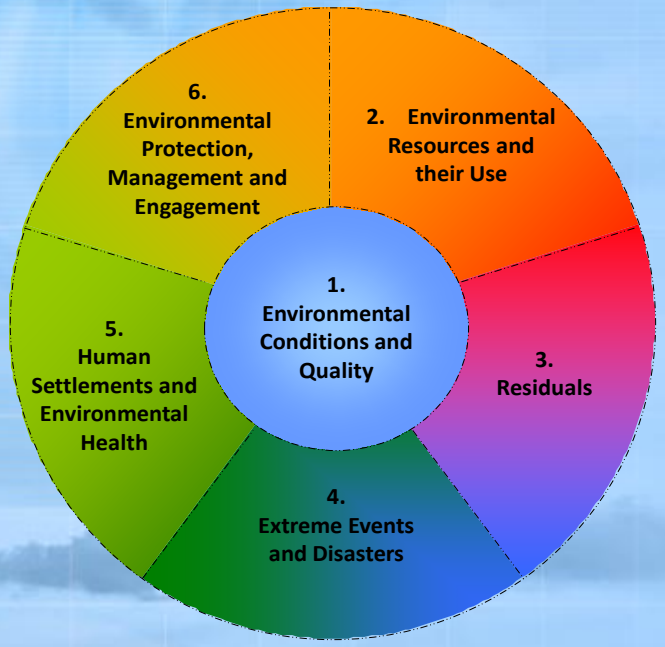
# Land Cover (Topic 1.2.1) and Land Use (Topic 2.3.1) statistics



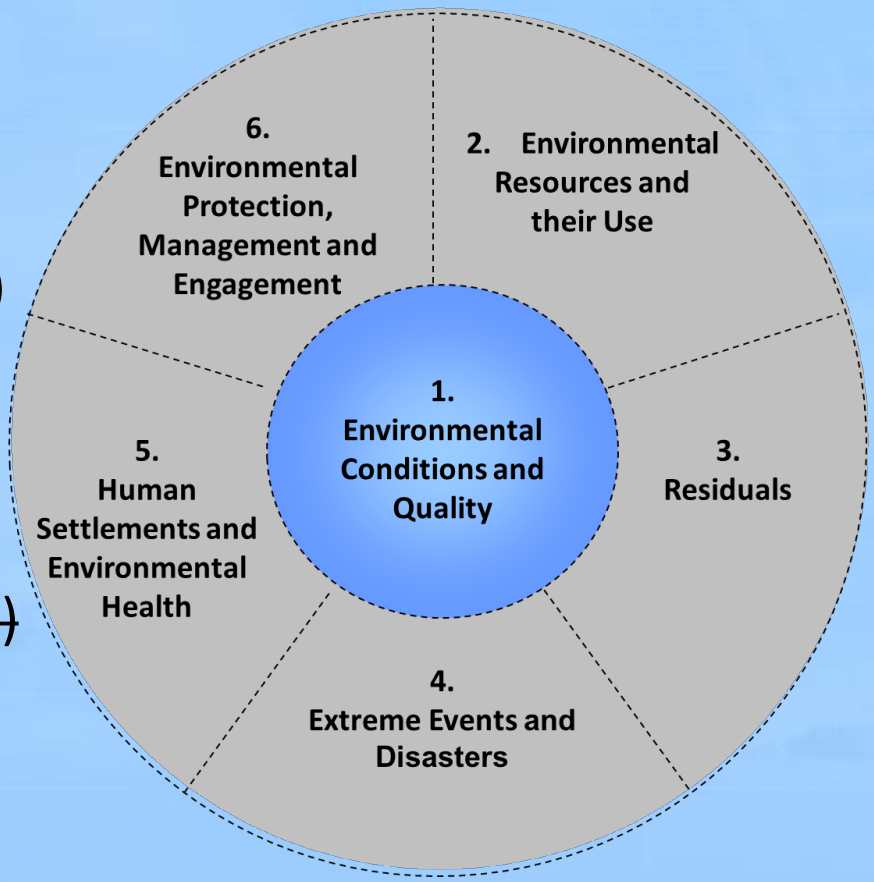

## National Workshop on Environment Statistics in Namibia

## Windhoek, 3-5 December 2019

Environment Statistics Section, United Nations Statistics Division

# Land Cover (Topic 1.2.1) and Land Use (Topic 2.3.1)

1. Learning objectives
2. Review of Level 0 (5m)
3. Level 1 (Compilers)
   - Concepts (10m)
   - Group exercise & Discussion (30m)
4. Level 2 (Data providers)
   - Data options, examples & issues (10m)
   - ~~Group exercise & Discussion (15m)~~
5. Closing Discussion



# What are land cover and land use statistics?

**Land** is a unique resource and asset, that delineates the space in which economic activities and environmental processes take place and within which environmental resources and economic assets are located (*FDES p. 43, also in SEEA-CF p. 174)*. Land is finite, and is under pressure to serve the growing demands for human needs

The two primary aspects of land, land cover and land use, are separate but related concepts. **Land cover** is the 'observed biophysical cover on the earth's surface (FAO, 2005) e.g., lakes, wetlands, forests, etc.; while **land use** refers to the socioeconomic or functional aspects of land, hence describing the activities, management and institutional arrangement put in place e.g., timber, fuelwood, commercial, recreation.

Statistics on land cover record systematically the areas defined by types (also termed extents with their characteristics). Land use statistics cover both land in use and land not in use.

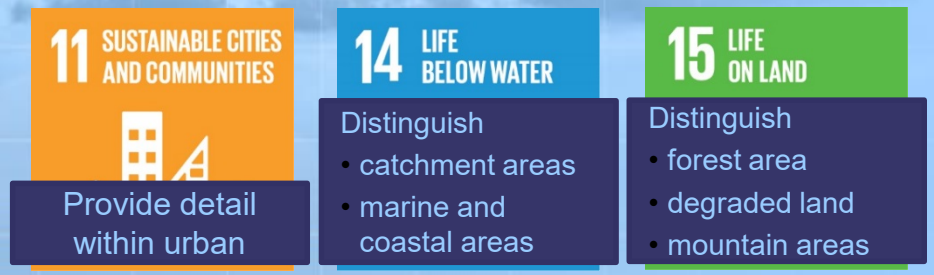
# Why are land statistics needed?

- Spatial foundation for all national administrative data and policies: spatial planning (urban, rural, nature); Land & resource management, conservation and restoration policies (biodiversity loss, desertification), land tenure
- Climate change and desertification: land use change, critical for understanding GHG emissions and removals
- Links to SEEA-CF (Forest, Soil); SEEA-Agriculture, Fisheries & Forests; Foundation for SEEA-EEA (Ecosystem Accounting)
- Indicators:
  - Land cover change - where are changes occurring?
  - Land cover by land use - who manages it?

