# REPORT OF THE 1st THEME TEAM MEETING OF THE INTEGRATED GLOBAL OBSERVATIONS OF THE LAND (IGOL)

**FAO, Rome, Italy**

**13-15 September 2004**

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# Introduction

## *The IGOS initiative*

The Integrated Global Observing Strategy (IGOS) seeks to provide a comprehensive framework to harmonize the common interests of the major space-based and in-situ systems for global observation of the Earth. It is being developed as an over-arching strategy for conducting observations relating to climate and atmosphere, oceans and coasts, the land surface and the Earth's interior. IGOS strives to build upon the strategies of existing international global observing programmes, and upon current achievements. It seeks to improve observing capacity and deliver observations in a cost-effective and timely fashion. Additional efforts will be directed to those areas where satisfactory international arrangements and structures do not currently exist.

## *IGOS themes*

It is not practical to attempt to define a comprehensive global system that would in a single step satisfy all the needs for environmental information. IGOS has therefore adopted a process of themes in which observations are made for selected fields of common interest among a group of partners.

The process of themes selection is based on an assessment of the relevant scientific and operational priorities for overcoming deficiencies in information, as well as analysis of the state of development of relevant existing and planned observing systems.

**The IGOS themes process involves:**

- Agreement by the Partners on a theme proposal, which must respect certain specified criteria.
- Establishment of a theme team with appropriate leadership and resources.
- Approval by the IGOS Partnership of the theme team's report, including agreement on a common set of essential observations and their technical characteristics (such as accuracy and frequency), and commitments from providers of space-based and in-situ observations.
- Establishment of an Implementation Team with the responsibility and capacity required for the long-term implementation of the necessary operational networks.
- A formal declaration of commitment to Theme Team recommendations by the governments and organizations, who actually implement, maintain and operate the relevant observing systems.
- Assessment of the value of the Theme.

IGOS provides opportunities for capacity building and assists countries to obtain maximum benefit from the total set of observations.

Additional information on IGOS and its themes can be found at: http://ioc.unesco.org/igospartners/

## *The IGOS Land Theme*

### Approval of the theme

A new IGOS Integrated Global Observation of Land (IGOL) was proposed by John Townshend, who was encouraged to develop the theme after an initial pre-proposal presentation at the IGOS-P10 bis meeting at Colorado Springs in November 2003. The proposal arose from the recognition that IGOS-P has not yet considered many observational needs relating to many aspects of the land, such as sustainable economic development, natural resources management, conservation and biodiversity.

The IGOL proposal was presented at the 14th CEOS SIT meeting (25 May 2004) and the 9th G3OS meeting (26 May 2004) and participants from both meetings indicated their support to the proposal. At the IGOS-Partners 11 Meeting (27 May 2004, details available at: www.fao.org/gtos/igos/11.asp) the IGOS-P Co-Chairs confirmed agreement for the adoption of the new IGOS Land Theme and referred the IGOL team to the IGOS Process Paper for guidance on the next steps.

The proposed main components of IGOL will be observations pertaining to: land cover and land use; human settlement and population; managed ecosystems; agriculture; pastoralism; forestry; natural ecosystems; conservation; biodiversity; sustainable use; soils, and elevation. Reliable knowledge, primarily from satellite remote sensing, of land cover and land cover change is central to most aspects of the Theme.

### Development of the theme

Since the approval of IGOL, John Townshend, co-chair of IGOL, and the GTOS Secretariat have started to plan the theme organization, activities and budget. An initial team has been formed of interested partners and internationally recognized experts (see next section). FAO, ESA, NRSCC, UNEP and USGS have already made early commitments to provide resources.

### Current IGOL Theme Team

Co-Chair: John Townshend, Chair, GOFC-GOLD, GTOS

Co-Chair: John Latham*, GTOS Programme Director

Secretariat: GTOS, FAO Head Quarters

Team members:

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|---|---|
| Dennis Ojima* (IGBP) | Alan Belward (GCOS) |
| Christiana Schmullius* (GOFC/GOLD) | Jeff Tschirley* (FAO) |
| Olivier Arino* (ESA) | Chris Justice* (GOFC/GOLD) |
| Tony Janetos (Heinz Center) | Ake Rosenqvist (JAXA) |
| Ashbindu Singh* (UNEP) | Roberta Balstad Miller* (CIESEN) |
| Jay Feuquay (USGS) | Jiyuan Liu* (CAS) |

* Present at the first meeting. The attendees of the first meeting are given in Appendix 11.

Additional details on IGOL theme can be viewed at: http://ioc.unesco.org/igospartners/land.htm

## Objectives of the meeting

The following report is the summary of the 1st IGOL Team Meeting, 13-15 September 2004, which was hosted by FAO and attended by representatives from CAS, CIESIN, ESA, GTOS, GOFC/GOLD, IGBP, JAXA, NOAA, NRSCC, UNEP and by specialists from FAO (see Annex II). The participants presented and reviewed land requirements from key international stake-holders' and programmes.

In addition national and international remote sensing plans and related programmes were presented focusing on operational capabilities and how research missions can contribute to operational capability.

The outcome of the meeting was a defined scope of the IGOL theme and an initial consensus on theme topics. The theme team also defined the theme organization and timelines (see sections below). In summary the main issues that were addressed by the participants, included:

- Defined the scope of IGOL theme and built consensus among team members on theme topics;
- Review of IGOL issues (programme relevance/context/implementation);
- Analysis of observation requirements/capabilities/gaps and deficiencies;
- Determination of the important cross-cutting issues for IGOL;
- Preparation of a draft-statement for GEOSS;
- Review land requirements of key international stake-holders';
- Examine operational capabilities and how research missions can contribute to operational capability by reviewing key national and international remote sensing plans and related programmes;
- Discuss and reach consensus on the fundamental deficiencies in measuring and monitoring land cover;
- Ascertain the need for sub-themes and who will develop them (especially for the themes that there was inadequate representation of experts attending the meeting);
- Agree on work and team organization and time lines and arrange dates and logistics for the next meeting.

## Presentations

A CD-ROM with all the presentations from the meeting can be requested from the GTOS Secretariat (GTOS@fao.org). Presentations can also be downloaded, until the end of 2005, from the GTOS ftp sever (from the folder "IGOL-2004"): ftp://FTP_Gtosr:password@ext-ftp.fao.org/SD/GTOS/

Presentations given at the meeting were in 3 main topic areas (see agenda, annex I):

1. Introduction to the IGOS theme process and the requirements in developing the IGOL theme report (presentations 01 to 03).
2. Overview of requirements, priority observations, deficiencies, and observational improvements required (presentations 04 to 14). Summary of requirements for: soils, land use, FAO global Forest Resource Assessment, Global Land Project, socio-economic and poverty mapping can be found in Annex III.
3. Current operational capabilities which can provide a contribution to the IGOL requirements (presentations 15 to 22). Status of global topographic data and the validation of global data sets can be found in Annex IV.

# Working groups and discussion

## IGOL Issues

After the introductory presentations working groups were formed to develop the initial outline of the IGOL theme. The following discussions and results were obtained.

### Relevance

The IGOL theme should have emphasis on societal benefits and the associated underpinning science. It should consist of variables and measurements required for land and resource management and be responsive to Conventions and assessments. Global observations must have relevance at both the national and local level.

### Programme context

It is recognized that the IGOL theme has commonalty with the other IGOS themes. This is seen as a strength, since the IGOL theme contains the baseline variables to many of the other themes (e.g. carbon, hazards, water). The IGOL theme will tie closely with the GEOSS process and the appropriate topic areas will be developed to support the GEOSS socio benefit areas, in particular ecosystems, agriculture and biodiversity. Although the coverage of the observations will be global the scale of the analysis will be at the local level. A time frame of objectives and implementation should be developed for 2-years, 6-years and 10-years time scales.

### Implementation background

Science programmes are evolving and can provide insights into improved methods of analysis, new indicators and new data needs. There are multiple approaches for assessment and monitoring and reporting of the same phenomena, IGOL will therefore need to be inclusive and responsive. In addition there will be need for independent evaluation of the different methodologies for collecting and utilizing observations. Ultimately the outputs need to be relevant to policy and decision-making at the national and local level. IGOL should therefore adopt the approach of first analyzing policy requirements and then determining the data needed, rather than starting with land cover methods and then investigating how they can be used. Support to the IGOL theme must ultimately come from National Governments it is therefore essential that the observations are relevant. In addition it will also be important to provide adequate capacity building at the national and local level to allow the proper use of the data.

