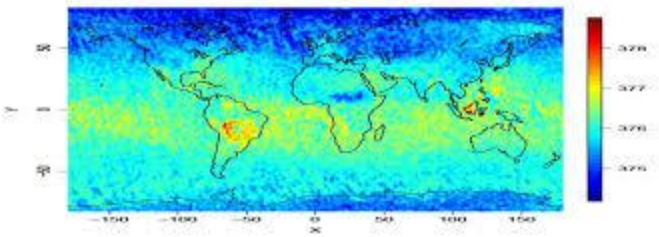
UNITED NATIONS STATISTICS DIVISION (UNSD)

**Workshop on Environment Statistics in support of the implementation of the Framework for the Development of Environment Statistics, Arusha, Tanzania, 6-10 July 2015**

# Land Cover and Land use in Environment Statistics



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- Land Cover Classifications
- Sources of global and regional land cover for environment statistics and indicators series
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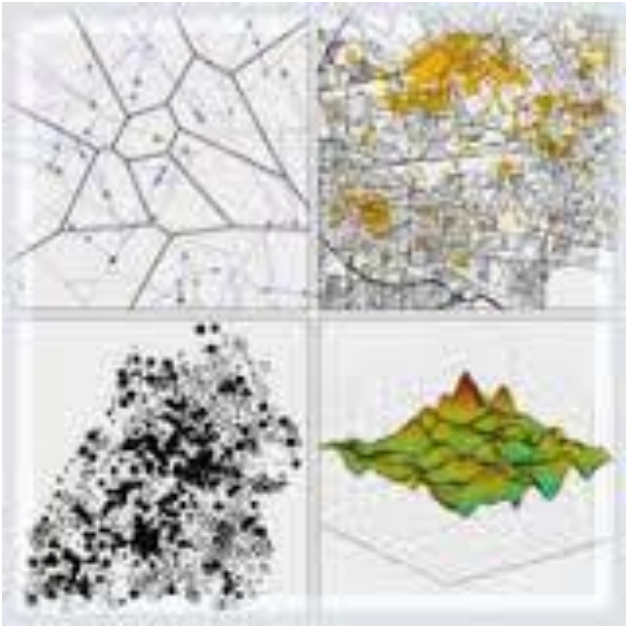
# Introduction

- Statistics on land use fulfil a basic informational need of governments, policy makers, analysts and civil society.
- Land is a unique environmental resource that delineates the space in which economic activities and environmental processes take place and within which environmental resources and economic assets are located.
- The two primary aspects of land are land cover (see Topic Land cover in FDES 2013) and land use (see Topic Land use in FDES 2013).
- These aspects are strictly related: while land cover describes the biophysical aspect of land, land use refers to the functional aspects of land.
- Changes in land cover can be the result of natural processes and of land use changes.
- Generally, the total area of a country will remain unchanged from one period to the next. Hence, changes in the stocks of land will comprise changes within and between stocks in different classes of land cover and land use (land restructuring) [FDES 2013].



# Definitions

- Land cover is defined by FAO as, “the observed (bio) physical cover on the earth's surface.” (FAO, 2005)
- Changes in land cover are the result of natural processes and changes in land use.
- The total area of a country is the area enclosed by its inland borders and, if applicable, the sea.
- While inland waters (e.g., rivers, lakes, ponds etc.), are included in land use, marine water areas can be included only in a broader concept of land use.
- Certain types of land use analyses may include coastal waters (internal waters) or even Exclusive Economic Zones (EEZs) [FDES 2013].

# Definitions

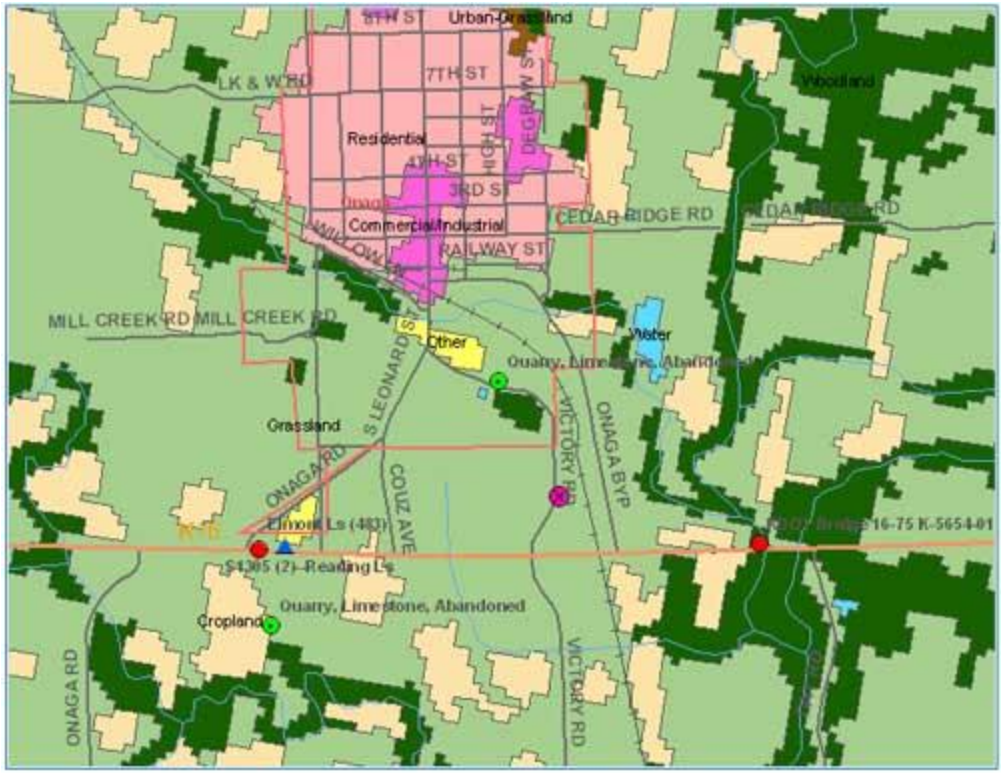
- Land cover assessments can be carried out from continental, through regional, national to sub-national levels. These location based classifications can be useful for specific purposes, such as ecosystem management or watershed management.
- At continental scales, map products aim to monitor land cover - the observed physical cover on the surface of the Earth - and its change over time.
- These maps can be based on Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery monthly composites at 250 m spatial resolution.
- The Nineteen land cover classes defined by the LCCS standard can be used. These sub continental scale maps can depict information about land cover and land cover change in a seamless, consistent, and automated way across at regular intervals.
- The technical aspects of geospatial information, including remote sensing data, can be dealt with experts in the domain. Section 1.8 of the FDES 2013 provides an overview of geospatial information and environment statistics.

