purpose for which land is being used. Definitions that have been proposed include, "the management of land to meet human needs" and "human activities which are directly related to land". These incorporate the same basic ideas. Technically an series of activities carried out anywhere in the world for the purpose of producing goods or services is a land use. A formal definition which draws attention to the fact than land and its use have two-way interactions is:

Land use Human activities which are directly related to land, making use of its resources or having an impact upon it.

Land cover is the observed cover, as seen on the ground or by remote sensing. It the a consequence of interactions between the natural environment (especially vegetation) and the use. The definition is:

Land cover The vegetation (natural or planted) or human constructions (buildings, etc.) that cover the earth's surface.

It is fundamental to statistical data, mapping and discussion that these two concepts should be clearly distinguished. Land cover is a major diagnostic feature employed when mapping land use, but it is not land use as such. Confusion has arisen because in some cases, land cover and use are closely equivalent, for example, the land cover 'permanent crops' corresponds to the land use 'permanent cropping'. In other cases the is no such correspondence; in particular, both natural forest and grassland may be under a variety of uses, which cannot be diagnosed from cover alone.

Two aspects of land use are the benefits obtained from the use, and the operations applied to the land in order to obtain these benefits. These are distinguished in the following concepts:

Functional land use The purpose for which the land is used, or the benefits obtained from it; benefits may be products (e.g. crops, wood) or services (non-material benefits, e.g. conservation, recreation).

Biophysical land use The sequence of operations carried out on an area of land in order to obtain products or other benefits; example are vegetation clearance, ploughing, grazing, building, and the application of material inputs, e.g. fertilizers.

Functional land use is the focus of interest with respect to the outputs obtained from land and the inputs required. Choices must be made between use for production or for non-material benefits, or between different types of production, for example of forest products, crops or livestock. It is the aspect most widely considered in discussion of land use in relation to human welfare and development.

Biophysical land use covers the more technical aspects of land use. It is of particular relevance in analysis of the impact of use upon land, for example in studies of land improvement or degradation.

Functional and biophysical aspects should both be included in an international classification intended for a wide range of purposes.

Space and time units for land use surveys

In surveys of land use, by whatever method, the primary spatial unit of observation is the plot:

Plot The smallest reasonably homogeneous area of distinctive land use.

Examples of plots are an agricultural field, or part of a field, under the same crop; an area of woodland managed for conservation; an area of range land used for grazing; and a block of residential housing.

A plot is frequently coincident with an agricultural field, or parcel of land as delineated on large-scale maps (e.g. 1:10000). However, where a field or other parcel is divided into two or more uses, each of these becomes a plot.

Surveys of land use are based on observations at the level of the plot, and statistics refer to aggregations of plots. Maps, particularly at small scales, may need to represent areas larger than plots (see Chapter 7), but these are not units of primary observation.

The alternative of having a larger unit of observation for surveys at smaller scales was rejected, since it would make land use classification scale-dependent, and inevitably lead to classes of mixed use. It is desirable to avoid both these features in a classification for bridging use.

The time frame for surveys of land use is normally the year of observation. However, specification of the use may require reference to operations carried out in the past or anticipated in the future. Examples are shifting cultivation, or a managed forest with rotational felling.

Land use refers to actual, observed, use. It should not refer to legally designated uses which are not in fact practised. Where, for example, there is illegal incursion for agricultural use into a forest reserve, this should be the recorded use.

Terms for land use description and classification

Three terms employed to describe and classify land use are:

- land use attribute: a standardized descriptor, employed to describe one feature of land use on a plot;

- land use system: the complete system of use on a plot, that is, the sum of the attributes;

- land use type: a defined class of land use in a classification system.

A method for the detailed description of land use is provided by a set of descriptors, the land use attributes. For systems with the objective of production, these can be called production attributes.

> **Land use attribute** A descriptor employed to specify the properties of systems of land use, and which is independent from other attributes. Attributes may refer to any defined feature related to functional land use (products or other benefits) or biophysical land use (operations on the land); they include economic and social information.

There are a large number of land use attributes. Some examples, relevant to agriculture, are land tenure, crops grown, cropping systems, use of fertilizers, irrigation, mechanization, soil conservation practices, commercial or subsistence orientation, and a variety of economic information. Lists of land use attributes are given in the FAO guidelines on land evaluation (FAO, 1976, 1984a, 1984b, 1985a, 1991) and the glossary to the *Land use database* (de Bie and van Leeuwen, 1994).