International Conventions are providing new requirements on data collection and information from national governments and international agencies and international science mechanisms are starting to guide these Conventions. IGOL should assist in meeting these new requirements as well as supporting any additional developments, for example Europe ‘directives’ are starting to change data collection and reporting at the local and national level.

IGOL should also consider the difficulties, which may be encountered by international programmes being implemented by UN agencies which can be sometimes constrained by the UN System, e.g. national submission and endorsement of information. In addition the constraints and problems of the space agencies should also be considered.

## *IGOL scope of discussion*

The IGOL theme is more associated with development and policy compared to the other IGOS themes. IGOL focuses on the human influence on the environment and *vise versa*. The theme team need to focus on the observations and recognize that requirements are set in the context of the eventual analysis and use. Fundamentally the observations collected should be of relevance to policy makers. One approach maybe to establish champion users to clearly define and refine observation needs. Consideration will also be needed on the balance between the different topics (land use / soils / managed ecosystems) and which variables need to be measured. Consideration will also be needed on the type of topic areas (could be possible divide into broader – physical / anthropogenic / ecosystem condition). Once the variables and observations have been identified it will be important to establish for each one the frequency and accuracy that needs to be made.

Socio-economic data should be an important component of IGOL and should not be restricted to human settlement and population. Roads/infrastructure, land tenure and the integration of socioeconomic components under other topics should all be considered. The recently prepared coastal GTOS implementation plan provides examples of relevant socioeconomic variables.

From the preliminary discussions a number of possible structures (topic areas) were considered but eventually, even though still not completely satisfactory, the following draft topic areas were developed:

- Land cover and land cover change (including water bodies, wetlands and albedo).
- Land use and land use change (including sustainable use and management):
    - Urban / Human settlement and population (including urban and civil, transportation infrastructure, roads, impervious surfaces, population density),
    - Agriculture,
    - Rangeland,
    - Forestry,
- Soils (including soil degradation?).
- Conservation and Biodiversity. (including wetlands and other issues related to human health)

  The major concern is that this does not address Ecosystem Goods and Services, it was felt that maybe Ecosystem should be at a higher level.
- Elevation / Physiography.

Once this initial outline was developed breakout sessions were held to further develop the individual topic areas. The discussions were based on requirements, current capabilities, gaps in observations and deficiencies. The following sections summarize the outcome of the discussions.

## *Land cover and land cover change*

There are a number of deficiencies in monitoring land cover which need to be addressed, of major concern are:

- Requirements:
  - Spatial resolutions (Mod/High/Very High – optical microwave );
  - Temporal resolution (NRT, hotspots, annual coverage);
  - Current capabilities.
- Perceived gaps.
- Issues of how to implement strategy (costs and resources).

An overview of policy drivers at European, National and Local level, related needs, existing capabilities and identified bottlenecks can be found in the document "SAGE Service Definition Phase U5 - Core User Needs Dossier" produced by ETC-TE on behalf of the SAGE Consortium in the framework of ESA's GSE initiative.

## *Land Use*

IGOL needs to fist determine a standardized characterization of the land use types (for example using LCCS of LU or something equivalent).

For the land use change the objective is to achieve global annual monitoring linked to land cover. For specific areas of interest *in situ* sampling and validation: e.g. 1:2 000, 1:10 000 will be carried out. It is recognized that during the initial start up phase of the initiative monitoring may need to be less frequent or at a lower resolution until the high resolution global monitoring system is in place (see section below on current deficiencies in high resolution observations).

The IGOL system will complement and harmonize the existing observations which already include: irrigated land, protected areas, forest, crop land and grazing land areas (yield and production, cultivation intensity, biomass), farming systems, water impoundments (includes water bodies such as wetlands), etc.. Examples of proposed new observations include: plantations and build up areas (urban/road/recreation etc., see appendix IV for examples).

Overviews of identified needs to fulfill Kyoto protocol requirements, at European national level, existing capabilities and proposed products and services based on EO data can be found in the documents "TESEO – Carbon Preliminary Report" (VTT, EFI, Gamma and Forest Consulting Oy Ltd) and "KYOTO-INV Services for the Kyoto Protocol Verification" (Intecs, Bodata, Dataspazio, GAMMA RS, NEO, Planetek, Telespazio, UniTN) produced in the framework of ESA's DUP/DUE programme.

### Socio economic context

A socio economic component will also be considered in the land use topic. Possible observations could include:

- Management level;
- Institutional responsibility;
- Services and benefits;
- Inputs e.g. fertilizers, labor, mechanization, technology;

- Product: Land use change;
- Degradation and disturbance.

### Land Use - Human settlements and populations

The following observations and variables were considered for the subtopic of human settlements and populations:

- Population distribution including density and ambient/residential;
- Impervious surface area (sealing), including height and density of structures (leading to earthquake risk assessment, L4);
- Infrastructure: transportation network (streets, roads, railways, etc.).
- Physical boundaries of settlements;
- Administrative boundaries;
- Land use within settlements;
- Land tenure;
- Derived L4 Products;
    - Spatial distribution of economic activity – gross domestic product,
    - Vulnerability (or exposition to hazards) (flooding, fire, earthquake, landslide, etc.),
    - Spatial distribution of emissions – related to air quality,
    - Quality of physical environment/life (distribution of roads, noise, air quality).

### Agriculture: Food Security

Observations that were relevant to agriculture and especially food security were considered to be an important element of the IGOL initiative, especially considering:

- there is a high stakeholder interest in food security;
- well documented observations are required;
- food security is closely linked with climate;
- the available *in situ* observations are better for agriculture than for other topics;
- there is a good remote sensing relevance and satellite data is required: geostationary, consistent time series;
- data integration is critical required by the end user.

## *Soils*

In the past soil observations have not been given a high priority although recently this has improved in Europe. Although the observations are mainly at the *in situ* level, some remote sensing data can be of use (e.g. topography, land cover and land degradation).

The Global Soil and Terrain Database (WORLD-SOTER) which is a joint initiative between FAO, UNEP, ISRIC, IIASA, European Soil Bureau and National Soil Institutes has the following main objectives:

1. To provide sound Soil and Terrain Resources Information on a global scale (1:5 Million). Users: Global and Continental models to simulate food production potentials, climatic change, river flow simulation, livestock distribution, research priorities, land constraint and (very) general land management advice.
2. To provide an educational tool to the Soil Science Community.
3. To provide harmonized norms for soil mapping, soil classification, soil analysis and interpretation of soil resources information

Mr Nachtergaele (FAO) indicated that SOTER would very much welcome the support of IGOL. He also estimated that an additional US$500,000 would be sufficient to complete the mapping of SOTER. The planned next steps are to develop more complete global time series which are will be more integration with other observations (e.g. land use and socio-economic data) and additional more detailed observations at the national level.

For additional details see: www.fao.org/ag/agl/agll/soter.htm.

Also see appendix III for requirements of the soil community from IGOL

## *Land Degradation – do be determined if to be included in IGOL*

Land degradation has a high priority in many venues, especially the United Nation Convention to Combat Desertification (CCD, www.unccd.int/main.php), so there is already an established stakeholder community.

The FAO Global Land Degradation Assessment (GLADA, www.fao.org/ag/agl/agll/lada/gladamap.stm) has recently been approved and is being implemented. The project will include GIS techniques and improved land degradation mapping as well as the identification of "hot spots" in dryland areas. The project will also carryout investigations on soil erosion and develop a photo reference library.

Remote sensing data could play role in: vegetation productivity/yields and land cover change, topography and invasive species and disturbances. GEOSS water social benefit area and the IGOS water theme should be reviewed for required observations on water resources and land degradation. In addition FAO and UNEP documents should be reviewed.

An overview of needs derived from UNCCD, expectations and existing capabilities at national level over a set of countries can be found in the document "USER REQUIREMENTS DOCUMENT - DESERTWATCH)" contained in an ESA Statement of Work produced in the framework of the DUP/DUE programmed.

### Biodiversity and conservation observations

There are already a large number of biodiversity initiatives. The first step is therefore to examine existing requirements, in particular those of the:

- Convention on Biological Diversity (CBD, www.biodiv.org/welcome.aspx) including its Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and its Conference of the Parties (COP)
- Millennium Ecosystem Assessment (MEA, www.millenniumassessment.org/en/index.aspx )
- Group on Earth Observations System of Systems (GEOSS) biodiversity social benefit area (http://earthobservations.org/).
- DIVERSITAS, which is the international programme of biodiversity science, integrating biodiversity science for human well-being (www.diversitas-international.org).

The topic will have to be further addressed by individuals with the relevant expertise, but it was felt that IGOL could make a significant contribution in this topic area (e.g. land cover/land use, special fragmentation, disturbance, invasive species, etc.).