# Coverage -Temporal and spatial considerations

- Spatial consideration
  - occurrence and impacts of environmental phenomena are distributed through space without regard for political-administrative boundaries.
  - The most meaningful spatial units for environment statistics are natural units, such as watersheds, ecosystems, eco-zones, landscape or land cover units; or management and planning units based on the natural units, such as protected areas, coastal areas or river basin districts.

# Classification

- The aim of the classification is to provide a common framework to compile and aggregate land cover information available at the national level and make it comparable at the international level, and to provide a structure to guide data collection and the creation of land cover databases for countries in the process of establishing a land cover statistics domain (FDES 2013).



# Classifications

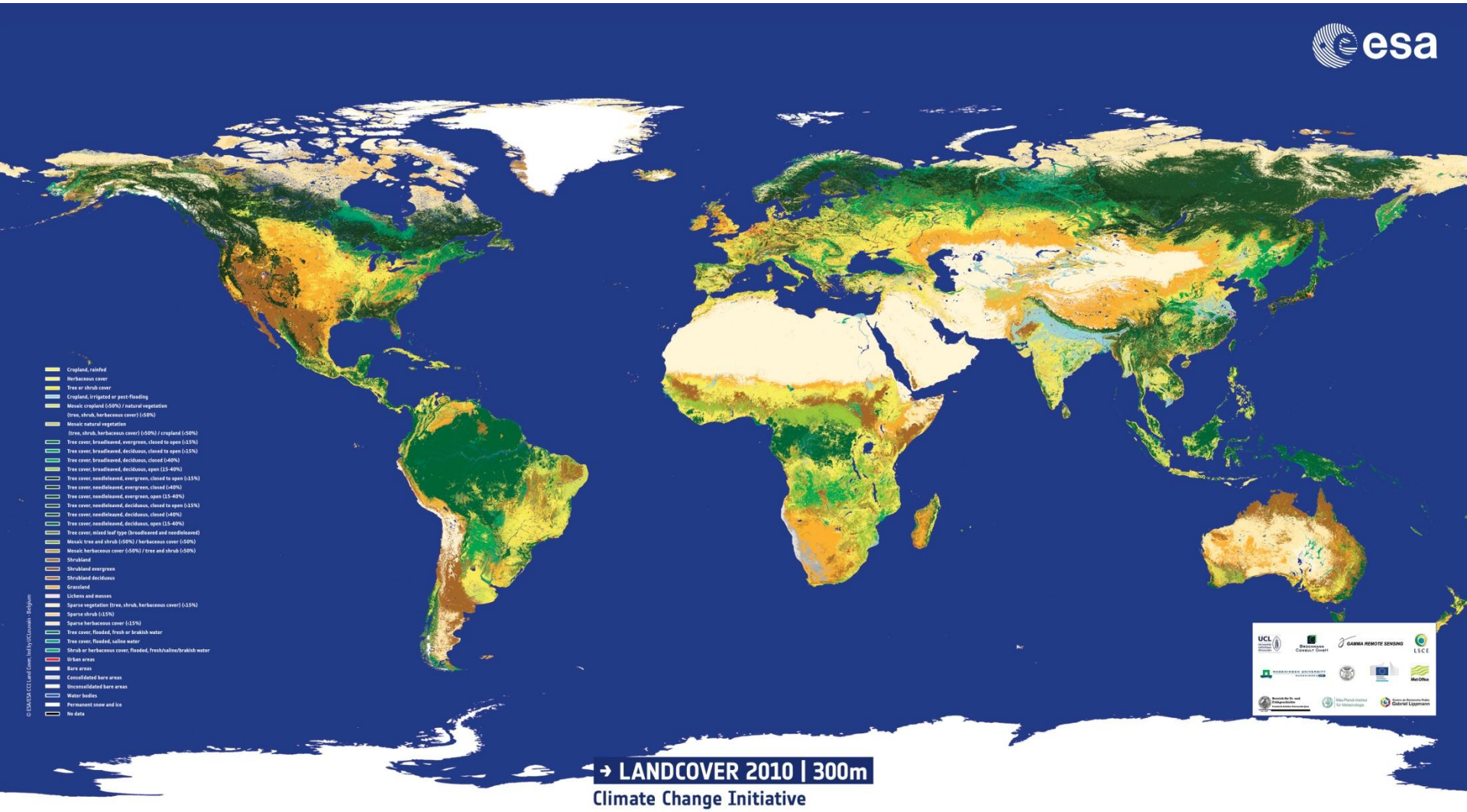
- Land cover can be classified into different classes and each country can customise the classes to meet their own needs.
- An international standard is not yet adopted but a Land Cover Classification System (LCCS) has been developed by the FAO.
- The large numbers of combinations of land cover features that can be created using the LCCS approach apply to any type of land cover.
- Moreover, after a comprehensive global consultation process, a classification composed of 14 classes has been developed in the SEEA Central Framework.
- These 14 classes have been generated using the LCCS approach and thus provide a comprehensive set of land cover types, mutually exclusive and unambiguous, with clear boundaries and systematic definitions.
- Furthermore, the identified classes are defined to be used as the basis for the development of ecosystem statistics.