Land use attributes can be employed:

1. As a framework for the detailed description of individual systems of land use, and the definition of locally-defined land use types.

2. As a means to construct special-purpose classifications. For example, agricultural systems could be classified according to method of tillage: mechanized cultivation, animal traction, or hand tillage.

Any given area of land must be under a land use system:

> **Land use system** The sequence of operations carried out on an area of land, and the benefits obtained from it. Benefits include both products and services.

There may be multiple benefits from the use, but a given area or land can have only one land use system. This may include, however, more than one unit in a land use classification (see Chapter 7).

For the purposes of classification, the basic unit is the land use type:

> **Land use type** A specified class of land use employed at any level in a land use classification system.

A classification system is based on an ordered arrangement of defined land use types.

It would be possible to define terms such as land use orders, groups, types, for different levels of a classification (as in some systems of soil classification). In the present version, this alternative is rejected, and the levels referred to as Levels I, II, III, each made up of land use types.

In writing about land use, words are also needed that are not technical terms. It is suggested that 'kind of land use' and 'type of land use' can be both be employed in their general sense, interchangeably, to refer to whatever is indicated by the context.

<u>Associated terms</u>

The *World agricultural census* is based on questionnaire survey or sampling of agricultural holdings:

> **Agricultural holding** An economic unit of agricultural production under single management, individual or institutional, comprising all livestock kept and all land used wholly or partly for agricultural production purposes (FAO, 1986, p.17).

For more general purposes of land use survey, this concept may be expanded into that of a land holding:

> **Land holding** An area of land which is managed by users (individual, communal or institutional) for specific purposes.

Land holdings include agricultural holdings, but also units of forestry and conservation management, e.g. forest reserves, national parks. Holdings are employed for the conduct of surveys, but are not units of land use. Holdings frequently include land under different kinds of use (plots), the areas under which are specified in the survey. Farm surveys specify areas under specific crops, and also grassland, woodland, etc.

Farming systems or farm-household systems, as employed in farm systems analysis, are not units of land use.

In land evaluation and land use planning it is frequently necessary to compare present uses with those which do not presently exist but are proposed for the future. A term well-established in land evaluation methodology is the land utilization type:

> **Land utilization type** A kind of land use used as the basis for land suitability evaluation, and defined or described in whatever degree of detail is needed for the evaluation.

The somewhat artificial word "utilization" is employed intentionally, to indicate that this is an idealized form of use, described for the purpose of land evaluation, and distinct from the real, observed, land use.

Chapter 6

COMPARISON OF LAND USE AND LAND COVER

Introduction

Surveys of land cover are nowadays largely based on data from remote sensing, with control by field observation. Mapping is normally carried out inductively, that is, by commencing with the classes that can be distinguished in the surveyed area (visually or by data processing) and constructing a map legend from these. Such legends are based on classes of land cover, mapped individually where possible, otherwise in spatial combinations where necessary.

Land cover types are extremely varied, and it will continue to be necessary to include classes of local significance. However, for purposes of comparison between regions it is highly desirable that there should be a set of standard land cover types, internationally recognized, to which locally-recognized classes can be related. The arguments for a basic land cover classification are no less strong than those for a basic land use classification, and the uses to which it could be put are also comparable (see Chapter 1).

It has been suggested that land use and land cover classifications should be developed separately but in parallel (Schomaker, 1994). It is appropriate that the land cover classification should be developed primarily by practitioners of remote sensing, and this present study contains only an outline classification. This is included as a means of making clear the essential differences between land use and land cover, and to provide a basis for comparison between these.

Vegetation classification is clearly distinct from land cover classification, even though land cover descriptors are frequently included. Vegetation classification and mapping is an important element in the survey and assessment of natural resources, but is not included in the present report. Reference may be made to UNESCO (1973), Howard and Schade (1982) and Kuchler and Zonneveld (1988).

Outline of a land cover classification

An outline classification of land cover is given in Table 3. It makes substantial use of a classification which has stood the test of time, that of Anderson et al. (1976), with supplementary use of the ITC land cover classification (van Gils et al., 1991), Loveland et al. (1991), the FAO *Forest resources assessment 1990* (FAO, 1993), and the CORINE classification for Europe (Directorate General for the Environment, 1992, 1993).