# Land statistics support many SDGs

## Land cover & change





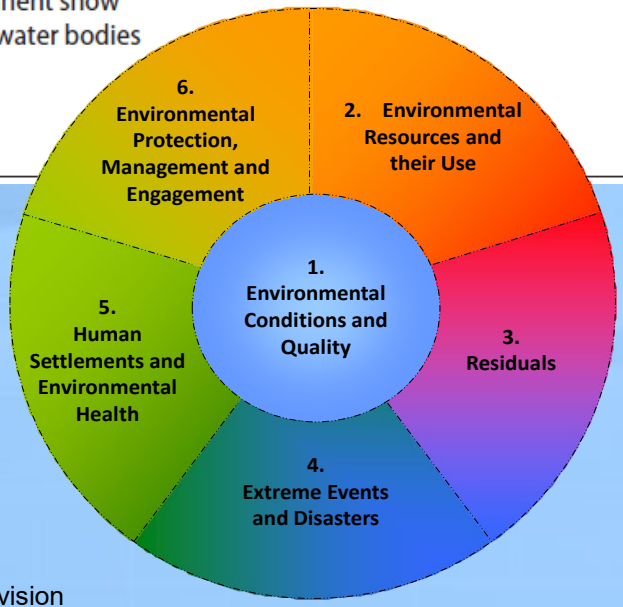

## Land use




## Land ownership

# How do land cover and use statistics look like?

| Component 1: Environmental Conditions and Quality | | | |
|---|---|---|---|
| Subcomponent 1.2: Land Cover, Ecosystems and Biodiversity | | | |
| Topic 1.2.1: Land cover | | | |
| Statistics and related information | | | |
| (**Bold text**—Core Set/Tier 1; regular text—Tier 2; *italicized text*—Tier 3) | Category of measurement | Potential aggregations and scales | Methodological guidance |
| a. **Area under land cover categories** | Area | • By location<br>• By type of land cover (e.g., 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 inter-tidal areas)[a]<br>• National<br>• Subnational | • FAO Land Cover Classification System<br>• System of Environmental-Economic Accounting (SEEA) Central Framework (2012) land cover categories<br>• European Environment Agency (EEA) |



# How do land cover and use statistics look like?

| Component 2: Environmental Resources and their Use | | | |
|---|---|---|---|
| Subcomponent 2.3: Land | | | |
| Topic 2.3.1: Land use | | | |
| Statistics and related information | | | |
| (Bold text—Core Set/Tier 1; regular text—Tier 2; *italicized text—Tier 3*) | Category of measurement | Potential aggregations and scales | Methodological guidance |
| a. **Area under land use categories** | Area | • By type of land use (e.g., agriculture; forestry; land used for aquaculture; use of built-up and related areas; land used for maintenance and restoration of environmental functions; other uses of land not elsewhere classified; land not in use; inland waters used for aquaculture or holding facilities; inland waters used for maintenance and restoration of environmental functions; other uses of inland waters not elsewhere classified; inland water not in use; coastal waters (including area of coral reefs and mangroves); Exclusive Economic Zone (EEZ))<br>• National<br>• Subnational | • FAO<br>• UNECE Standard Classification of Land Use (1989)<br>• SEEA Central Framework (2012) Annex 1 |
| b. Other aspects of land use | | • National<br>• Subnational | |
| 1. *Area of land under organic farming* | Area | | • FAO Inter-departmental Working Group on Organic Agriculture |
| 2. Area of land under irrigation | Area | | |
| 3. Area of land under sustainable forest management | Area | | • Forest Stewardship Council |
| 4. *Area of land under agroforestry* | Area | | |
| c. Land ownership | Area | • By ownership category<br>• National<br>• Subnational | • FAO |

# How do land cover and use statistics look like?

| Topic | Statistics and Related Information (**Bold Text - Core Set/Tier 1**; Regular Text - Tier 2; *Italicized Text - Tier 3* ) | | Area (ha) 2000 | Area (ha) 2018 |
|---|---|---|---|---|
| **Topic 2.3.1: Land use** | a. | Area under land use categories | Area | Area |
| | | 1. Agriculture | Area | Area |
| | | 2. Forestry | Area | Area |
| | | 3. Aquaculture | Area | Area |
| | | 4. Built up and related area | Area | Area |
| | | 5. Land used for maintenance and restoration of environmental functions | Area | Area |
| | | 6. Other land use not elsewhere classified | Area | Area |
| | | 7. Land not in use | Area | Area |
| | | 8. Inland waters used for aquaculture | Area | Area |
| | | 9. Inland waters used for maintenance and restoration of environmental functions | Area | Area |
| | | 10. Other uses of inland waters not elsewhere classified | Area | Area |
| | | 11. Inland water not in use | Area | Area |
| | | 12. Coastal waters (includes area of coral reefs, mangroves, etc.) (also in 1.1.3.b) | Area | Area |
| | | 13. Exclusive Economic Zone (EEZ) (also in 1.1.2.e) | Area | Area |
| | b. | Other aspects of land use | Area | Area |
| | | 1. *Area of land under organic farming* | Area | Area |
| | | 2. Area of land under irrigation | Area | Area |
| | | 3. Area of land under sustainable forest management | Area | Area |
| | | 4. *Area of land under agroforestry* | Area | Area |
| | c. | Land ownership - private land | Area | Area |
| | c. | Land ownership - public land | Area | Area |

# How do land cover accounts look like?

Table 5.13
Physical account for land cover (*hectares*)