Requirements derived from the Ramsar convention and expressed at national level for a set of key users distributed over the world are described in the document: “USER REQUIREMENTS DOCUMENT – GLOBWETLAND” contained in an ESA Statement of Work produced in the framework of the DUP/DUE programme.

### How to deal with sub themes

Due to the complexity and extent of the IGOL topics there was some discussion between participants on the need for sub-groups to develop the individual topic areas. Although this issue was not resolved it was agreed that IGOL should attend specific meetings (e.g. on biodiversity, soils, etc.) to obtain guidance from the different specialised communities.

### Cross cutting issues

There are a number of common issues that need to be addressed for all the IGOL topic areas, these include:

- Long term archiving and retrieval, which is also required for monitoring change.
- Funding required for the re-analysis of data.
- Dynamic continuity of products (multi-source).
- Product Validation (standards, protocols, and data free availability).
- Balance between in-situ and satellite support.
- Harmonization of classification systems, data formats and projections.
- Data integration /assimilation (modeling):
  - Most data products are used in concert;
  - Multidisciplinary / Expertise.
- Commercialization issue:
  - Environmental data as a public good vs. commercial opportunity;
  - Cost / benefit of the observations (the real market for the data);

- Involving the commercial sector / competition / quality;
- Privatization of environmental data, including satellite data.

- Capacity and sustainable infrastructure for data use and monitoring (at national and international level).
- Socioeconomic data and privacy.

## Current obstacles for IGOL implementation

### Technical

- Coverage and Availability of current data:
  - Needs to be in a user friendly format;
  - Data could be available (Spot, IRS, etc.) for global high resolution mapping;
  - Consensus on the methodology used;
  - Consensus methodology for validation of products.
- Processing

### Financial

Donors (interested user group) need to be identified to support the IGOL theme. The estimated cost of implementation needs to be calculated.

### Institutional

- There is currently no institutional mechanism or responsibility for implementation.
- There is limited institutional capacity for global wall to wall monitoring (e.g. Earthsat).
- Centralized versus distributed production.
- There is uncertainty on the continuity of data provision.

## Initial draft statement for GEOSS

There are strong cross links between the IGOL topic areas and the nine GEOSS social benefit areas (disasters, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity). Careful examination of GEOSS documents and the other IGOS themes should be carried out to insure that IGOL provides the required observations to GEOSS and the other user groups.

The following outline was developed for the preparation of a statement for submission to GEOSS.

### Early Identification of Critical Gaps

- Global high resolution wall to wall map, annual, multiyear, land cover and land cover change:

  - Ensured Data Continuity - operational Landsat Class verses equivalent LTAP;
  - Missions or coordinated international acquisition prior to 2010;
  - Enhanced data access (cost issue);
  - Enhanced hyperspatial data availability (commercial systems).
    - Kyoto Goal - systematic global, . 5ha, 10m, 24hr revisit e.g. Rapideye – LULCF
- NRT/RR/Alert/ Detection e.g. LCC/Disturbances/Crop condition (hrs)
  - Including fire. Floods, drought
  - Including early warning of crop pests and drought
    - (High Temporal, SAR Soil Moisture/Hyperspectral Condition and Pests)
- Multi-stage Sampling of Global Land Use (inc. In-situ, RS Land Cover)
- Global 30m DEM
- Urban and Rural Settlement and Infrastructure Products
  - Enhanced, georeferenced, disaggregated (gridded) population data
- Enhanced capacity to process, assemble, analyze observations from multiple sources (satellite and in-situ (including socioeconomic)) by
  - National RM agencies
  - International organizations
- Development of improved Agricultural Monitoring
  - Seasonal/Annual - crop acreage, cropping type, types and distribution, crop growth condition and yield (combination of optical and microwave issue of SAR continuity)

## *Action items*

### Next meetings, team organization and tentative schedule

- Summary Requirements from IGOL (1-2 page) to be submitted by: Ergin Ataman (poverty mapping); Freddy Nachtergaele (soils); Hubert George (agriculture maps); Mohamed Saket (FAO, Forest Resource Assessment) and Roberta Balstad Millar (Socio-economic requirements including results of IGOS/ICSU meeting). All submitted and in appendix III.
- Doug Muchoney to submit the current capability of elevation data: global, gaps, data availability, etc. outside US. Submitted and in Appendix IV.
- John Townshend to contact Bob Scholes and Salvatore Arico to investigate the possible participation of IGOL at the Paris biodiversity meeting in January 2005, including a possible side event. GTOS Chairman, Mr Berrien Moore, will also contact the conference organizers on his next trip to Paris.

- IGOL Chairs and GTOS Secretariat to develop a statement on enhancement needs which includes an introduction on the benefits if IGOL including the synergies with the implementation of the GEOSS strategy document. Get consensus on drafts by December/January.
- GTOS Secretariat to prepare a standard set of IGOL slides to be used by team members.
- GTOS Secretariat to prepare an IGOL webpage and will populate the IGOL land theme page on the IGOS website (http://ioc.unesco.org/igospartners/land.htm).
- ESA to develop IGOL logo and to provide access to GMES and DUE projects User Requirement Documents, such as:
    - TESEO-Carbon: Preliminary Report,
    - Kyoto-Inv: User Requirements Document,
    - DESERTWATCH: Statement of Work, Annex A: User Requirements Document,
    - GLOBWETLANDS: Statement of Work, Annex A: User Requirements Document,
    - GMFS -Global Monitoring for Food Security: Core User Needs Dossier,
    - SAGE: Core User Needs Dossier.

- Freddy Nachtergaele (FAO) to provide details on suitable meeting during the next few months where the soils requirement could be more broadly discussed.
- Reuben Sessa (GTOS Secretariat) to prepare the report from the First IGOL Meeting by late October or early November, the document should be reviewed by Chris Justice before distribution to the IGOL theme team.
- GTOS Secretariat to extract from project documents and summarize the needs and requirements of existing programmes for IGOL (projects on biodiversity, soils, land degradation, food security, health, wetlands and including the requirement assessments done for GMES and DUE). Circulate for review by December 2004.
- Decide if additional ad-hoc sub theme meetings are needed (e.g., soils, biodiversity)
- GTOS Secretariat to examine the reports of the other IGOS themes to identify cross-cutting research/observations areas relevant to IGOL.
- GTOS Secretariat to analyze the requirements of the nine social benefit areas of GEOSS (examine 10 year implementation plan).
- John Latham at the next GTOS Steering Committee should explore the potential relationship between *in-situ* networks and IGOL, i.e. the potential contribution that ILTER could contribute to IGOL.
- There should be an increase in developing country participation in IGOL. Ashbindu Singh and John Townshend will propose additional participants. The FAO, Global Land Cover Network (GLCN) will contribute by requesting inputs from its networks and workshop participants.
- IGOL Chair and GTOS Secretariat to develop an initial outline of the IGOL report and circulate for discussion, teleconference should be held in December/January to refine the scope of IGOL and to reaffirm theme team individual commitments and insuring that IGOS process is being followed.
- Writing assignments should be assigned to Team Members to draft specific sections of the report (during December to February). Manuscripts should be circulated before the 2nd IGOL meeting (which should be held in March/April of 2005).

- John Townshend to organize the next theme team meeting, which should be held in March or April 2005[1]. Offers to host the meeting have been received from USGS/NRSCC/ESA. Issues that should be addressed at the meeting should include:
    - Review, refine and merge early draft sections of the report;
    - Initiate the preparation of the final draft of the report (April/May/June);
    - Discuss self-evaluation criteria for IGOL.

- First Draft of IGOL Report to be completed by July ’05 and final document should be submitted by December 2005.

[1] It should be noted that some participants considered the time between meetings too long, which might cause a loss of momentum.