The outline is by no means complete. By definition, both levels are based on the same criterion, that of land cover, Level 2 being subdivisions of Level 1. The classification will need to be amplified by detailed definitions and guidelines for recognition, and subdivision of classes at lower levels.

Table 3

An outline classification of land cover

LEVEL 1	LEVEL 2
INLAND WATER	RIVERS FRESHWATER LAKES RESERVOIRS LAGOONS (BRACKISH WATER)
SWAMP	
BARREN LAND	Subdivisions: rock, sand, ice, etc.
FOREST AND WOODLAND	FOREST WOODLAND WOODED GRASSLAND FOREST PLANTATIONS
SHRUB FORMATIONS	THICKET BUSHLAND
HEATHLAND	
GRASSLAND	UNIMPROVED GRASSLAND (RANGELAND) IMPROVED GRASSLAND
CROPLAND	PERMANENT CROPS TEMPORARY CROPS WETLAND CROPS COVERED AGRICULTURAL LAND
BUILT-ON LAND	MINING AND QUARRYING RESIDENTIAL COMMERCIAL INDUSTRIAL TRANSPORT AND INFRASTRUCTURE

Table 4

Definitions of cover classes of mixed trees and grassland

Based on White (1983).

TREE OR SHRUB HEIGHT (m)	CANOPY COVER (%)	TERMINOLOGY FOR LAND COVER CLASSIFICATION	TERMINOLOGY USED IN FOREST RESOURCES ASSESSMENT
> 7 m	> 70 %	FOREST	DENSE FOREST
	40-70 %	WOODLAND	CLOSED FOREST
	10-40 %	WOODED GRASSLAND	OPEN FOREST
< 7 m	> 70 %	THICKET	-
	40-70 %	BUSHLAND	-
	10-40 %	WOODED GRASSLAND	-
Any	< 10 %	GRASSLAND	-

A solution is suggested to one major problem, that of the classification and naming of land with a mixed cover of grass with trees or shrubs. For purposes of forest resource assessment, areas with more than a 10 % crown cover of trees are classed as forest. This, however, conflicts with the concepts and terminology of range managers and ecologists, to whom areas with substantially over 10% tree cover are still called wooded grassland, savanna, etc.

The present proposal, based on White (1983), is shown in Table 4. Tree formations are separated from shrub formations by a plant height of 7 m. Tree formations are divided on the basis of canopy cover into forest (tree canopy cover >70 %), woodland (40-70%), and wooded grassland (10-40 %). Shrub formations are separated into thicket (shrub canopy cover >70%) and bushland (40-70 %).[1] The corresponding terms employed in the FAO *Forest resources assessment 1990* are also shown, based on FAO (1993) and internal guideline documents for assessment.

Comparison between land use and land cover

In land use surveys that are based mainly on remote sensing, the diagnosis of use from cover must be widely employed. The extent of correspondence, or otherwise, between land use and land cover classes is shown in Table 5.

The association between land use and cover is close, and hence diagnosis of the former from the latter is usually possible in management of planted forests, all classes of crop production. quarrying, fisheries production, and the subclasses of settlement. In practice, the use of land for nomadic or extensive grazing will frequently be based on a land cover of unimproved grassland, although this is an inference which requires field checking. Major areas of non-correspondence, or in which use cannot be diagnosed from cover, are:

> **Land cover of forest or woodland (excluding forest plantations):** Not known if used for conservation, collection, production and multipurpose forestry, or not used.
>
> **Land cover of grassland, bushland or wooded grassland:** Not known if used for conservation, collection, nomadic grazing, extensive grazing, or not used.

It should be stressed that land cover does *not* form part of the definition of land use types, even in cases where there is a close correspondence. Land use is defined on the basis of function and operations. Many of the operations lead to change in the land cover, but for purposes of analysis and planning, the cause and effect should be kept separate.

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[1]The White (1983) classification does not differentiate formations with 10-40% crown cover on the basis of plant height.