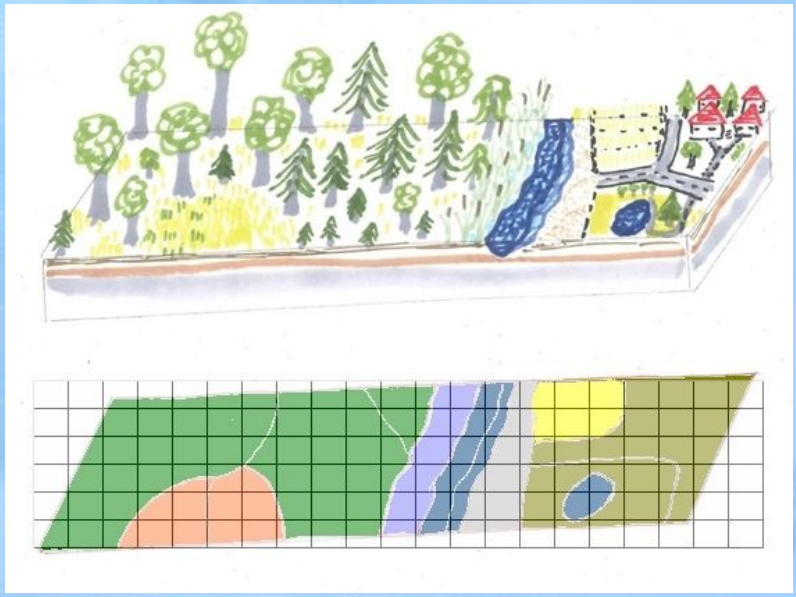
| | Artificial surfaces | Crops | Grassland | Tree-covered area | Mangroves | Shrub-covered area | Regularly flooded areas | Sparse natural vegetated areas | Terrestrial barren land | Permanent snow, glaciers and inland water bodies | Coastal water and inter-tidal areas |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Opening stock of resources** | 12 292.5 | 445 431.0 | 106 180.5 | 338 514.0 | 214.5 | 66 475.5 | 73.5 | 1 966.5 | | 12 949.5 | 19 351.5 |
| **Additions to stock** | | | | | | | | | | | |
| Managed expansion | 183.0 | 9 357.0 | | | | | | | | | |
| Natural expansion | | | 64.5 | | | | | | | | 1.5 |
| Upward reappraisals | | | 4.5 | | | | | | | | |
| *Total additions to stock* | 183.0 | 9 357.0 | 69.0 | | | | | | | | 1.5 |
| **Reductions in stock** | | | | | | | | | | | |
| Managed regression | | 147.0 | 4 704.0 | 3 118.5 | 9.0 | 1 560.0 | 1.5 | | | | |
| Natural regression | | | | | 1.5 | 64.5 | | | | | |
| Downward reappraisals | | | | | | 4.5 | | | | | |
| *Total reductions in stock* | | 147.0 | 4 704.0 | 3 118.5 | 10.5 | 1 629.0 | 1.5 | | | | |
| **Closing stock** | 12 475.5 | 454 641.0 | 101 545.5 | 335 395.5 | 204.0 | 64 846.5 | 72.0 | 1 966.5 | | 12 949.5 | 19 353.0 |

**Note:** Crops include herbaceous crops, woody crops, and multiple or layered crops.

# What do you need to compile land statistics?

1. GIS platform

2. Maps



Review available data sources

3. Expertise (EO, vegetation)

4. Ground truthing and statistics

Assess inputs,
Confusion matrix, Kappa

5. Classification(s) and units

International ones
Re-classify
Harmonize inputs

6. Compilation template

At least 2 time periods
Changes in additions and reductions
Aggregate and allocate statistics

# Welcome to
# Level 1: Land statistics

# Level 1: learning objectives

Basic spatial data analysis concepts

- Definitions
- Classifications: SEEA CF, LCCS
- Thinking spatially: maps to data to statistics
- Land cover/use change
- Data quality
- Error matrix

# Key definitions

- Area under land cover categories (FDES 1.2.1.a): The area of land cover is the area under each land cover category of the classification used. Land cover change is an equally important statistic and indicates the changes occurring to the land cover over time
- Area under land use categories (FDES 2.3.1.a): The area of land use is the area under each land use category of the classification used. Land use change is an equally important statistic and indicates the changes occurring to the land use over time.
- Area of land under organic farming (FDES 2.3.1.b.1): Organic agriculture (farming) is a specific and precise standard of production which aims at achieving optimal agroecosystems that are socially, ecologically and economically sustainable.
- Area of land under irrigation (FDES 2.3.1.b.2) …
- Area of land under sustainable forest management (FDES 2.3.1.b.3)
- Area of land under agroforestry (FDES 2.3.1.b.4)
- Land ownership (FDES 2.3.1.c)

# Classifications and legends

- Land use or land cover products develop their legends based on a classification. There is often a lack of comparability between products as land use or land cover classification definitions can vary between dataset or map
- A legend is the
defined mappi
- Most relevant

1. Land Cover Cla
SEEA Land cov
p. 299)

**SEEA CF Land cover classification**

1 Artificial surfaces (including urban and associated areas)
2 Herbaceous crops
3 Woody crops
4 Multiple or layered crops
5 Grassland
6 Tree-covered areas
7 Mangroves
8 Shrub-covered areas
9 Shrubs and/or herbaceous vegetation, aquatic or regularly flooded
10 Sparsely natural vegetated areas
11 Terrestrial barren land
12 Permanent snow and glaciers
13 Inland water bodies
14 Coastal water bodies and intertidal areas