# Classification

- Land cover can be classified according to location and area. Type of land cover can be:
  - artificial surfaces including urban and associated areas;
  - herbaceous crops;
  - woody crops; multiple or layered crops;
  - grassland; tree covered areas;
  - mangroves; shrub covered areas;
  - shrubs and/or herbaceous vegetation, aquatic or regularly flooded;
  - sparsely natural vegetated areas;
  - terrestrial barren land;
  - permanent snow and glaciers;
  - inland water bodies; and
  - coastal water bodies and intertidal areas

# World Land Cover 2010

http://cdn.phys.org/newman/gfx/news/hires/2014/landcover2010.jpg



# International sources and recommendations

- International organizations have produced guidance documents for the collection of land cover data, e.g. for the monitoring of policy targets and/or implementation of legislation and international conventions: (non exhaustive list):
  - FAO LCCS: It aims to provide improved access to reliable and standardized information on land cover and land cover change. It is a comprehensive, standardized a priori classification system designed to meet specific user requirements, and created for mapping exercises, independent of the scale or means used to map.
  - IPCC LULUCF and AFOLU classes: Good Practice Guidance for Land Use, Land-Use Change and Forestry (http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf) and 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html)
  - UN SEEA: The System of Environment economic Accounting (SEEA) Central Framework (http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf) and the SEEA Experimental Ecosystem accounts (http://unstats.un.org/unsd/envaccounting/eea_White_cover.pdf ) both include some information on land cover.

# International sources and recommendations (continued)

- CBD ENCA QSP: The Convention on Biodiversity (CBD) prepared the ECOSYSTEM NATURAL CAPITAL ACCOUNTS: A QUICK START PACKAGE For implementing Aichi Biodiversity Target 2 on Integration of Biodiversity Values in National Accounting Systems in the context of the SEEA (http://www.cbd.int/doc/publications/cbd-ts-77-en.pdf)
- North American Land Change Monitoring System (NALCMS). NALCMS is a collaborative initiative between Canada, Mexico, and the United States to monitor land cover and its change over time.
- EU: CORINE Land cover: In 1985 the Corine programme was initiated in the European Union. Corine means 'coordination of information on the environment'. The Corine databases and several of its programmes includes an inventory of land cover in 44 classes, and presented as a cartographic product, at a scale of 1:100 000. This database is operationally available for most areas of Europe.
- European Communities, 2001: Manual of concepts on land cover and land use information systems (http://ec.europa.eu/eurostat/ramon/statmanuals/files/KS-34-00-407-__-I-EN.pdf#page=10)

# Geospatial information

- Geospatial information presents the location and characteristics of different attributes of the
  - atmosphere,
  - surface and
  - sub-surface.

- It is used to describe, display and analyze data that have discernible spatial aspects, such as land use, water resources and natural disasters.
- Geospatial information allows for the visual display of different statistics in a map-based layout, which can make it easier for users to work with and understand the data.

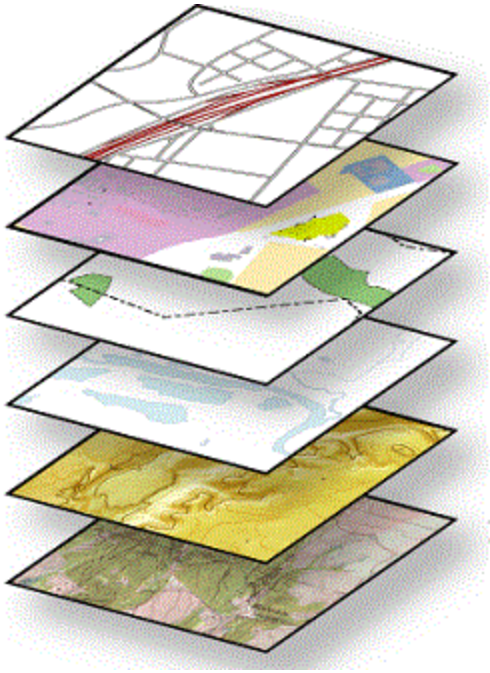
# Geospatial information

- The complexity of current environmental issues

  (e.g., climate change, biodiversity loss, ecosystem health, natural disaster frequency and intensity, population growth, food and water shortages, etc.)

  increasingly calls for the integration of geospatial information, statistics and sectoral data for more effective and efficient monitoring of progress in the environmental pillar of sustainable development.

- Geographic Information Systems (GIS) can help establish the links between different types and layers of data by providing powerful tools for storage and analysis of spatial data and by integrating databases from different sectors in the same format and structure.



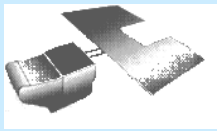
# Geospatial information

- A GIS is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information.
- Geospatial data can be acquired using a variety of technologies such as Global Positioning System (GPS) and Remote Sensing satellites.
- Land surveyors, census takers, aerial photographers, police, and even average citizens with a GPS enabled cell phone can collect geospatial data using GPS or street addresses that can be entered into GIS.
- The attributes of the collected data, such as land-use information, demographics, landscape features, or crime scene observations, can be entered manually or, in the case of a land survey map, digitized from a map format to a digital format by electronic scanning.

# Spatial Integration of Environmental & Socio-Economic Data Collection

Mapping

Earth Observation



## Socio-Economic

Statistics

Land cover continuous mapping as well as censuses, registers or exhaustive surveys: main features & spatial distribution