Table 5

Approximate correspondences between land use and land cover

LAND USE TYPES	LAND COVER TYPES
NOT USED	Many possible classes; may include BARREN LAND depending on conservation status
CONSERVATION) COLLECTION)	Any class other than CROPLAND and BUILT-ON LAND
PRODUCTION AND MULTI-PURPOSE FORESTRY:	
MANAGEMENT OF NATURAL FORESTS	FOREST, WOODLAND, WOODED GRASSLAND
MANAGEMENT OF PLANTED FORESTS	FOREST PLANTATIONS
LIVESTOCK PRODUCTION:	
NOMADIC GRAZING) EXTENSIVE GRAZING)	WOODED GRASSLAND, BUSHLAND, UNIMPROVED GRASSLAND
INTENSIVE LIVESTOCK PRODUCTION	IMPROVED GRASSLAND
CONFINED LIVESTOCK PRODUCTION	AGRICULTURAL BUILDINGS
CROP PRODUCTION:	
SHIFTING CULTIVATION	Pattern of CROPLAND within FOREST, WOODLAND, WOODED GRASSLAND or BUSHLAND
PERMANENT CROPPING	PERMANENT CROPS
TEMPORARY CROPPING	TEMPORARY CROPS
WETLAND CULTIVATION	WETLAND CROPS
COVERED CROP PRODUCTION	AGRICULTURAL BUILDINGS
FISHERIES PRODUCTION	INLAND WATER
RECREATION	Recognition dependent on type of recreation
MINERAL EXTRACTION	
MINING	Limited land cover
QUARRYING	QUARRYING
SETTLEMENT and subclasses	BUILT-ON LAND and subclasses
USES RESTRICTED BY SECURITY	Land cover survey may be prohibited

Chapter 7

QUESTIONS OF MAPPING AND STATISTICS

It is common to find that an area of land, as shown on a map or represented in statistical tables, has more than one use. This situation can arise for two different reasons:

- multiple land use on a single plot;
- problems of scale, in representing spatial complexes of different uses on a map.

Multiple land use

It is common to find land used for more than one distinct purpose, that is, functional land use. These uses may take place simultaneously, at different seasons of the year, or in different years of a repeated cycle of use. Examples are a forest plantation, used for wood production and also for forest grazing; an area of grassland, used for grazing and as a camp site (recreation); and the 'taungya' agroforestry system, in which crop production occurs during the early years of establishment of a forest plantation. Multiple use is defined in terms of functional use:

> **Multiple land use** The use of an area of land for more than one significant purpose.

Multiple use necessarily also applies to biophysical land use. Two or more sequences of operations, as employed to define a class of biophysical use, may be applied to the same land area.

Multiple land use can be handled by recognizing that:

- a single *plot* can have only one *land use system*;
- this land use system may, however, include two or more *land use types*, as described in a classification system.

In a land use systems database, the complete sequence of operations, with their intended outputs or purposes, can be described. For practical reasons, however, it will frequently be necessary to assign land to one single class of use, which may be called the primary use:

> **Primary land use** The purpose of use which is the primary objective of management.

There is an inevitable element of subjective judgement in assigning a primary use. On holdings managed for economic purposes, the primary use is in principle that which contributes most to the value added, as in the *International standard industrial classification* (United Nations, 1990). However, economic data are not normally available in land use surveys. Where non-economic benefits such as conservation are included, the assignment of primary use must necessarily be a matter of judgement. Cases of conflict will certainly arise, for example between the relative importance of conservation and productive uses, although this is likely to apply only to a low proportion of the land area.

For practical reasons, most statistics and maps are likely to represent only the primary land use. For sectoral purposes, however, it may be important to know the areas under secondary uses, for example forestry areas available for forest grazing.

Mapping units

Land use and land cover are sometimes found in closely mixed spatial combinations, which it is impossible to represent individually on maps. This is a problem of mapping, not of classification.

It is handled by the definition of mapping units in a map legend. Mapping units need coincide with units of classification, although it is an advantage if they do so.

Guidance on this problem comes from comparison with the mapping of soils. Map legends make use of the soil association, an area of two or more soil types which cannot be separately shown at the scale of mapping. A corresponding unit, the land use association, could be utilized:

> **Land use association** A mapping unit consisting of two or more land use types, at any level in a classification, which cannot be represented individually at the scale of the map.