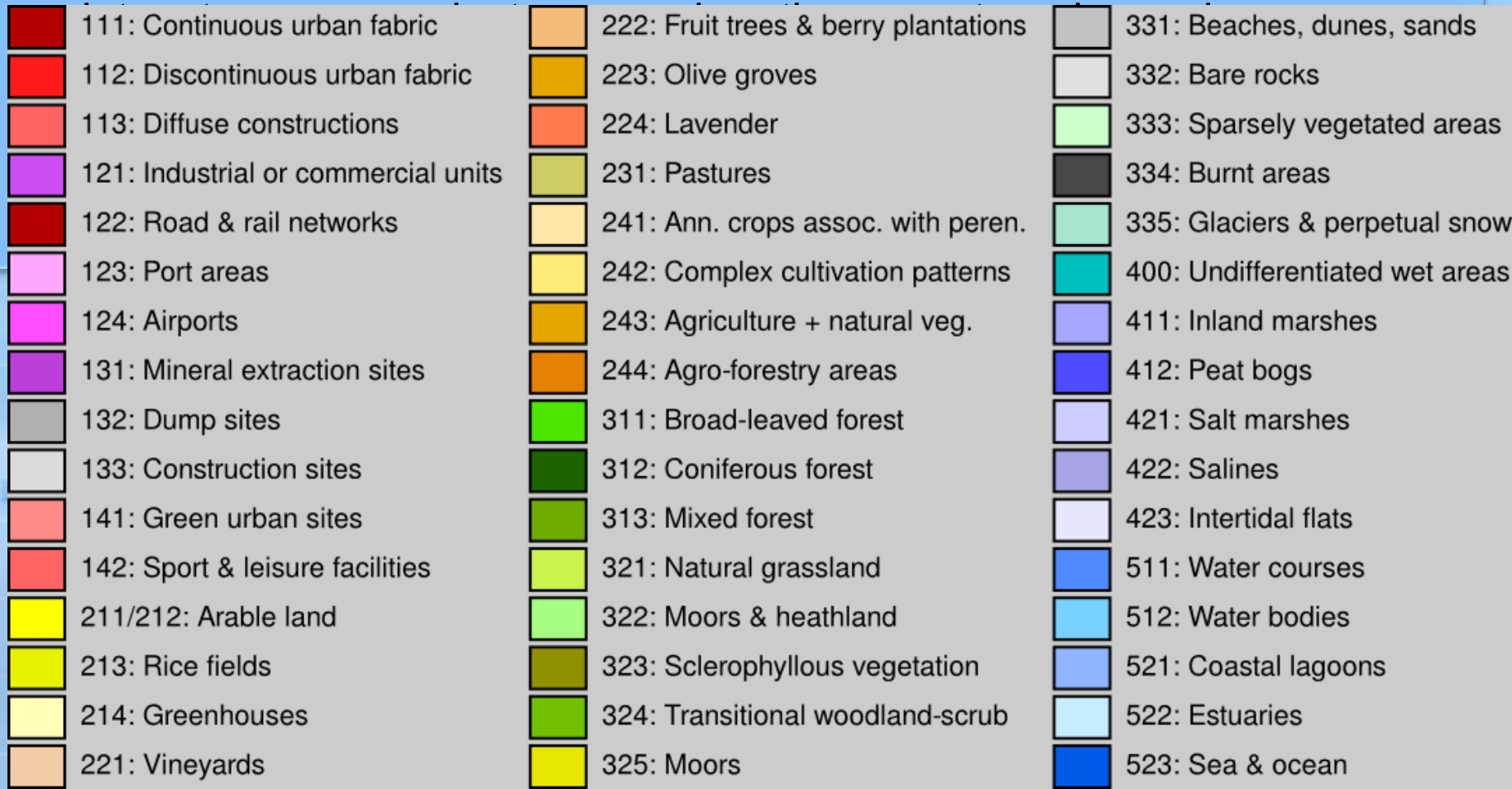
# Classifications and legends

- Land use classifica as land u dataset c
- A legend defined n
- Most rele

2. IGBP Class

# Classifications and legends

- Land use or land cover products develop their legends based on a classification. There is often a lack of comparability between products as land use or land cover classification definitions can vary between

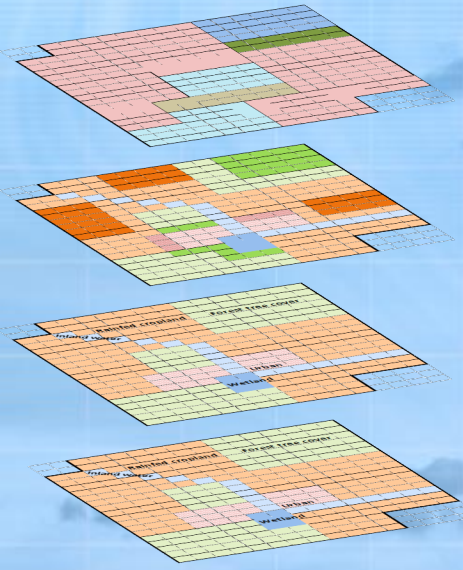


# Input data, EO and GIS

1. GIS platform: ArcGIS, qGIS, R, Python

2. EO instruments: ESA Sentinels, NASA MODIS, Landsat

3. Maps



Land cover: vegetation, water bodies, dry areas, built and crop areas

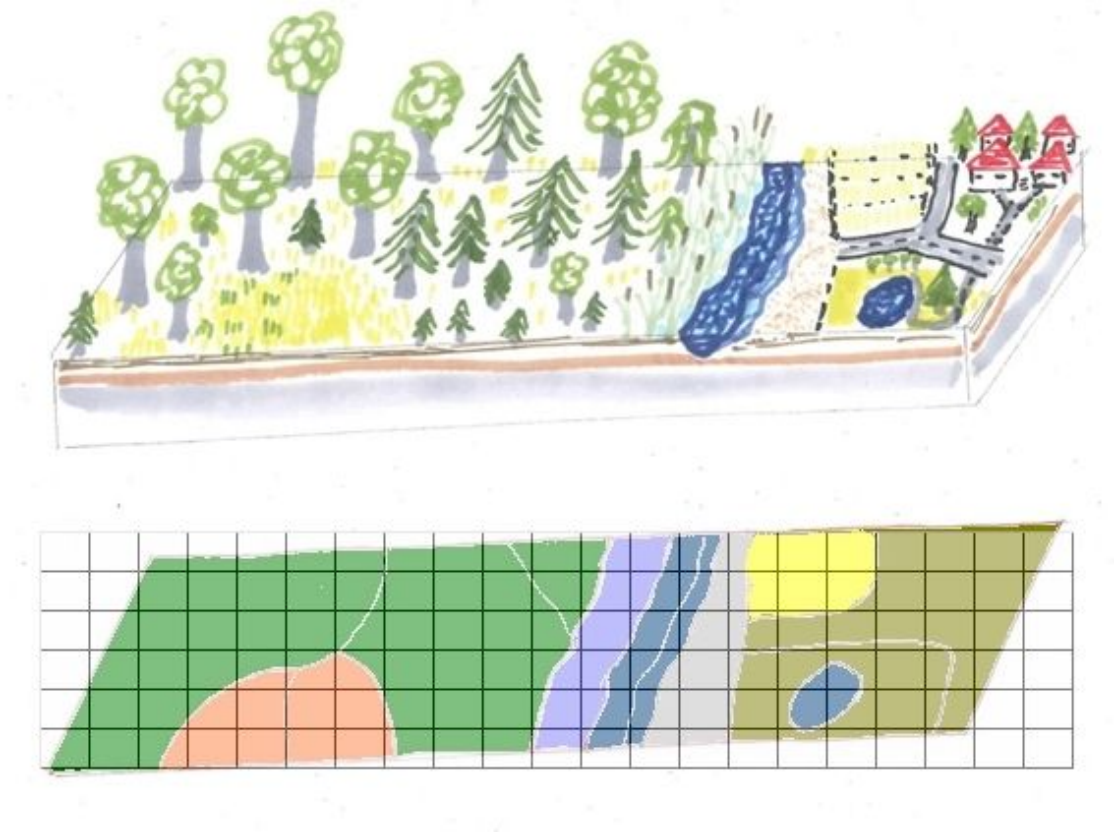
Use and ownership: cadastre, urban plans, public/private land