# **Appendix I** Workshop agenda

| **Monday, 13 September** |
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## Introductions and preliminaries

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| **14:00** | Introductions and welcome | *J. Tschirley* |
| | The IGOS-P Theme Process | |
| **14:10** | IGOS-P background | *J. Tschirley* |
| **14:20** | Consideration of examples of Theme Reports | *C. Justice* |
| **14:30** | An outline of IGOL | *C. Justice* |

## Overviews of requirements

Presenters should be aware that the final IGOL document should be relatively concise if it is to be a useful high-level strategic document. Past experience has shown that long "shopping lists" of numerous variables is unlikely to be of value. Try and focus therefore on the intersection of the following sets:

I. *high priority observations*
II. *observations where there are clear marked deficiencies.*
III. *observations needing improvements where it is clear what is required to substantially improve them either technically, organizationally or in terms of policy changes.*

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| **14:45** | UNEP and Millennium development goals | *A. Singh* |
| | GOFC/GOLD requirements for land observations | |
| **15:00** | Land Cover | *C. Schmullius* |
| **15:15** | Fire | *C. Justice* |
| **15:30** | **Coffee** | |
| **15:45** | IGBP requirements for land observations | *D. Ojima* |
| **16:00** | GCOS/GTOS TOPC | *C. Justice for A. Belward* |
| **16:15** | Session summary and discussion | |
| **17:00** | **Session close** | |

| **Tuesday, 14 September** |
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| **9:00** | Biodiversity and conservation requirements | *C. Justice* |
| **9:15** | Status of soil information world wide | *F. Nachtergaele* |
| **9:30** | Requirements for socio-economic observations | *R. Balstad Miller* |
| **9:45** | Agro-MAPS: A global spatial database on sub-national land use statistics | *H. George* |
| **10:00** | Forest Resources Assessment | *M. Saket* |
| **10:15** | Land applications and requirements for agriculture | *J. Latham* |
| **10:30** | **Coffee break** | |

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| **10:45** | Other requirements (discussion) | *J. Townshend* |
| **12:00** | **Lunch** (12:00 – 13:30) | |

## Capabilities

The emphasis in these presentations should be either on operational capabilities or how research missions are likely to make contributions to operational capability. One-off systems to carry out process research experiments are not really relevant.

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| **13:30** | Update on European remote sensing plans | *O. Arino* |
| **13:45** | Update on US remote sensing plans | *C. Justice and J. Townshend* |
| **14:00** | Population and urban land use from space | *C. Elvidge* |
| **14:15** | Japanese remote sensing plans | *C. Justice* |
| **14:30** | Chinese remote sensing plans | *C. Justice* |
| **14:45** | Update on availability of digital topographic data sets | *D. Muchoney* |
| **15:00** | Poverty mapping initiative | *E. Ataman* |
| **15:15** | **Coffee** | |
| **15:30** | Discussion of needed break-out groups | |
| **17:00** | **Session close** | |

**Wednesday, 15 September**

## Future work to complete the IGOL theme

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| **9:00** | Break-out sessions (coffee 10:30 - 10:45) |
| **12:30** | **Lunch** |
| **14:00** | Report back from break-out groups |
| **15:30** | **Coffee** |
| **15:45** | Scoping IGOL: what to include and what to exclude |
| **16:45** | Next steps |

Date and location of next meeting
Any other business

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|---|---|
| **17:00** | **Close of meeting** |

# **Appendix II** List of workshop participants

## *External participants*

| | | |
|---|---|---|
| Olivier **Arino** | ESA | Olivier.Arino@esa.int |
| Chris **Elvidge** | NOAA | Chris.Elvidge@noaa.gov |
| Wang **Hong** | NRSCC | wanghong@nrscc.gov.cn |
| Chris **Justice** | University of Maryland | cjustice@umd.edu |
| Jiyuan **Liu** | IGSNRR | liujy@igsnrr.ac.cn |
| Roberta Balstad **Millar** | CIESIN, Columbia University | roberta@ciesin.columbia.edu |
| Doug **Muchoney** | USGS | dmuchoney@usgs.gov |
| Dennis **Ojima** | NREL - Colorado State University | dennis@nrel.colostate.edu |
| Francesco **Palazzo** | ESA | Francesco.Palazzo@esa.int |
| Christina **Schmullius** | Friedrich-Schiller-Universität (FSU) | c.schmullius@uni-jena.de |
| Ashbindu **Singh** | UNEP | ashbindu.singh@rona.unep.org |

## *Staff of the Food and Agriculture Organization participants*

| | | |
|---|---|---|
| Ergin **Ataman** | SDRN | ergin.ataman@fao.org |
| Juan **Fajardo** | AGPS | juan.fajardo@fao.org |
| Hubert **George** | AGLL | hubert.george@fao.org |
| Kailash **Govil** | FORM | kailash.govil@fao.org |
| John **Latham** | SDRN | John.Latham@fao.org |
| Freddy **Nachtergaele** | AGLL | freddy.nachtergaele@fao.org |
| Mohamed **Saket** | FORM | mohamed.saket@fao.org |
| Reuben **Sessa** | SDRN | reuben.sessa@fao.org |
| Rio **Tanabe** | SDRN | rio.tanabe@fao.org |
| Jeff **Tschirley** | SDRN | jeff.tschirley@fao.org |

# **Appendix III** Requirements from IGOL

## *Priority soil measurements required from IGOL*

**Input: Mr Freddy Nachtergaele, AGLL, FAO**

Soil is an important inherent part of the land and therefore should be a prime consideration in IGOL. However, the importance of soil has been diluted in so far that is often neglected when describing the ecosystem, while observation systems can only partially characterize it.

Other problems related to global soil inventories include:

- Nations are not easily convinced of their interest to contribute to global soil inventory efforts. International mandates to harmonize clash with national priorities (scale issues).
- Soil/land is a national property, trans-national implications are difficult to grasp.
- Funding for soil inventories is difficult to obtain.
- Harmonization of analytical methods, mapping methods and classifying soils has been difficult to achieve although great progress was made over the last 5 years.
- Soil information is often protected by copyright and distribution rights.
- Soil information in classical form (maps/soil profiles/parameters measured ) is not geared to provide a good base for monitoring purposes, because most of the information is gathered over time (40 year period) and different quality of information is mixed in the same map/database.

Present state of the art of soil inventories

- The FAO soil map of the world at 1: 5 Million scale (5 mins resolution) remains 23 years after its publication, the only harmonized global dataset on soils.
- Harmonized more detailed datasets are regionally available in SOTER format but are still incomplete. Completing Global SOTER should be a priority (to be supported by IGOL), but lacks resources at the moment.
- ISRIC's WISE-2 soil profile database is the most comprehensive one containing nearly 10 000 soil profiles, most of them georeferenced, but the profiles are unevenly distributed geographically and large areas (Russia, China) remain without punctual soil information.
- An increasing problem with data availability linked to a misguided "protection" of research results by stringent copyright and distribution provisions, particularly in Western Europe but also in other parts of the world hampering expansion and renewal.
- Soil Maps, SOTER databases and WISE soil profile databases cannot be used as Base line soil information but they are extremely useful for extrapolation of results when (stratified) sampling schemes are proposed.
- Soil monitoring where undertaken is a slow and expensive process. Little agreement exist to-date on which parameters to sample as a priority and under which sampling scheme. The TEMS scheme is one example but is not systematic nor universal.
- The LADA (Land Degradation Assessment in Drylands) project may provide supplementary soil and land degradation data in a systematic way.

Remote sensing products and derived information are since a long time well appreciated tools in soil inventories and land degradation assessments. The main RS information as far as monitoring of land and its quality are concerned, are related to information on land cover, topography and, since recently, information on population and population density.

Land cover and topography are two (of the six) of the main soil forming factors and are used routinely to derive the mapping boundaries of soil bodies. However, soil characterization as such, in spite of some very interesting results obtained with spectral analysis, is really mainly based on in-situ observations and sample analysis. Available RS products, in particular the DEM with 90 meter resolution, are presently investigated to be introduced in SOTER (Soil and Terrain Database) and will enormously improve the terrain part in the World SOTER inventory. RS will also be a very important tool in the upcoming global (dryland) land degradation assessment (LADA) where particular land cover changes, wind erosion and major land slides are benefitting from RS tools. IGOL, if it is able to provide higher resolution images in direct support of better land use and socio-economic characterization and some physical factors (e.g salinization) will also be an important factor to better define land degradation and its causes.

IGOL could do a lot to enhance the importance of in-situ observations. The establishment of a modest (1 degree, 30 mins or 16 km or whatever low resolution) world-wide grid of observations with common analysis of land use, land cover and soils (and socio economics already partly included in Land Use) would benefit several scientific communities. It would also form the basis for a systematic monitoring system of the environment.

## *Priority requirements of the Global Forest Resources Assessment (FRA)*

**Input from: Mr Mette Loyche Wilkie, FORM, FAO**

The Global Forest Resources Assessment (FRA) has been carried out by FAO since 1947. Traditionally, FRA has presented reports on 10 year intervals, but lately the COFO has mandated 5-year updates. Currently, information is collected for FRA 2005 that will be published during 2005.

The main data sources for the FRA are country reports. A network of country correspondents assures an active country participation in the compilation of the reports and validation of country data. The country ownership of the information is one of the FRA fundaments.

Of particular interest for FRA are estimates of changes in land use and land cover. Country information collected over the years has provided a long time series of land-use and land cover information. These have been complemented by special studies based on satellite image interpretation for regional estimates on land use change.