Where uses are intimately mixed over small areas, it may be necessary directly to conduct field survey in terms of land use associations. An example is common presence, in dry areas of the tropics, of scattered, small areas of crop production amid land used for grazing. In surveys, the relative areas under different land use types in an association should be estimated as percentages, and shown on map legends.

The frequent existence of land use associations gives rise to substantial problems of representation on maps. Many land use maps shown a bewildering complexity of coloured stripes, cross-shading and other cartographic devices, making them almost impossible to interpret. Comparison with the same problem in soil mapping suggests that map legibility is best obtained if, for all or most mapping units:

- one colour only is shown for the unit, the colour representing the dominant use in multiple use, or the use occupying the highest proportion of area in an association;

- other uses included in the unit should be represented by numbers of reference letter, the meaning of which is set out in the extended legend.

The *FAO/UNESCO Soil map of the world* illustrates cartographic methods by which complex spatial patterns can be shown in a legible manner.

Relating data from different sources

The combination of data from statistical sources with that from remote sensing is a question of current interest (European Communities - Commission, 1993). Established statistical data, collected by means of questionnaires, have stood the test of time. Many developed countries have statistical series extending over time. Data are given as tables, generally aggregated for administrative units. These can be mapped only indirectly, e.g. as proportional circles or bar charts.

In contrast, remotely sensed data (supported by ground observations) lead directly to the production of maps, of land cover or inferred use. The cover or use for specific locations are shown, but summaries of areas covered are not directly available for administrative units. Remote sensing can lead to considerable economies of effort and expense in data collection but the results are often not fully comparable with data from questionnaire surveys.

Data from these two sources could be made compatible if:

1. Both types of survey collect data on the basis of common classification systems for land use and cover.

2. Questionnaire statistics are collected for geo-referenced areas, either administrative units or specified census areas (comparable to those used in population surveys); and the results are made available at subnational level, as summations for these areas.[1]

3. In remote sensing surveys, the boundaries of the administrative units or census areas are transferred to the maps, and data abstracted for these.

Whilst possible in principle, the practical problems of achieving such integration are considerable. They include both technical problems, such as delineating census areas in countries with a poor cadastral basis, and problems of confidentiality in the release of subnational data. Integration of this kind has been achieved in Canada (Korporal, 1993).

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[1]To protect confidentiality, with aggregation of adjacent units containing few land holdings, as in the case of population censuses.

Chapter 8

TOWARDS INTERNATIONAL STANDARDS FOR LAND USE AND LAND COVER DESCRIPTION AND CLASSIFICATION

Description and classification

This report is a summary of the first round of discussions directed at reaching agreement on an internationally-accepted classification of lánd use. It offers only a first approximation, as a starting for future development of such a system. Certain basic principles are set out, which it is hoped will be found useful as the basis for future work. Details of the classification, however, will certainly require modification.

The next steps are discussion and testing. Discussion is needed among as wide a range of interests as possible, both among organizations responsible for the collection of land use dat and those with interests in its applications. Testing can include both desk exercises, in relating specific national or special-purpose classifications to the international classification; and field testing, by sample area surveys using all types of observation.

Opportunities for application of the system arise in the *World census of agriculture 2000* and the *Forest resources assessment 2000*. These will, no doubt, continue to employ established and tested methods, developed by experience over many years. It is hoped, however, that these surveys can be made compatible with the international classification, including through guidelines for the national surveys which are contributory to them,

In the case of agricultural land use, there is the advantage of a considerable degree of coincidence between land use and cover, such that one set of enquiries on agricultural holdings can provide data for both. For the case of forestry, compatibility will require that the present survey, which is primarily of forest cover, should be extended to include forestry as a form of land use.

At the same time as these two surveys, efforts are needed to integrate data from the agriculture, forestry and conservation sectors. Systematic data needs to be acquired on land use for settlement. For this integration to be achieved, organizational responsibility and capacity, for the coordination of information on land use as a whole, will need to be assigned.

International, or bridging, classifications of land use and land cover are one step towards achieving better integration of information. This must be supported by surveys and analysis, again on a common basis. If over coming years, such integration could be achieved, then international organizations, governments and peoples will be in a position, for the first time, to know the status of use of their land resources, as a basis for the planning and development of sustainable uses in the future.

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INDEX OF DEFINITIONS

Where two page numbers are given, these refer to definitions in terms of functional and biophysical land use, at Levels II and III in the classification respectively.