Admin. units, boundaries: country boundary, coast and islands

Other helpful spatial data: e.g. deforestation, protected areas, infrastructure

3. Ground truthing and statistics: forest plots etc. (EU Lucas)

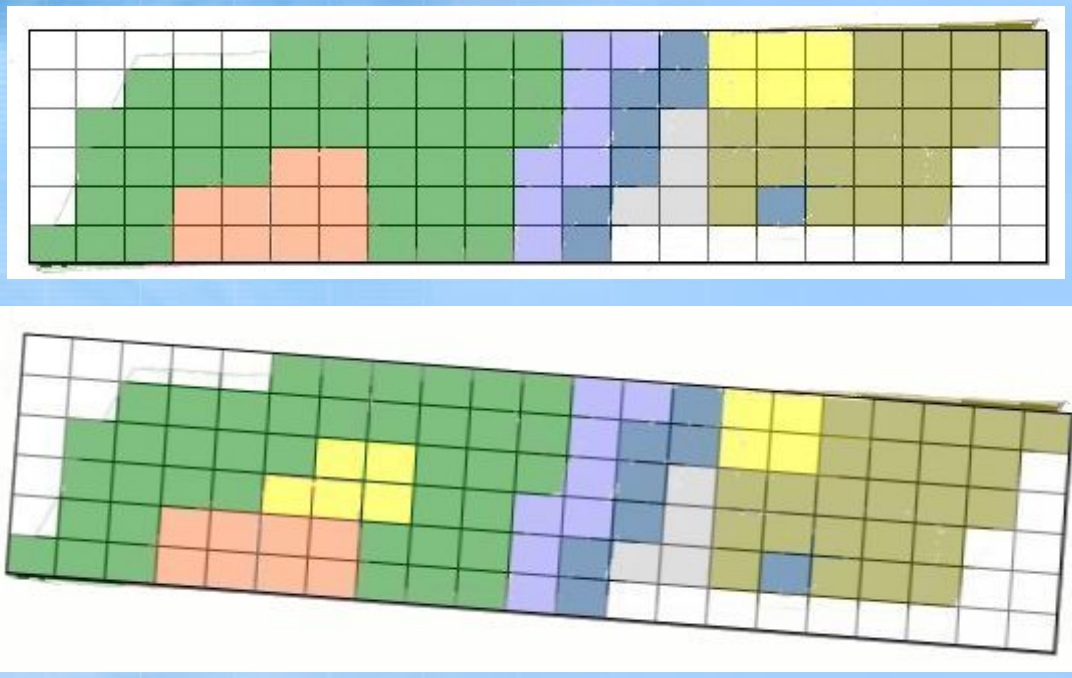
# Think Spatially: maps to data



- What you see…
- and generalized to a grid (raster)
- …where cell value is “predominant” land cover type

| | LEGEND |
|---|---|
| | Artificial Surfaces |
| | Crops |
| | Grassland |
| | Tree covered areas |
| | Regularly flooded |
| | Inland waters |
| | Barren land |

# Boundaries and objects …

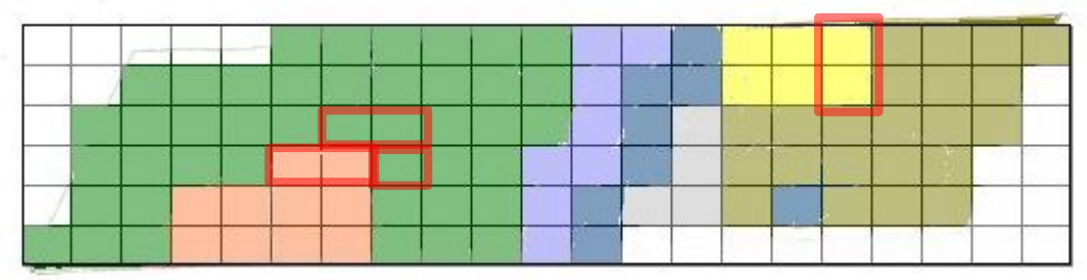


- …don't always match because of different:
  - projections
  - scales
  - sources
  - methods

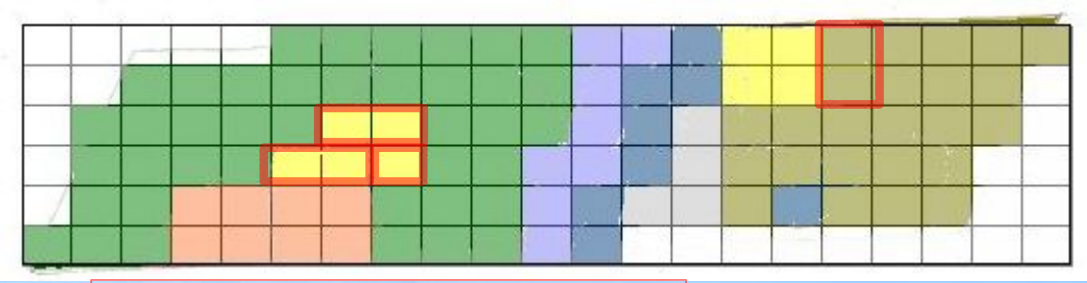
- and need some adjustment before overlaying

# Land cover change

•2ha Crops to artificial



•Now we can compare the two!



•What has changed?

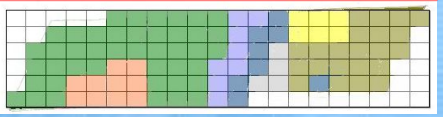
•2ha Grassland to crops

•3ha Tree covered to crops

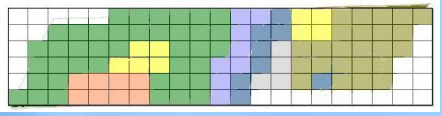
| | LEGEND |
|---|---|
| | Artificial Surfaces |
| | Crops |
| | Grassland |
| | Tree covered areas |
| | Regularly flooded |
| | Inland waters |
| | Barren land |

# Land cover timeseries – basic statistics

Land cover 2000



Land cover 2018

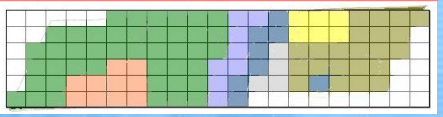


| LEGEND |
| --- |
| Artificial Surfaces |
| Crops |
| Grassland |
| Tree covered areas |
| Regularly flooded |
| Inland waters |
| Barren land |

| | Land cover, ha | 2000 | 2018 |
| --- | --- | --- | --- |
| 1 | Artificial surfaces | 22 | 24 |
| 2 | Crops | 6 | 9 |
| 3 | Grasslands | 10 | 8 |
| 4 | Tree covered areas | 43 | 40 |
| 5 | Regularly flooded ar | 8 | 8 |
| 6 | Inland waters | 8 | 8 |
| 7 | Baren lands | 3 | 3 |
| | Total | 100 | 100 |

# Land cover timeseries – calculate SDGs

Land cover 2000



Land cover 2018

| LEGEND |
| --- |
| Artificial Surfaces |
| Crops |
| Grassland |
| Tree covered areas |
| Regularly flooded |
| Inland waters |
| Barren land |