The IGOL framework may serve FRA in various ways. First and foremost, it can be used to facilitate continuous regional estimates of land cover, land use and land use change. It may also provide complementary information for land use and land cover for individual countries.

Another possible area of collaboration could be a closer coordination of data collection and data processing. In particular, FRA would benefit from integrating variables related to forest resources in global efforts of satellite image interpretation.

In order to facilitate an easy exchange of information, it is of utmost importance to harmonize classifications, terms and definitions. FRA is already taking part of ongoing international processes on harmonization of terms and definitions for international reporting.

## *Priority maps required for Poverty Mapping*

**Input from: Mr Ergin Ataman, SDRN, FAO**

All the maps listed below are global maps for the current year statistics and at the scales/resolutions stated below unless otherwise specified:

**Vector format maps** in 4 different scales: 1: 1 Million, 1: 5 million, 1:10 million and 1:25 Million

**Raster maps** in two different resolutions: 30 arc-second and 5 arc-minute

1. Standard coastlines and country boundaries (in vector format. UNGIWG is already working on these maps)
2. Standardization of the raster version of the vector maps in 1 for two pixel sizes: 30 arc-second and 5 arc-minute
3. Population density for at 30 arc-second raster (essentially update of LandScan or CIESIN GPW)
4. Population density for the year 2015 at 30 arc-second raster (essentially update of the CIESIN/FAO "Population density for 2015" map)
5. Rural/urban splits of 3 and 4
6. Population centres (names, and population and exact lat/long)
7. Percent agricultural population components of maps 3 and 4
8. Agricultural economic (or production ) value of pixel in PPP$
9. Four land-use maps: Croplands, forest, pasture and other lands at 30 arc-second raster;
10. Crops potential and actual distributions at 30 arc-second raster ( only major crops)
11. Irrigation at 30 arc-second raster
12. Roads/rails in vector at 1: 1million (with comparable attributes across countries)
13. Subnational boundaries at second admin level

## *Priority measurements in the area of land use*

**Input from: Hubert George, AGLL, FAO**

Addressing real needs for land use information

IGOL data collection in relation to agricultural land use should be focussed on addressing real and anticipated development needs by countries, particularly developing countries whose economies are dominated by the agricultural sector. A convenient reference framework for the global development community summarizing needs and priorities is the 2000 Millennium Development Goals (MDGs). Many bilateral and multilateral funding agencies and NGOs have already aligned their priorities to meeting the MDGs. It would therefore be appropriate for the land-use related measurements of a global initiative such as IGOL to support activities aimed at meeting these goals. Two goals are directly relevant to agriculture: Goal 1: Eradicate extreme poverty and hunger, and Goal 7: Ensure environmental sustainability.

Progress in these goals can be achieved through the expansion of agricultural areas and/ or the intensification of agricultural practices in a sustainable manner. IGOL measurements should yield information that supports decision making, particularly at policy-relevant scales, in these two critical areas.

Land related measurements

Land-use information includes a characterisation of the purpose (e.g. for specific material and/or immaterial benefits) of land management activities carried out by humans on the land as well as characterisation of those land management activities (e.g. use of inputs as well technologies). Only some broad land-use characteristics may reliably be inferred from satellite imagery (such as certain upper level classes specified in the IPCC good practice guidelines – e.g. forest land, cropland and rangelands/pasturelands). More detailed specification of land-use purpose and associated management (as well as the socio-economic context of land use) requires more costly ground surveys. These considerations are the basis for the following proposed scheme of measurements.

2. small scale, global, wall to wall map of broad land use classes;
    - using highest-resolution imagery (select resolution that is feasible to interpret within an acceptable time frame).
    - Frequency – every 5 years (or more frequently in sub regions of rapid land-use change)
3. in-situ global area frame sampling of land use using as guidance for data collection a flexible, land use characterisation system based on land-use purpose and land management (under development).
    - Using high resolution (<1m) IGOL imagery to support the in-situ operations (e.g. field orientation and data collection, planning, ..).
    - Frequency - every 5 years, but more frequently in zones of rapid land-use change, in response to country needs.
    - Sampling intensity - to be determined by the effort required and cost (e.g. primary sampling units for the LUCAS project for EU are spaced at regular 18km intervals). Sampling intensities could be increased in response to country needs.

## *Priority measurements in the area of socioeconomic requirements*

**Input from: Ms Roberta Balstad Miller, CIESIN, Columbia University**

1. Purpose of land observations

   Purpose of land observations is understanding whether the objective is science or policy.

   - That is, the goal is to understand patterns of land cover/land use (including successive patterns of land cover/use over time) and to understand the dynamics or causes of land use/land cover change (and their consequences).
   - Both types of understanding require socioeconomic observations of land use and anthropogenic influences on land use in addition to biophysical observations of land.

2. What influences land use?

   a. **physical conditions**, including soil, rainfall, etc.
   b. **ecological conditions**, including patterns of ecological succession.
   c. **population**, including population size, distribution, market location and demand, consumption patterns (another way to think about this is "demand").
   d. **transportation** (e.g., access to markets via roads, shipping capacity, communication of market information, bridges/fords).
   e. **institutional and civil framework**, including government rules, regulations, and actions (e.g., taxes and tax policies, war/conflict, land grants).
   f. **social and technological framework**, including social and agricultural practices, customs, technologies (e.g., farm machinery, irrigation, dams, fertilizers, etc.).

3. Types of socio-economic data by origin

   a. **spatial boundaries**: political and administrative, as well as ecological., hydrological, geophysical.
   b. **demographic**: population and vital statistics (including morbidity, mortality, migration). Often obtained through enumeration censuses, national registration systems, or probability samples.
   c. **administrative data**: can be governmental or commercial and can include data on energy use, taxes on production or sales of agriculture.
   d. **survey data**: generally obtained for portions of a population and generalized to the entire population. This is often accomplished by the use of probability samples that provide a high degree of accuracy in generalizing to total population.
   e. **remote sensing**: though its use is not widespread among social scientists, this is a data source of growing importance for socio-economic analysis.

4. Characteristics of socioeconomic data

   a. The quality of the data is generally excellent and they have been collected and preserved for decades (and in some cases, centuries) so that many of these data can be used for analysis over long periods of time.

b. Socioeconomic data are produced by "social observing systems" that are generally administratively separate from climate or land observing systems. They also have different collection, preservation, and distributional strategies.

c. These data are subject to privacy and confidentially restrictions. Social scientists have worked out ways to get the most analytic power out of the data even in linked data sets without revealing the specifics of data on individuals.

5. Differences between socioeconomic data and geophysical or ecological data

a. Most socioeconomic data can be classified as "level one", and there is very limited financial and institutional support for producing higher level databases.

b. For most data, the base analytic and collection unit is the political or administrative jurisdiction (e.g., nation, state, municipality, settlement).

c. Textual and event data can be important but are difficult to incorporate into quantitative models; they are generally capable of being presented spatially.

d. Integrating socio-economic and biophysical data is complicated by vocabulary. The categories and terminologies used in the social and biophysical sciences differ. E.g., does *in situ* apply to all ground-based data, including demographic data? Can we use "sensor" metaphorically in speaking of socio-economic data? Can an institution and its practices be called an "observing instrument?" Terminological differences often impede cross-field data integration.

e. In the natural and physical sciences, scientific data are adapted to policy uses and requirements (this is a goal of IGOS). But many socio-economic data are initially produced for policy and administrative purposes and are then adapted for scientific research.

6. Requirements for integrating data for science and policy

a. Data must be comparable

i. This is easiest when there are common metrics, such as in economics, where the monetary currency becomes the unit of analysis, or in demography, where humans are the base unit of analysis.

ii. Data must also be comparable across political units. This is easiest within countries, since many socio-economic data are obtained on a national basis. But comparability is also needed across multiple local levels, across countries, and for trans- or multiple boundary regions.

b. Data bases must be capable of integration across and within units. Space is probably the best way to integrate various types of data. There is also a need to be able to aggregate data across space and to disaggregate data.

c. We need a better understanding of anthropogenic influences on and interactions with land and land processes.

d. We need data at multiple time periods. "Time" and time-related characteristics and events are importance influences on human behaviour.

## 7. Proposed approach

Start with what we do well and place markers in the IGOL report for what we need to learn to do.

We do well:

- Population
- Population distribution and density
- Urban settlements
- Boundaries

We have the capacity to complete databases on:

- Roads
- Poverty (demand)
- Hunger
- Trade
- Government rules, regulations related to land use
- Customary land use practices

We need to improve our capacity in several areas, frequently in relationships among available and needed data to particular types of land use/land cover. Specifically, we need spatially arrayed data on the following:

- Policy and land ownership (e.g., land tenure, collectivization, clan ownership, private property, primogeniture);
- Agricultural practices, customs, technologies;
- Disturbances (political, civil, climate/weather).