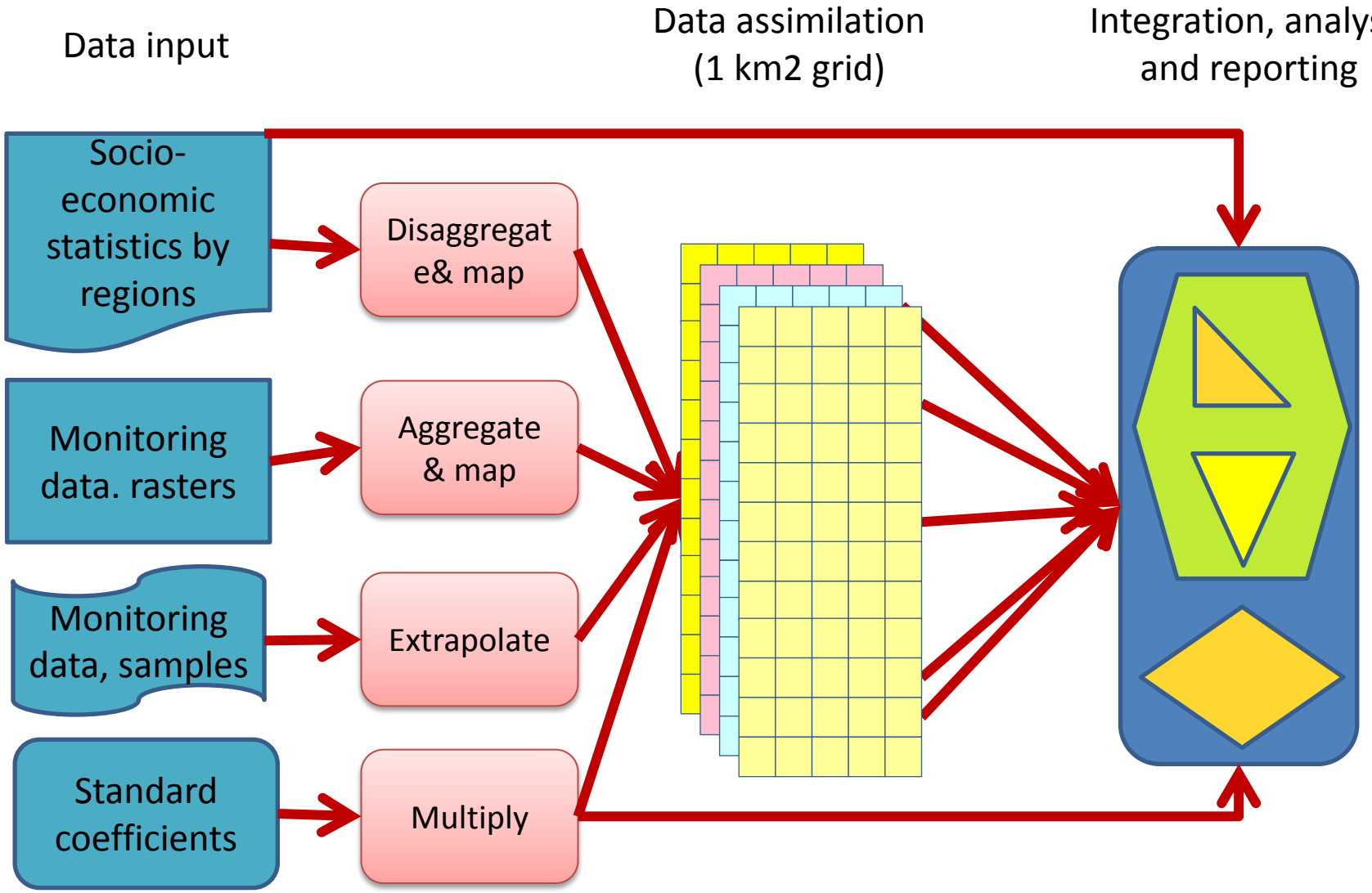
## Sampling

detailed information representative for an area, a type, a group

## Individual Sites Monitoring

Complete investigation of important or rare ecosystems, protected areas, case studies, long term ecological monitoring

# Main data flows to compile Land use statistics



# Data - Sources of global and regional land cover for environment statistics and indicators series

- There are several international organisations that collect data on land cover and data from which land cover can be assessed. Many of these are remote sensing data. Below is a list of these data sources (non exhaustive):
- U.S Geological Survey (USGS) Land Cover Institute (LCI) (http://landcover.usgs.gov/index.php): A list of land cover data can be found on the LCI website, http://landcover.usgs.gov/landcoverdata.php, for every continent and for various uses such climate, fires, eco-regions etc. http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp
- Global Land Cover Network (GLCN) (http://www.glcn.org/prj_0_en.jsp) provides global information on land cover and its dynamics, harmonizing land cover mapping and monitoring at national, regional and global levels.
- The GLCF is a center for land cover science with a focus on research using remotely sensed satellite data and products to access land cover change for local to global systems. (http://glcf.umd.edu/)

# Data - Sources of global and regional land cover for environment statistics and indicators series (continued)

- EU Eurostat: Land cover and land use statistics at regional level (http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Land_cover_and_land_use_statistics_at_regional_level) provides regional data in
- **Africover**: This is part of the Global Land Cover Network (GLCN) (http://www.glcn.org/activities/africover_en.jsp). The **Africover** project, on which the GLCN programme has built its success, was established to develop a digital georeferenced database on land cover and a geographic referential for the whole of Africa including geodetical homogeneous referential, toponomy, roads and hydrography. Methodologies, operational procedures and software tools for the land cover analysis in the Africover program have been developed through the Africover Eastern Africa module under the financing of the Italian Cooperation.
- The **University of Maryland** produces forest change data for the whole world. These can be freely accessed for any country and region. Results are available for time-series analysis of 654,178 Landsat 7 ETM+ images in characterizing global forest extent and change from 2000 through 2012. Web-based visualizations of these results are also available at http://earthenginepartners.appspot.com/science-2013-global-fores and http://earthenginepartners.appspot.com/science-2013-global-forest.

# Data - Sources of global and regional land cover for environment statistics and indicators series

- **North American Land Change Monitoring System (NALCMS).** NALCMS is a collaborative initiative between Canada, Mexico, and the United States to monitor land cover and its change over time.
- **EU: CORINE Land cover**: In 1985 the Corine programme was initiated in the European Union. Corine means 'coordination of information on the environment'.
- **LUCAS** is the acronym of Land Use and Cover Area frame Survey. The aim of the LUCAS survey is to gather harmonised information on land use and land cover. The survey also provides territorial information facilitating the analysis of the interactions between agriculture, environment and countryside, such as irrigation and land management. Since 2006, EUROSTAT has carried out LUCAS surveys every three years (http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/lan_esms.htm)
- **C-CAP Land Cover Atlas**: This online data viewer provides user-friendly access to regional land cover and land cover change information developed through NOAA's Coastal Change Analysis Program (C-CAP). The Land Cover Atlas eliminates the need for desktop geographic information system software, or advanced technical expertise, by processing C-CAP data for the user and providing easy access to that distilled information. The tool summarizes general change trends (such as forest losses or new development) and can highlight specific changes of interest (salt marsh losses to open water, or evergreen forest losses to development, for instance). http://coast.noaa.gov/digitalcoast/tools/lca