SDGs metadata source: https://unstats.un.org/sdgs/metadata/

**Indicator 15.1.1:** Forest area as a proportion of total land area

*Forest area (reference year) / Land area (2015) * 100*

**Indicator 15.3.1:** Proportion of land that is degraded over total land area

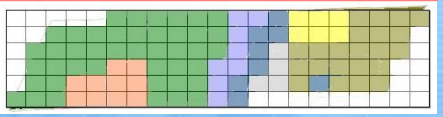
$$A(Degraded)_{i,n} = \sum_{j=1}^{n} Arecent_{i,n} + Apersistent_{i,n}$$

$$P_{i,n} = \frac{A(degraded)_{i,n}}{A(total)_{i,n}}$$

| | | 2000 | 2018 |
| --- | --- | --- | --- |
| SDG 15.1.1 | % forest | 43 | 40 |
| SDG 15.3.1 | % degraded | 3 | 3 |

# Land cover timeseries – calculate stocks and flows

Land cover 2000



Land cover 2018

| | LEGEND |
|---|---|
| | Artificial Surfaces |
| | Crops |
| | Grassland |
| | Tree covered areas |
| | Regularly flooded |
| | Inland waters |
| | Barren land |

- Artificial surfaces +2
- Crops -2

- Grassland -2
- Crops +2

- Tree covered -3
- Crops +3

**Physical account for land cover**

| | Artificial surfaces | Crops | Grass-land | Tree covered | Regularly flooded | Inland waters | Barren land | **Total** |
|---|---|---|---|---|---|---|---|---|
| Opening | 22 | 6 | 10 | 43 | 8 | 8 | 4 | 101 |
| Additions | 2 | 5 | | | | | | 7 |
| Reductions | | 2 | 2 | 3 | | | | 7 |
| Closing | 24 | 9 | 8 | 40 | 8 | 8 | 4 | 101 |

# Level 1 - Group Exercise (30m)

- Validation (ground data) preferably more than 30 points per class, larger classes with larger validation samples
- Develop a error matrix to validate a land cover map
- Estimate commission and omission errors
- Estimate Kappa
- Discuss reliability of validation results

The Kappa statistic varies from 0 to 1, where.

0 = agreement equivalent to chance.

0.1 – 0.20 = slight agreement.

0.21 – 0.40 = fair agreement.

0.41 – 0.60 = moderate agreement.

0.61 – 0.80 = substantial agreement.

0.81 – 0.99 = near perfect agreement

1 = perfect agreement.

**Grid/Classified land cover data**

| | | | | |
|---|---|---|---|---|
| M | M | C | A | A |
| R | R | C | C | A |
| R | R | C | C | C |
| T | T | T | T | T |
| T | T | T | T | T |

**Point/Reference land cover data**

| | | | | |
|---|---|---|---|---|
| M | C | C | A | A |
| R | C | C | A | A |
| R | R | C | C | A |
| T | T | C | C | T |
| T | T | T | T | T |

**Agreement/disagreement pairs**

| | | | | |
|---|---|---|---|---|
| MM | MC | CC | AA | AA |
| RR | RC | CC | CA | AA |
| RR | RR | CC | CC | CA |
| TT | TT | TC | TC | TT |
| TT | TT | TT | TT | TT |

**Land cover Error Matrix**

| | | Reference data | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | A | C | M | T | R | |
| Classified data | A (Artificial Surfaces) | | | | | | |
| | C (Crop) | | | | | | |
| | M (Mangrove) | | | | | | |
| | T (Forest) | | | | | | |
| | R (Regularly flooded) | | | | | | |
| | Total | | | | | | |

**Step 1: Transcribe the number of agreement and disagreement pairs of data (left down) from the classified (left top) and reference (left middle) data in the error matrix (shown above).**

Record the number of agreements in diagonal

Record the number of disagreements in rows

**Step 2: Estimate overall accuracy**

Overall accuracy = total agreements / total samples

**Step 3: Estimate omission errors (Producers accuracy)**

By column class = incorrectly classified / total reference samples by class

**Step 4: Estimate commission errors (Users accuracy)**

By row class = incorrectly referenced / total classification samples by class

**Step 5: Estimate Kappa**

Kappa = (total agreements - agreements by chance) /(total samples - agreements by chance)

Estimate agreements by chance per class (total by column*total by raw/total)

Estimate sum of agreements by chance

Estimate total agreements (sum of diagonal counts)

# Welcome to
# Level 2: Land statistics

# Level 2: Learning objectives

- More conceptual issues – one official map, multiple uses
- Examples from other countries
- Input data options and sources
  - International data
  - Multiple sources, metadata
  - Differing class definitions
  - Limitations of remote sensing

# One official map for multiple uses

- Different departments often use different classifications and sources
- Key objective is to agree on one map able to serve multiple purposes
- Consistency with international sources will facilitate reporting obligations

# European example: CORINE Land cover and LUCAS

- CORINE land cover is an example of harmonized and decentralized production of land cover data
- Customized software tool ensures complete comparability between countries and time periods although input data differs
- LUCAS is a network of sample points for which land data is regularly observed and recorded

# Examples from countries

## EnviStats India 2018

**Statement 1.23 : Land use and land cover classes - India**

| S. No. | L 1 | L 2 | Area (Sq. Kms.) | | |
|---|---|---|---|---|---|
| | | | 1985 | 1995 | 2005 |
| 1 | Agriculture | Crop land | 1,558,712 | 1,556,346 | 1,614,921 |
| | | Current Shifting cultivation | | | |
| | | Fallow | 252,073 | 266,671 | 221,136 |
| | | Plantation | 77,493 | 77,956 | 78,560 |
| | | ***Sub Total -1*** | **1,888,278** | **1,900,973** | **1,914,617** |
| 2 | Barren/ unculturable/ Wastelands | Barren Rocky | 65,484 | 71,250 | 69,855 |
| | | Gullied / Ravinous Land | 84,414 | 78,649 | 74,355 |
| | | Rann | | | |
| | | Salt Affected Land | | | |
| | | Sandy Area | | | |
| | | Scrub Land | 182,860 | 188,342 | 192,873 |
| | | ***Sub Total-2*** | ***332,758*** | ***338,241*** | ***337,083*** |
| 3 | Builtup | Mining | | | |
| | | Rural | | | |
| | | Urban | 34,019 | 40,090 | 47,239 |
| | | ***Sub Total-3*** | **34,019** | **40,090** | **47,239** |
| 4 | Forest | Deciduous | 317,429 | 294,777 | 280,684 |
| | | Evergreen/Semi evergreen | 208,063 | 205,160 | 197,992 |
| | | Forest Plantation | 150,163 | 149,523 | 147,284 |
| | | Scrub Forest | 84,368 | 91,188 | 98,723 |
| | | Swamp / Mangroves | 4120 | 4525 | 4579 |
| | | ***Sub Total-4*** | ***764,143*** | ***745,173*** | ***729,262*** |
| 5 | Grass / Grazing | Grass / Grazing | 54,553 | 56,604 | 61,595 |
| | | ***Sub Total-5*** | ***54,553*** | ***56,604*** | ***61,595*** |
| 6 | Snow and Glacier[2] | Snow and Glacier | 97,152 | 91,636 | 92,522 |
| | | ***Sub Total-6*** | **97,152** | **91,636** | **92,522** |
| 7 | Wet lands / Water bodies[1] | Inland Wetland | | | |
| | | Coastal Wetland | | | |
| | | River/Stream/Canals | | | |
| | | Water bodies | 116,119 | 121,148 | 114,856 |
| | | ***Sub Total-7*** | ***116,119*** | ***121,148*** | ***114,856*** |
| | ***Grand Total*** | | ***3,287,022*** | ***3,293,865*** | ***3,297,174*** |