We also need data on socio-economic disturbances or events that alter land use/land cover, e.g., war, internal political revolution, famine, colonization.

## *Requirements of the Global Land Project*

**Input: Mr Dennis Ojima, NREL - Colorado State University**

A summary is provided of the essential data sets that the Global Land Cover Project would like to see observed on a routine basis.

See GLP science plan draft document at: www.glp.colostate.edu/scienceplan.pdf

Critical data bases

- Disturbance and Extreme Events
- Land Use
- Built areas (Urban-rural gradient)
- Wetland (water bodies, inundated areas: seasonal to permanent))
- Snow-water-ice
- Permafrost area

Disturbance and Extreme Events

Despite the large impact that such events have on ecosystem structure and function, there does not currently exist a spatially and temporally explicit database of extreme disturbance events. Similarly lacking are adequate data on the impacts that such events have on ecosystem structure and function. Quantification of nonlinear feedbacks and cross-scale interactions, as well as identification of critical thresholds that exist between disturbance behavior and landscape attributes, such as connectivity and heterogeneity, are needed (Peters et al. 2004).

A key requirement is, therefore, the establishment of a global database of extreme events, and a research program to quantify the impacts that these events have on the structure and functioning of the ecosystems affected, including the propagation and spread of disturbances in fragmented versus highly connected landscapes.

Develop a freely available and continually updated spatially and temporally explicit global database of the frequency and intensity of extreme events from both the past to provide a baseline, and recent times to provide indicators of rates and extent of such changes.

Identify and develop a data harmonization effort of local to regional data on environmental stressors related to biophysical and socio-economic factors..

Promote integrated research efforts to quantify the impacts of extreme events on ecosystem properties and dynamics, including effects on biogeochemical cycling and land-atmosphere interactions, biodiversity, air and water quality, patterns of ecosystem recovery, and the impacts on the provision of essential ecosystem services to human society, across spatial and temporal scales.

Develop coordinated research strategies to facilitate the further development of integrated tools to deal with non-linear dynamics associated with extreme events experienced at different scales of time and space.

Aerosols

While there exists large data sets of the impacts of land use change on the atmospheric increase of $CO_2$, there is only limited information available on the contribution of land use change (deforestation in tropical zones, overgrazing and rain fed agriculture in arid zones) on aerosol production (carbonaceous aerosols from fires, mineral dust from soil degradation, sulfates from urban systems), their transportation patterns and their direct and indirect effects on climate, precipitation states and efficiency. Hence, it is the singular and multiplicative effects of atmospheric changes and their feedback with the terrestrial and aquatic ecosystems that should be the focus of this activity.

Establish monitoring networks for the observation, quantification, and characterization of biogenic and human-induced aerosols, ozone, and greenhouse gases, including their emission centers and patterns of distribution caused by land use and land cover change.

Establish spatially and temporally explicit data sets of aerosol, ozone, reactive nitrogen and greenhouse gases emission centers.

Manipulative experiments at various spatial scales and the use of natural and human-perturbation gradients as appropriate.

Multi-factorial field experiments that allow for interactions and feedbacks.

Experiment with more than two levels for a given stressor to detect thresholds, rapid changes, and saturation responses.

Synthesis of existing studies across spatial scales, from local to landscape, regional and global levels, and along natural and human-perturbation gradients on the combined effects of land use change and atmospheric composition/deposition.

Modeling to assess the overall net effect of multiple stressors on ecosystem functioning and resilience.

Environmental Quality

At the same time, global databases containing high resolution data on all possible drivers of global change should be developed, including baseline data and rates of change for each variable. Many of these databases do not exist, so an important output will be establishment of monitoring networks for atmospheric deposition, atmospheric composition, species diversity (e.g., Global Observation Research Initiative in Alpine Environments [GLORIA]), and water quality.

To evaluate the Earth System consequences of changes in ecosystem structure and functioning and to test the global land models, several critical global and regional data sets are required. An obvious data set is historical, spatially-explicit, climate data, which have recently been created at very high resolution. Global land cover data are now becoming available through the use of satellite-based remote sensing. However, several important properties of ecosystems remain poorly known, such as biomass, canopy heights, species distributions, disturbances, and soil properties. Land use management information is needed to document the extent and intensity of anthropogenic activities on the land, including cropping systems, irrigation, fertilization, crop yields, and livestock density, although available at the administrative level, are not always compatible between different countries and are not in the spatially-explicit format that is suitable for ecosystem modeling harmonization, and gridding is required.

Moreover, historical data on the changes in ecosystem structure, including human activities and disturbance (e.g., fire, insect/pest extent), is also critically required because the land systems of the present-day reflect a legacy of historical change. Some of the challenges involved are validating the quality of satellite data using ground-based observations, as well as assessing the spatial representativeness of field observations (normally point measurements) to be able to scale up to the region or globe. The continued development of these types of new and improved global datasets is critical for much of the Global Land Project.

The scaling of information within and across disciplines will also be an important undertaking. Some phenomena are difficult to scale, especially those related to linking social activities to ecosystem services. In addition, certain phenomena are difficult to observe and therefore difficult to scale, such as soil and lateral water fluxes. It is necessary to determine in which ways spatial and temporal variability of the coupled human-environment system will be represented in terms of physical, chemical, biological, and social structure and functions. The representation and modeling of the lateral exchanges between landscape components or grid cells are important considerations regarding changes in feedbacks and interaction between components of the coupled land system.

Many of the research tasks enumerated in the Science Plan concern the exchange of existing data, and the generation of new data in ways that make it easy to share among researchers. There is a need to characterize the status quo of key data sets and collate baseline data. The monitoring systems must extend beyond the existing climate monitoring system. Large quantities of surface data, including air and water quality, are being collected hourly and daily around the world, however, access to the local datasets is difficult and access to full continental data sets is challenging at best. A coordinated effort is required to do the necessary data quality evaluation, as well as, data set assembly. Negotiation of the international data exchange policies is critical to the success of such an undertaking. These include mapping of land cover and land use, social data sets, and environmental data sets.

There is an urgent need for land use maps, especially at global and regional scales. Currently, most of the global mapping products are land cover classifications, with land use categories limited to cropland, pasture, and urban. A concurrent activity should be the implementation of standard procedures for classification and production of land use maps. Data sharing and accessibility needs to be encouraged. This is especially true for fine resolution household and biophysical data collected for individual case studies. As more data become available and are shared within the Global Land Project community, meta-data standards will be necessary. Standards for meta-data should be outlined in anticipation of increased data sharing. The spatial resolutions of socio-economic data, remote sensing images, and ecosystem characteristics often are not compatible. In particular, there is a need for disaggregated socio-economic data beyond those data collected for specific case studies. Data integration, especially at multiple spatial scales, will be a challenge for the GLP.

Integration of observation and experimentation methodologies needs to be developed in order to better link process studies across larger spatial domains. For instance, data integration of field-based studies of biogeochemical cycles, studies of belowground biogeochemical processes, as well as, modeling studies at eddy flux tower sites, will be needed for a wide variety of terrestrial and aquatic ecosystems. These data integration techniques will provide new insights aimed at closing the elemental budgets across various scales. Remote sensing and other mapping products will also be an important aspect of spatial and temporal extrapolation of site- based data gathering.

It is imperative that the Global Land Project confront the challenge of land cover and use data from its very inception. Among the key factors that require standardization are land cover and land use. While a solid foundation has been laid for the standardized description of land cover by the United Nations Food and Agriculture Organization (UN FAO), its Land Cover Classification System (LCCS) has yet to enter into widespread use. The GLP community must commit itself to the adoption, improvement or replacement of the LCCS immediately. Some initial efforts have been undertaken to standardize the description of land use; rapid progress on this front is required. This may entail an expansion of the LCCS, the development of a parallel system, or a wholly new, combined effort. Either way, it is crucial that the GLP quickly move to plan and implement a standard approach to the description of land use.

Once the description of these crucial “dependent” variables is achieved, work can begin on the huge number of “independent” causal and contextual variables. While some work will be required on the handling of biophysical variables, it is the human/social variables that are especially problematic. The factors outlined in Theme 1 and 2 have been the objects of study in the varied social science disciplines, as well as in the humanities, each using its own vocabulary and methods of description, measurement and analysis. In order to understand how specific determinate structures enable and constrain options of particular land managers, it will be necessary to establish a rigorous system for the description and analysis of both the outcomes of interest, changes in land use, and the contextual and causal factors associated with those changes.