# Data collection

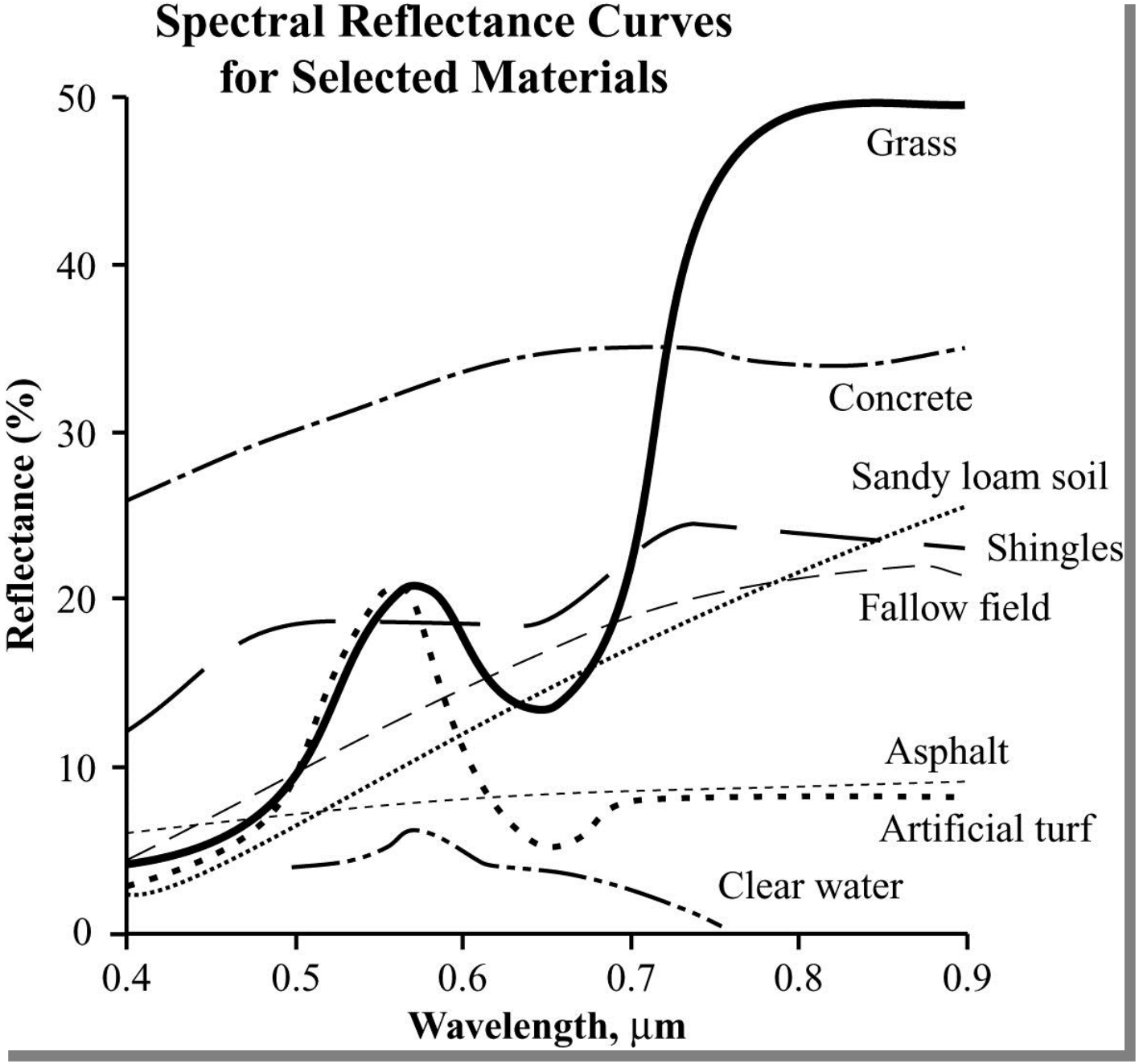
- Land cover data are normally managed by specialized agencies which work on GIS and land administrations etc.
- Other agencies, such as those responsible for forestry, water or agriculture may keep good databases on land cover.
- Geographically referenced information that includes digital maps, satellite and aerial imagery, and other sources of data that are linked to a location or a map feature, all structured in databases, will also add significantly to the quantity and quality of information that is organized within the context of environment statistics.
- GIS can be viewed as an integrating technology that helps to capture, manage, analyze, distribute and use a wide range of data with a spatial or locational component (FDES 2013).

# Data compilation (procedures and instruments) and transformation into environment statistics series

- Remote sensing data normally deals with pixel of information.
- The value for the pixel may indicate the change in classification, e.g. between 2005 and 2010. Codes can also be used within pixels.
- For instance, values other than 0 are either three or four digits. The first digit or the first two digits for a 4-digit Value, indicate the 2005 classification for the area whereas the last two digits indicate the 2010 values

# Remote sensing

- Remote sensing data from satellites are acquired digitally and communicated to central facilities for processing and analysis in GIS.
- Digital satellite images, for example, can be analyzed in GIS to produce maps of land cover and land use.
- When different types of geospatial data are combined in GIS (e.g., through combining satellite remote sensing land use information with aerial photographic data on housing development growth), the data must be transformed so they fit the same coordinates.
- GIS uses the processing power of a computer, together with geographic mapping techniques (cartography), to transform data from different sources onto one projection and one scale so that the data can be analyzed together


Spectral Reflectance Curves
for Selected Materials
Reflectance (%)
50
40
30
20
10
0
0.4
0.5
0.6
0.7
0.8
0.9
Wavelength, μm
Grass
Concrete
Sandy loam soil
Shingles
Fallow field
Asphalt
Artificial turf
Clear water