1 Includes Aqua Culture, Water bodies, and Permanent Wetlands;
2 Includes Salt Pan, Snow and Ice.
Source: Remote Sens. 2015, 7(3), 2401-2430; doi:10.3390/rs70302401 Article "Development of Decadal (1985-1995-2005) Land Use and Land Cover Database for India

## Compendium of Environment Statistics; Ethiopia, 2016

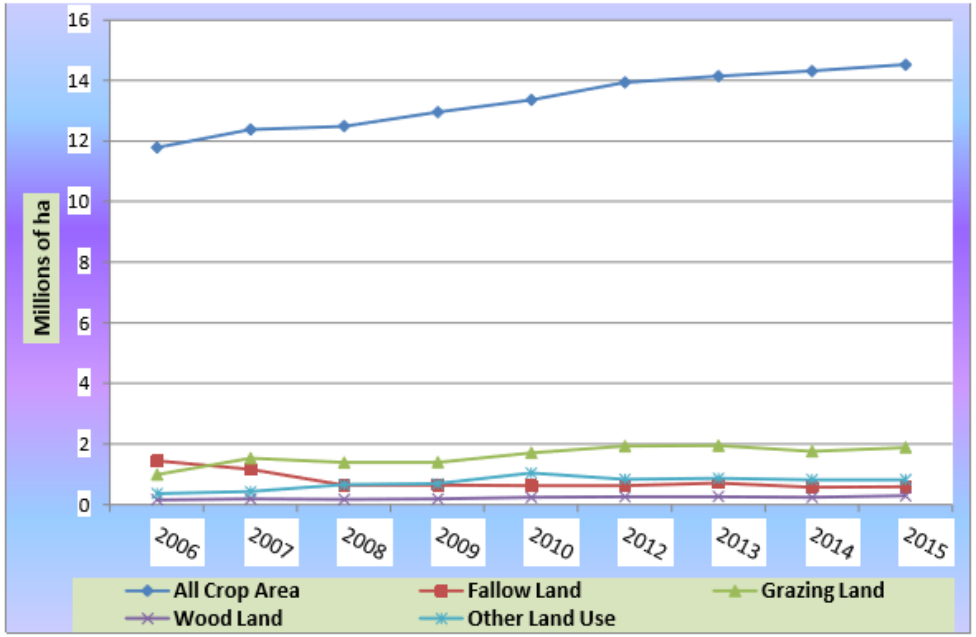



**Figure 17: Land Use Area and Category by Year**
*Source: AgSS main season reports of CSA 2006/07-2015/16*

# Input data options and sources

International data sources

- European Space Agency
- NASA
- Many more

**Three global LC maps for the 2000, 2005 and 2010 epochs**

The CCI-LC team has successfully produced and released its 3-epoch series of global land cover maps at 300m spatial resolution, where each epoch covers a 5-year period (2008-2012, 2003-2007, 1998-2002). These maps were produced using a multi-year and multi-sensor strategy in order to make use of all suitable data and maximize product consistency. The entire 2003-2012 MERIS Full and Reduced Resolution (FR and RR) archive was used as input to generate a 10-year 2003-2012 global land cover map. This 10-year product has then served as a baseline to derive the 2010, 2005 and 2000 maps using back- and up-dating techniques with MERIS and SPOT-Vegetation time series specific to each epoch.