At the same time, global databases containing high resolution data on drivers of global change (biophysical and socio-economic) should be developed, including baseline data and rates of change for each variable. Many of these databases do not exist, so an important output will be establishment of monitoring networks for atmospheric deposition, atmospheric composition, species diversity (e.g., GLORIA), and water quality. Development of a freely available and continually updated spatially and temporally explicit database of land dynamics which reflects the frequency and intensity of extreme events, other disturbances, and land use changes, will be needed to better evaluate current land conditions and project future land system changes.

Integrated Analysis Tools

Development of various integrative research tools will be necessary in order to bridge interdisciplinary questions and to evaluate the complex suite of interactions within the coupled human-environmental system. Field techniques which integrate across space/time scales and across processes need to be further developed for both disciplinary and interdisciplinary studies. Techniques which can better evaluate multiple parameters of the land system simultaneously relative to the vulnerability of the system need to be developed. Advances are needed in the development of integrated analytical tools related to decision-making models, “dynamic global land models,” data model fusion techniques, and remote sensing applications.

Integration of observation and experimentation methodologies needs to be conducted in order to address these issues. For instance, field-based studies of biogeochemical cycles, studies of belowground biogeochemical processes, as well as, modeling studies at eddy flux tower sites, will be needed for a wide variety of terrestrial and aquatic ecosystems across all biomes to better quantify effects of land use and cover changes and other global environmental changes on coupled biogeochemical cycles at the regional and global scale. These techniques will provide new insights aimed at closing the elemental budgets across various scales. Such studies also need to incorporate the influence of disturbances and increased human activities on biogeochemical cycling. Integration of remote sensing data will provide a method to extrapolate across a region and to evaluate spatial/temporal relationships.

Integrated research techniques are being developed based on advanced uses of isotopic studies, such as those conducted in the Biosphere-Atmosphere Stable Isotope Network (BASIN). These techniques can provide insight into how to partition flux measurements into their various components, such as, photosynthesis, respiration and decomposition. Likewise, coupled estimates of trace gas fluxes ($NO_x$, $N_2O$, $CH_4$, VOC, CO, etc.) and use of free-air-carbon-exchange (FACE) experiments and ecosystem warming experiments will lead to a better understanding of integrated ecosystem responses to multiple stresses. Approaches of regional-to-global scaling are being enhanced through innovations in remote sensing and modeling as demonstrated in studies such as the "Big Foot" study and other regional studies.

Social science has made advances in the development of agent-based models and other analytical tools to evaluate factors associated with land use decision-making and now provide a new set of research tools to evaluate changes in socio-economic factors linked to environmental conditions. These methods can be coupled to the biophysical and biogeochemical models to evaluate the integrative response of the coupled human-environmental system to changes in the Earth System.

Comparisons of these new models and other integrative techniques need to be conducted. These comparisons will be informative in how to best approach data-model fusion within and between disciplinary fields of study. In addition, these comparative studies will serve as a guide to future research of land system dynamics. These comparisons will need scenarios of climate, social dynamics, land use patterns, and ecosystem dynamics so that sensitivity tests of these integrated analytical tools to changes in the coupled human-environment system can be better evaluated.

# Appendix IV Status of current operational capabilities

## *Status of global topographic data*

**Input: Mr Doug Muchoney, USGS**

GTOPO30 is the most widely used topographic dataset with global coverage. Completed in 1996, the 30-arc-second (approximately 1-kilometer) resolution elevation model was derived from multiple sources of regional and national elevation data, both raster and vector. Further information and data access are available at: http://lpdaac.usgs.gov/gtopo30/gtopo30.asp. HYDRO1k is a global dataset derived from GTOPO30 that includes elevation derivatives, both raster and vector, geared toward large area hydrologic applications.

SRTM data with a 3-arc-second (approximately 90-meter) resolution are available for about 80% of the global land surface (areas between 60 degrees north and 56 degrees south latitude). The data are available in a variety of formats on media (http://edcsns17.cr.usgs.gov/srtm/index.html) and by interactive download (seamless.usgs.gov). Note that the final SRTM products do have void areas where the radar data were not suitable for deriving reliable elevations.

The SRTM data have been aggregated to 30-arc-seconds and merged with GTOPO30 by JPL to create a global dataset called SRTM30. No specialized processing was done along the boundaries where SRTM and GTOPO30 meet (including the SRTM void areas). Further information on SRTM30 and access to the data are available at: ftp://edcftp.cr.usgs.gov/pub/data/srtm/SRTM30/

Since the time GTOPO30 was completed, new source datasets (in addition to SRTM) have become available that offer substantial improvement over some areas. Some of these datasets are located in high-latitude areas where there is no coverage by SRTM. Datasets that are improvements over the source data used for GTOPO30 include:

- Antarctica DEM derived from radar altimeter data; produced by Ohio State University's Byrd Polar Research Center
- Greenland DEM derived from radar altimeter data; produced by University of Bristol's Glaciology Centre
- CONUS 30-meter data and Alaska 60-meter data from the USGS National Elevation Dataset (NED) derived from topographic maps
- Canada 3-arc-second DEMs derived from 1:250,000-scale topographic maps; produced by Natural Resources Canada
- Australia 9-arc-second (approximately 300-meter) DEM derived from 1:250,000-scale topographic maps; produced by AUSLIG

These data are available as regional datasets, but they have not been assembled into a consistent global 1-kilometer elevation model. Merging these new data sources with SRTM data and, where necessary, GTOPO30 data would result in a significantly improved global topographic base for land studies. Where the source data support it, some continental and regional areas could be made available at a resolution much higher than 1-kilometer.

GLOBAL Datasets

- The ACE (Altimeter Corrected Elevations) 30 arc-sec Global DEM has been produced by the Monfort University combining available ground truth with a unique global database of satellite altimeter (ERS-1 and ERS-2) derived heights. More information is provided at: http://www.cse.dmu.ac.uk/geomatics/ace/
- A 15 arc-minute DEM, 1 m elevation interval derived from the German X-band radar onboard SRTM is being produced by DLR. The discontinuous coverage produced data gaps especially near the equator, however 40 percent of the covered land areas were mapped with almost twice the vertical resolution of the SRTM C-band data. More information is provided at: http://www.ixl-satinfo.com/english/productsrtm.shtml.

Regional/National datasets

- DEM of Central Europe, derived from ERS-1/ERS-2 radar data. Its quality equals the DTED-2 standard with 25 m horizontal spacing, +/-20m vertical accuracy and 1 m vertical spacing. It is distributed by IXL. More information is provided at: http://www.ixl-satinfo.com/english/producttandem.shtml
- The Landmap project carried out by Manchester InforMation and Associated Services (MIMAS), The University of Manchester, University College London and EduServ, has produced a 25m DEM of the British Islands by processing ascending and descending datasets provided by ESA's ERS-1 and ERS-2 satellites. More information is provided at: http://www.landmap.ac.uk/index.html

## *Status of the joint initiative on validation of all global land cover datasets fostered by the GOFC-GOLD Land Cover Implementation Team and CEOS Group on Calibration and Validation*

**Input: Mr Martin Herold and Curtis Woodcock**

Background

A number of global and regional land cover datasets have been produced or are currently in production. These land cover products have been produced in different ways, for different purposes and using different kinds of remote sensing data. While there is great demand for land cover products by the global science community it is hard for individual users to know which products are best suited to their needs. Two issues in particular are exasperating for users: (1) the differences in legends among the various land cover products; and (2) the lack of sufficient accuracy data to allow comparison of the various products. The result is that considerable resources are being devoted to the production of these land cover products but their ultimate utility is undermined by the lack of sufficient funding for validation. Completely missing from the current situation is recognition of the opportunity to provide improved land cover products that combine the strengths of the individual products. Given the push from international conventions, treaties and implementation guidelines (UNFCCC, IPCC, GEO, WSSD etc.) for harmonized and validated products, the current initiative for an international effort on validation and harmonization was outlined in previous GOFC-GOLD workshops in Jena and Rome in 2004 and is coordinated by the GOFC-GOLD Land Cover Implementation Team (LC-IT) and the CEOS Cal-Val group. The overall goal is to overcome limitations in the comparability of land cover dataset by making the harmonization and validation processes parallel and proving a solid estimate of the accuracy of current and future (e.g. GLOBCOVER) land cover datasets. Ultimately, this process will improve the value of these land cover datasets for a multitude of applications and contributes to the overall goal of operational terrestrial observations of the land surface.