# Remote sensing

- Remote sensing is a technique for gathering information about an object without coming into physical contact with it.
- It is the quantitative analysis of digital information where measurements can be made from ground, aircrafts or satellites. The information is carried by electromagnetic radiation.
- With remote sensing, skills are needed in digital image analysis where computer programming, image display tools and statistics, etc., are required for interdisciplinary work that might involve scientists and experts in various fields - biology, climatology, geology, atmospheric science, chemistry, oceanography, and more.
- With satellite remote sensing, global issues can be addressed by monitoring regional and global changes

- Source: Government Accountability Office, (2004), *Geospatial Information: Better Coordination Needed to Identify and Reduce Duplicative Investments,* http://www.gao.gov/assets/250/243133.pdf34

# Methods and Concepts

- The **statistical population** comprises all land cover categories at national, sub-national, regional and/or river basin level or any national delineation. It also includes all public and private land for economic activities, land under municipalities including households and settlements.
- The **statistical unit** is a unit of observation or measurement for which data are collected or derived. The statistical unit is therefore the basic element for compiling and tabulating statistical data. The statistical units of the environment are the parts of the environment about which information is collected and statistics are compiled. For land cover, the term Basic Spatial Unit (BSU) has been used in the SEEA. In the CBD QSP (see section 3B above), the BSU has been taken as a grid of 1 ha and 1 km2 (large areas, e.g Europe) and 10 m x 10 m and 1 ha for small areas (e.g Mauritius).
- **Reporting unit:** The reporting unit is the unit of the economy that reports information about the statistical unit. For example, a lake can be a statistical unit but any information about the lake will have to be reported by a unit of the economy that owns, manages or monitors the lake or any part thereof. Reporting units are public and private enterprises and establishments, or parts of thereof, and municipalities that owns and/or use the land

# Methods and Concepts (continued)

- **Measurement unit:** Land cover and land use are expressed in square kilometers ($Km^2$) and percentage (%). For landscape indicators, relative % frequencies are given. The hectare (Ha) is also often used for land cover measurement.
- **Validation:** The validation of the data may require specialized skills, e.g remote sensing. Checking can involve seeing whether data are o compliant with standards; without formal errors; without obvious content errors, Comparing with previous data (where available), checking transect; checking GPS tracks; checking the quality of the photos and anonymizing them where needed. Sampling and non sampling errors may also need to be assessed.
- **Metadata:** Metadata is a set of data that describes and gives information about other data. Metadata forms an important item in land cover data, particularly because it involves remote sensing and GIS. For the description of the statistics produced it is recommended to use agreed meta-data formats for statistics. A widely used format is the SDMX metadata format.

# Tools and Softwares for land data

- Tools and Softwares can be easily available for compiling or producing land cover statistics. Use of these tools may require from basic to advanced trainings in GIS and remote sensing. Some tools and softwares freely available are:
  - LCCS: The software is freely distributed by FAO through a self-extracting executable file that produces the entire set of files necessary to run the setup. The LCCS software contains four modules and tools: -Classification; -Legend; Link and Translator.
  - QGIS: A Free and Open Source Geographic Information System. QGIS has a lot of documentation and is a user-friendly GIS, providing common functions and features.
  - GeoVis: Provides a list of software tools for land cover data. The LCCS is also include in this tool.

# Presentation/Disseminations formats

- Tabular: Land cover statistics can be presented in tables, by country or region, by river basin (catchment area), by economic activity of the land user and/or land owner, and by land type (residential/commercial/industrial). Indicators could be presented per capita or related to economic output of the land cover activity. Land cover indices could be calculated and presented, e.g Normalised difference vegetation index – NDVI, land cover diversity index .
- Graphs: Graphs could, if data availability allows, show long term trends in land cover. If data is available, seasonal differences could be presented. Useful breakdowns could be by economic activity of the land user and/or by region. The share of land cover could be presented in appropriate charts.
- Maps: Geographical maps are very useful for the visualization of geo-referenced land cover, such as by river basin districts and their use and/or exploitation.

# Potential disaggregations and scales of the statistic

- By type of land cover/ecosystems/eco zones
- By economic activity of the land cover/use.
- Spatial: National and sub-national, see classifications of regional geographical units and of river basin districts.

# Demo on GIS

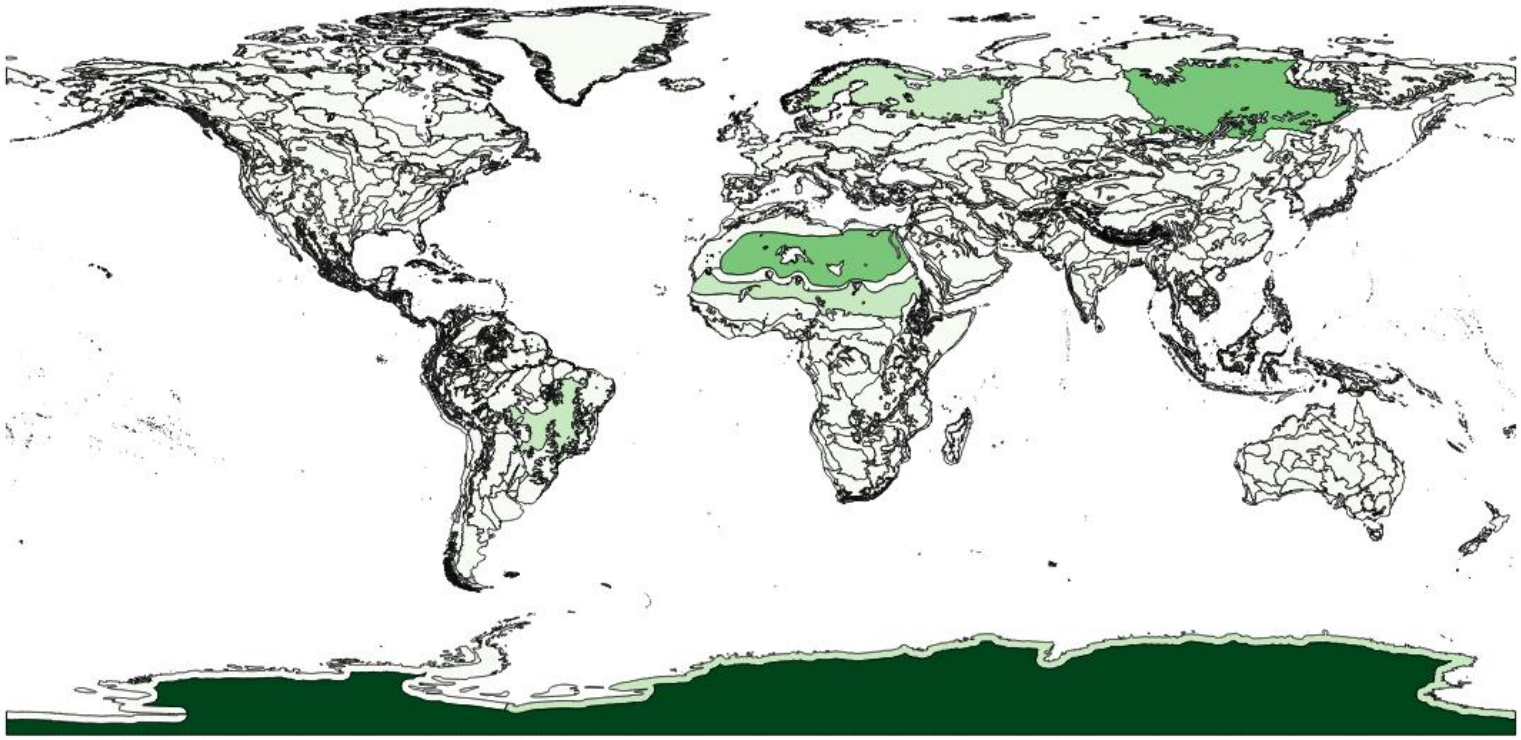
- **QGIS - A Free and Open Source Geographic Information System (http://www.qgis.org/en/site/)**
- **Refer to QGIS Tutorial: http://www.qgistutorials.com/en/**
- **A simple map with attributes for environment statistics**