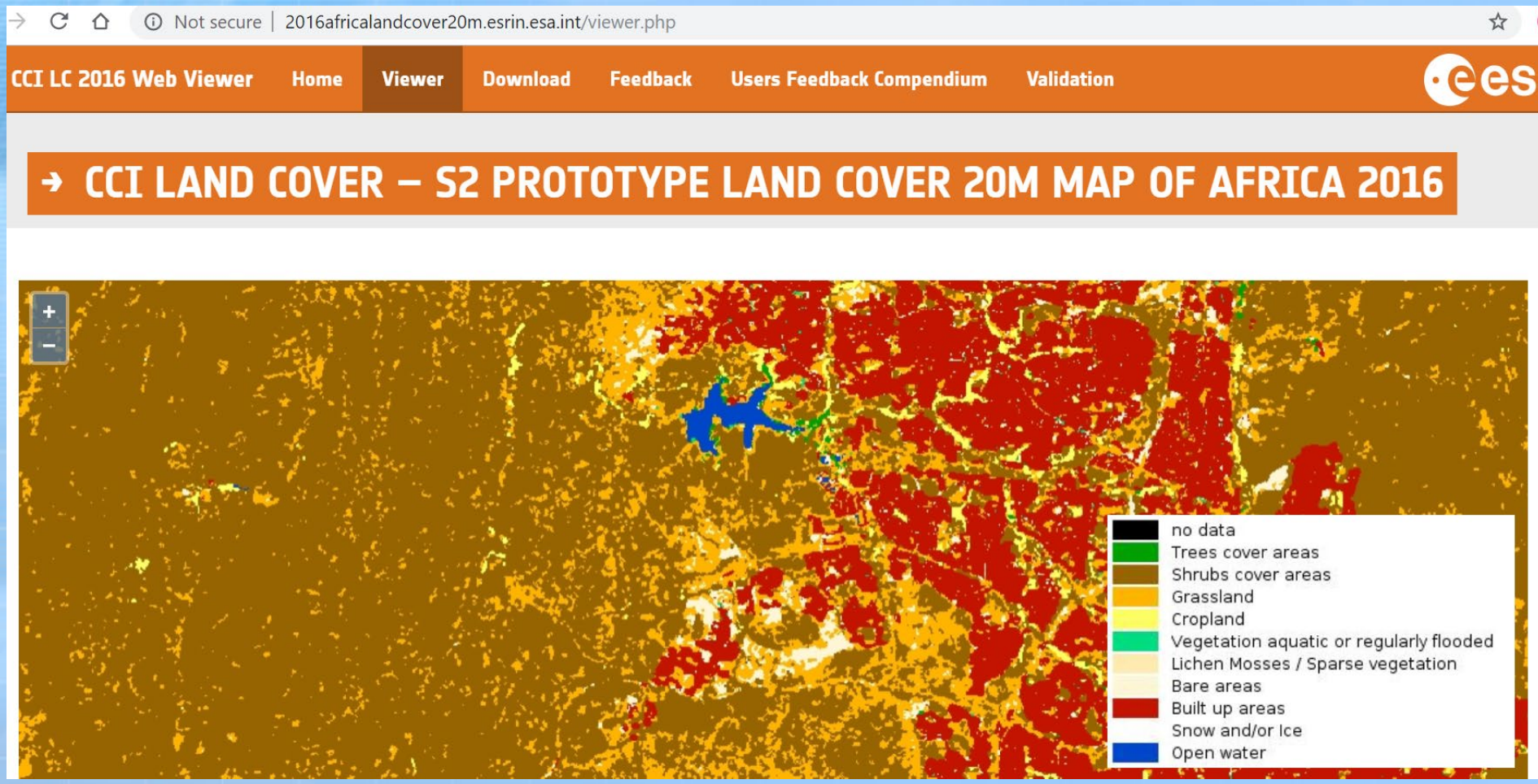

In order to meet the user requirement set in this project, the map proposes a legend based on the UN Land Cover Classification System (LCCS) with the view to be as much as possible compatible with the GLC2000, GlobCover 2005 and 2009 products. The level of thematic details was found to be improved with respect to previous global LC products. Each map is characterized by a set of quality flags.

*For more information on the products, go to: http://maps.elie.ucl.ac.be/CCI/viewer.*

•Source: https://www.esa-landcover-cci.org/?q=node/158

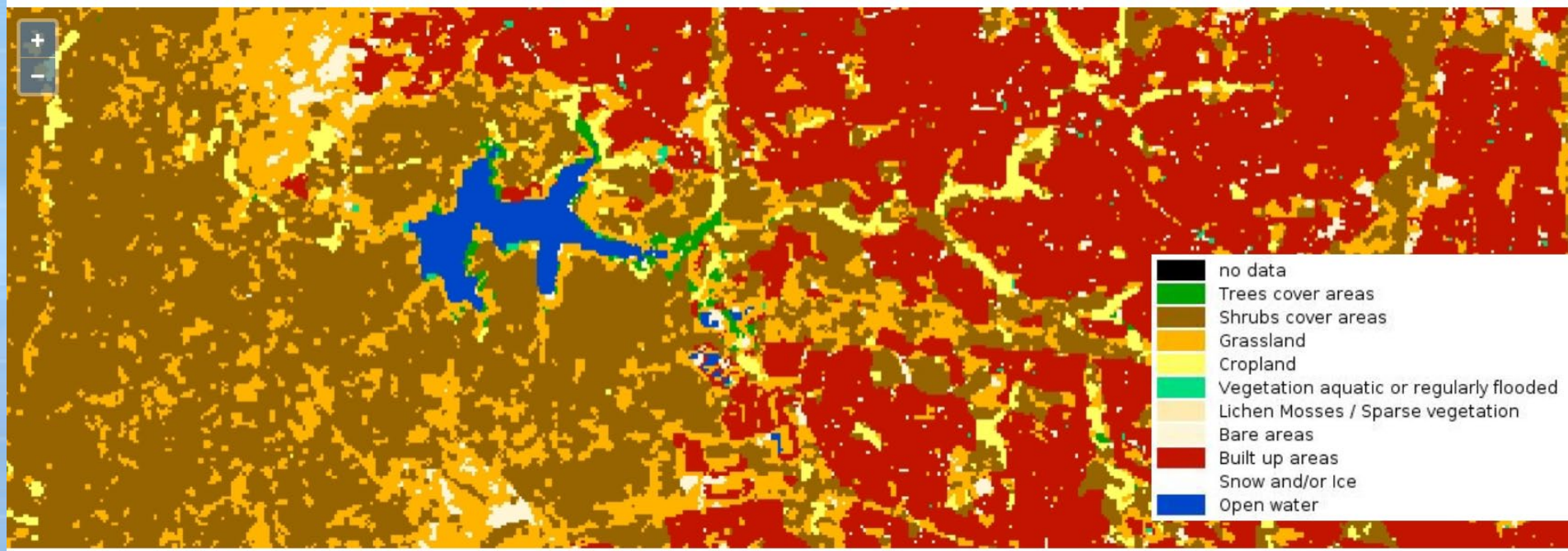
•Viewer: http://maps.elie.ucl.ac.be/CCI/viewer/index.php

# Spatial data: CCI LAND COVER – S2 PROTOTYPE LAND COVER 20M MAP OF AFRICA 2016




Source: http://2016africalandcover20m.esrin.esa.int/

Viewer: http://2016africalandcover20m.esrin.esa.int/viewer.php


+
−
no data
Trees cover areas
Shrubs cover areas
Grassland
Cropland
Vegetation aquatic or regularly flooded
Lichen Mosses / Sparse vegetation
Bare areas
Built up areas
Snow and/or Ice
Open water

# Input data options and sources

- Lots of data from international sources
- Multiple sources of imagery, metadata
- Differing class definitions
- Limitations of remote sensing

# Discussion points

1. What national data and classifications for Land are already available for your country?
2. If there are no national sources, what data could you use to create Land statistics?
3. What would be the priorities (Cover, Use, Ownership; Agreement on “One Map”)?
4. Discuss and report your results

# Take home points

- Land Cover maps, classified by the SEEA-CF classification are a useful starting point for creating Land statistics and accounts
- Data need to be national and comparable
- Combine satellite data with other data
- An interdepartmental team should agree on “One Map”
- Global data for Land Cover may be used if there is no national alternative
- Mixed land cover and land use will often be practical but consider land cover first before land use

# Acknowledgements


- This presentation has been elaborated by the Environment Statistics Section of the United Nations Statistics Division.

- It is based on Chapter 3 of the Framework for the Development of Environment Statistics (FDES 2013).

- It contains materials developed by the Statistics Division of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP): http://communities.unescap.org/environment-statistics

# Questions and comments?

# Thank you for your attention!

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