Actors involved

The joint use of international forces and comprehensive consensus building efforts are essential for such a task to be successful. The general approach is to combine experiences and resources from all actors involved in global earth observations of land including space agencies such as the European Space Agency (ESA) and the National Aeronautics and Space Administration (NASA), the Food and Agricultural Organization (FAO) with GTOS and the Global Land Cover Network (GLCN), the Committee Earth Observation Satellites (CEOS) with the group on calibration and validation (Cal/Val) and the Joint Research Center (JRC). All of these organizations as well as the users will profit from such a combined effort.

Approach

Core analysis methods exist for accuracy assessment, which should be routinely adopted as a baseline for reporting map accuracy. These methods are outlined in the 'best practices' document recently developed by the CEOS Cal-Val group and will be a central component of this initiative. The key of the validation is a global set of land cover validation sites:

- A new set of validation sites is needed to provide a statistically robust, consistent, harmonized, updated, and accessible reference database. The intent is to select the sites in such a way that they are not associated with any specific land cover map and that they may retain statistically rigor when used on a variety of maps.
- The approach is to develop a "living" dataset of validation sites that could be used to verify any existing and new land cover map. Such a dataset will allow continued assessment of the accuracy and validity of datasets and associated changes even after many years of their production.
- The validation will be based on high-resolution satellite data like Landsat ETM+, SPOT and others. For example, global Landsat TM/ETM mosaics exist for the years 1990 and 2000. Continued observations on this scale are essential to maintain the keep the reference database "living" and up to date.
- The GOFC-GOLD regional networks with local remote sensing/validation experts will play an important role in development and maintaining this database.
- A common language for land cover and understanding of semantic differences between the datasets is essential for comparative analyses of accuracy. Thus, the GOFC-GOLD/GTOS harmonization strategy and the validation are parallel efforts. For example, the individual validation site interpretations will be generic descriptions of land cover characteristics in LCCS language and independent of any specific land cover legend. LCCS will be used to assign land cover classes to the validation sites based on the different legend translations. This makes the validation process transparent, consistent and applicable to any land cover map compatible with LCCS. The comparative validation will move forward the implementation of harmonization.

Status and Timeline

There are four main current action items:

1) Completion of CEOS Cal-Val 'best practice' document. A complete draft is completed, is currently under review and will be available soon.
2) Modification of a funding proposal originally submitted to NASA. This proposal needs to transformed into an international effort and extended to include the GOFC/GOLD harmonization strategy. This process is ongoing and a first draft should be available by the end 2004. Most of that work will be done by Curtis Woodcock and Martin Herold.
3) To make this effort truly international, it will be important to engage many participants and thus a number of funding sources. One issue requiring work is the sorting of tasks and costs, such that we are able to get different agencies to sign-up for the appropriate components. The

process of deciding how to divide the effort most effectively is ongoing and suggestions are welcome. It is acknowledged that some agencies will most readily support specific components of such an effort. Any guidance regarding the anticipated preferences of the various agencies would be appreciated. To support this effort, Herold and Woodcock will circulate a list of resources required for this effort within GOFC/GOLD for comment.

4) Members of GOFC-GOLD and CEOS have to start engaging the mentioned actors and possible funding agencies to build awareness and seek funding for such an effort. It also important to think about how this effort relates to programs like GLCN.

Once funding is secured, the start time can be short. One of the main efforts of GOFC-GOLD is to get all regional networks together and do capacity building on the harmonization/validation methods and resources. The initiative should ensure funding for them.

Final comment

The political framework, the organizations for international cooperation as well as methodological resources exist to approach a joint harmonization and validation initiative for land cover datasets. GOFC-GOLD (GTOS) with its regional networks in conjunction with the CEOS Cal-Val group seem to be the right implementation platforms to coordinate such an effort. It is now up to the individual members of the community to provide their share of support for this initiative. Previous efforts have suffered from a lack of funding for harmonization and validation and limited available resources.

## Global observations of human settlements

### A suggested contribution for IGOL by Martin Herold

The persisting dynamic urban change processes, especially the tremendous worldwide expansion of urban population and urbanized area, affect and drive natural and human systems at all geographic scales. Urbanization is the trigger for a variety of other land change processes in natural and semi-natural environments. Any operational efforts tailored at sustainable and desirable future development have to consider urban dynamics as one of the key human-induced processes for understanding and managing our fast changing world.

Earth observation has been focused on mapping, monitoring and understanding these urban phenomena for many years, however, with more emphasize on local to regional scales. Global mapping of human settlements faces particular challenging due to spatial and spectral heterogeneity of urban environments, as well as, their small and fragmented spatial configuration. There is large disagreement between urban areas mapped in different global land cover products (Fig.1).

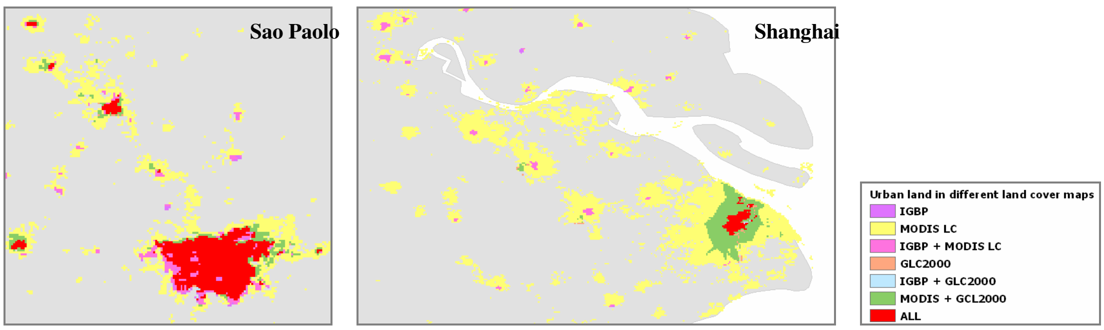


*Figure 1. Comparison of urban land in three different global land cover products: IGBP DIS (urban areas from Digital chart of the world), MODIS land cover (urban areas from MODIS (2000), DMSP (1994/95) and ancillary data), and GLC2000 (urban areas from DMSP (1994/95)).*

The recent proliferation of new sources of data and tools for data processing, analysis and modelling has provided and opened up avenues for significant progress toward global observations of urban patterns and dynamics. Due to the heterogeneity of global urban characteristics, the key issue is to combine earth observation indicators for characteristics and change in human settlements. Sensors like MODIS or LANDSAT give spectral evidence for built-up areas and the land cover configuration within urban environments; night-time observations by DMSP are a strong indicator of populated areas; SAR measurements emphasize the three-dimensional characteristics of urban surfaces; thermal IR data contain information about energy fluxes and local climatic conditions. Other key projects and programs have been looking at representative urban agglomerations world wide to monitor spatio-temporal urban dynamics. Hence, there is need for an integrated urban observatory to provide continuity and consistency for global observations of human settlements. The efforts have to address the variety of operational scales, including global and super-regional urban networks, metropolitan agglomerations, as well as urban growth and land use change within individual cities. The overall goal of earth observation in that context is the mapping, monitoring, and analysis of urban form and processes towards support and improvement of urban modeling, management and planning efforts, and advances in spatial urban theory. Sustainable development activities benefit from the resulting better data, knowledge, and information, if the integrated framework includes a better integration and communication of the earth observation results, and works towards general acceptance of new and innovative techniques in approaching urban dynamics.

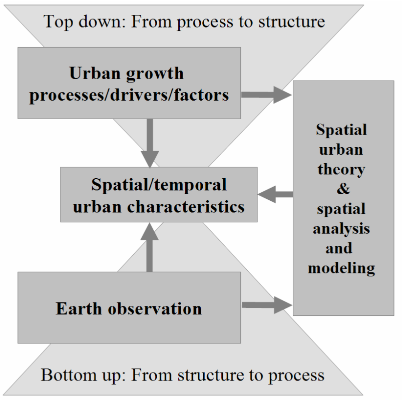


*Figure 2. Conceptual framework for integration of earth observation data and drivers and factors of urban growth processes.*

An urban observatory would provide great opportunities for integration of earth observation products with ancillary information reflecting drivers and factors of urban development (Fig. 2). Earth observation measures urban characteristics "bottom up" describing the outcome of various processes at work (from structure to process). Socio-economic drivers or specific urban models usually follow a "top-down" approach by studying a pre-specified process of urban change and the resulting spatio-temporal patterns (from process to structure). Linking these two (empirical growth observations and urban processes) using spatial urban theory, and spatial analysis and modeling provides a framework for monitoring, understanding, and modeling urban phenomena. This information is essential to anticipate and forecast future changes or trends of development, describe and assess economic, ecological, and social impacts of urbanization, and explore different policies and scenarios in support of planning and management decisions.