# Some resources and data

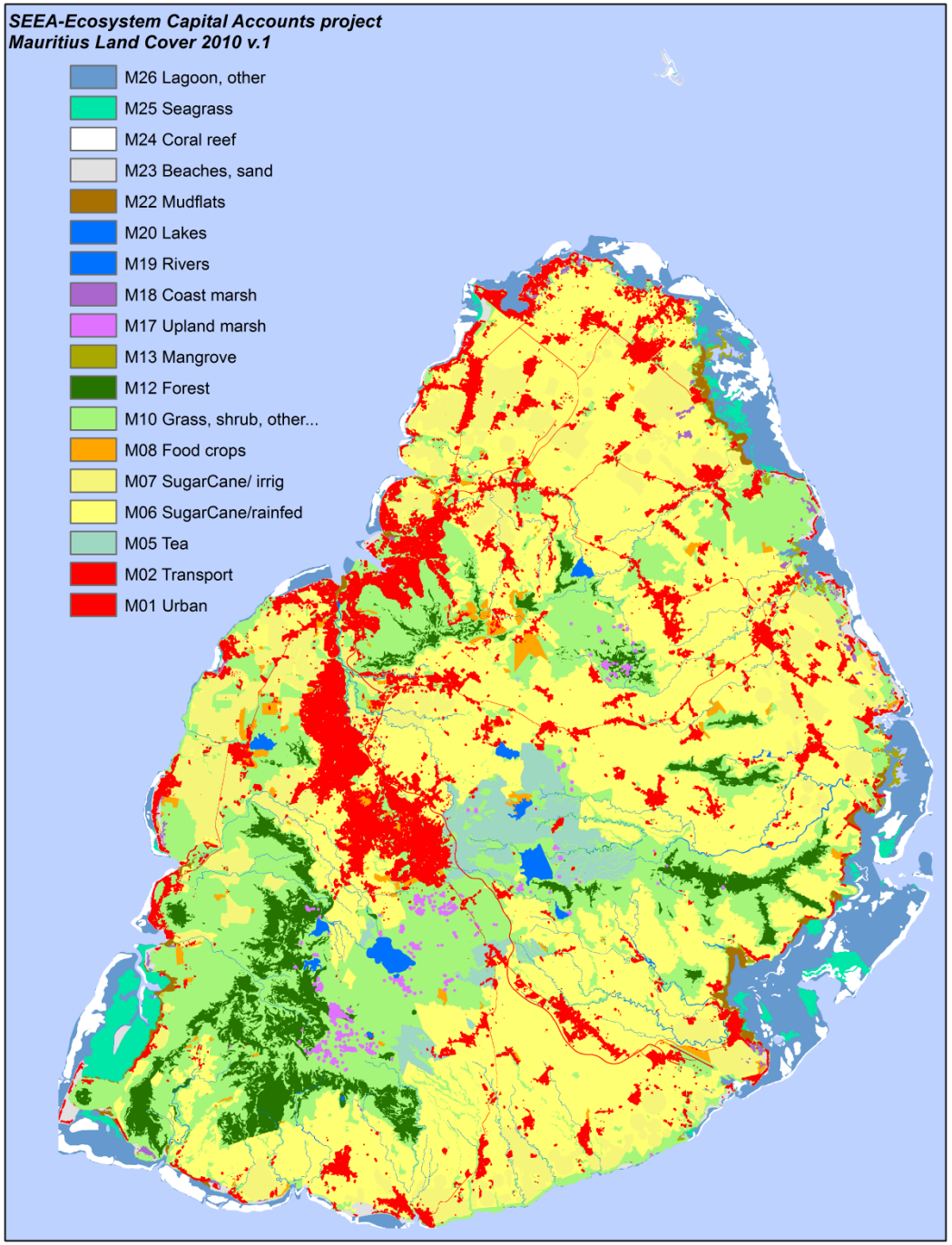
- Tutorials: http://spatial-analyst.net/wiki/index.php?title=Main_Page
- Maps, Data, Models: http://sage.wisc.edu/mapsdatamodels.html
- Satellite data: https://earthdata.nasa.gov/
- VIEWER: http://www.esri.com/software/landsat-imagery/viewer
- Ecol/footprints: http://www.arcgis.com/home/webmap/viewer.html?webmap=1a40fa5cc1ab4569b79f45444d728067
- Data portal: http://knoema.com/onsbcce/new-page
- SEDAC: http://sedac.ciesin.columbia.edu/maps/tools
- R Software: https://github.com/Pakillo/R-GIS-tutorial/blob/master/R-GIS_tutorial.md
- Forest: http://earthenginepartners.appspot.com/science-2013-global-forest
- Data Websites: Africa: https://lib.stanford.edu/gis-branner-library/data-websites-africa
- AfricaMap: http://worldmap.harvard.edu/africamap/
- Statistics: http://vassarstats.net/index.html

# Example

- Eco regions



- **Example Land Cover in Mauritius**



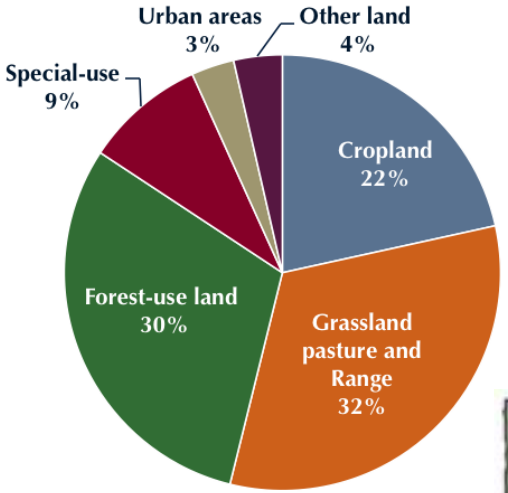
# Example table

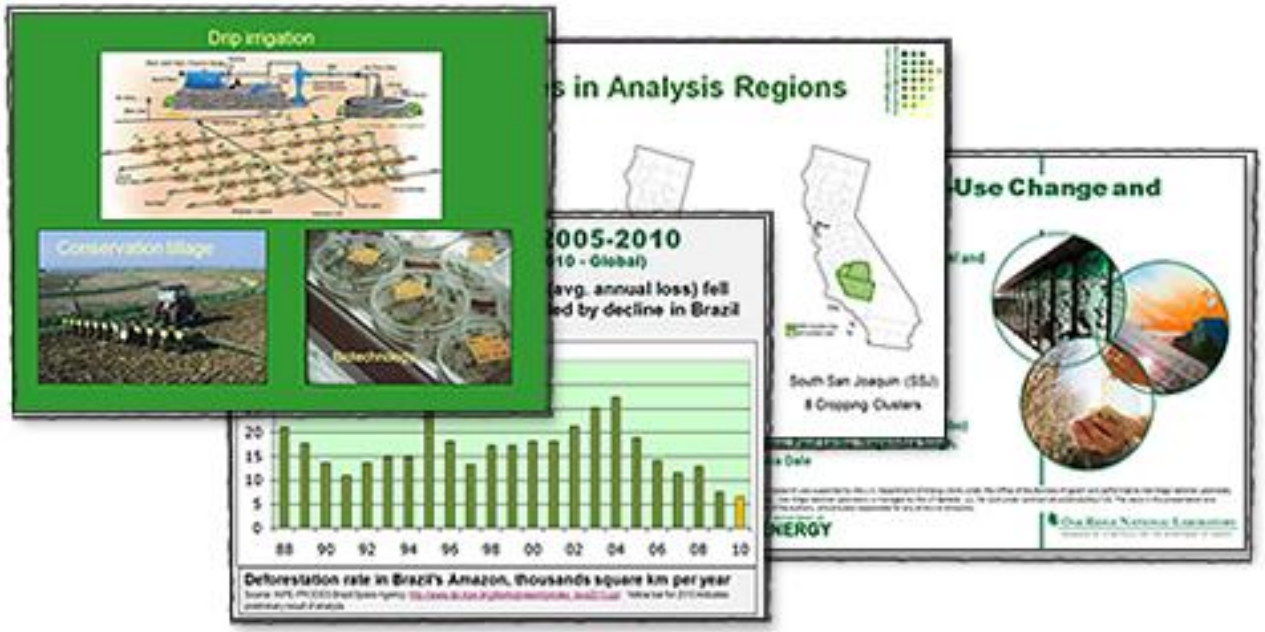
- Tabular data

| | Runoff Coefficient, C | | | | | |
|---|---|---|---|---|---|---|
| | Soil Group C | | | Soil Group D | | |
| Slope : | < 2% | 2-6% | > 6% | < 2% | 2-6% | > 6% |
| Forest | 0.12 | 0.16 | 0.20 | 0.15 | 0.20 | 0.25 |
| Meadow | 0.26 | 0.35 | 0.44 | 0.30 | 0.40 | 0.50 |
| Pasture | 0.30 | 0.42 | 0.52 | 0.37 | 0.50 | 0.62 |
| Farmland | 0.20 | 0.25 | 0.34 | 0.24 | 0.29 | 0.41 |
| Res. 1 acre | 0.28 | 0.32 | 0.40 | 0.31 | 0.35 | 0.46 |
| Res. 1/2 acre | 0.31 | 0.35 | 0.42 | 0.34 | 0.38 | 0.46 |
| Res. 1/3 acre | 0.33 | 0.38 | 0.45 | 0.36 | 0.40 | 0.50 |
| Res. 1/4 acre | 0.36 | 0.40 | 0.47 | 0.38 | 0.42 | 0.52 |
| Res. 1/8 acre | 0.38 | 0.42 | 0.49 | 0.41 | 0.45 | 0.54 |
| Industrial | 0.86 | 0.86 | 0.87 | 0.86 | 0.86 | 0.88 |
| Commercial | 0.89 | 0.89 | 0.90 | 0.89 | 0.89 | 0.90 |
| Streets: ROW | 0.84 | 0.85 | 0.89 | 0.89 | 0.91 | 0.95 |
| Parking | 0.95 | 0.96 | 0.97 | 0.95 | 0.96 | 0.97 |
| Disturbed Area | 0.68 | 0.70 | 0.72 | 0.69 | 0.72 | 0.75 |

Rational Method Runoff Coefficients - Part II

# Example Charts



# THANK YOU