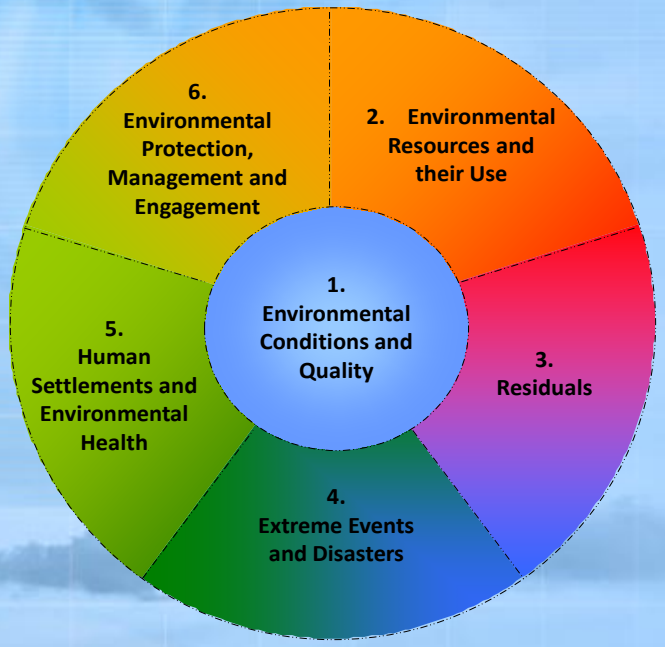
Land Cover (Topic 1.2.1) and Land Use (Topic 2.3.1) statistics



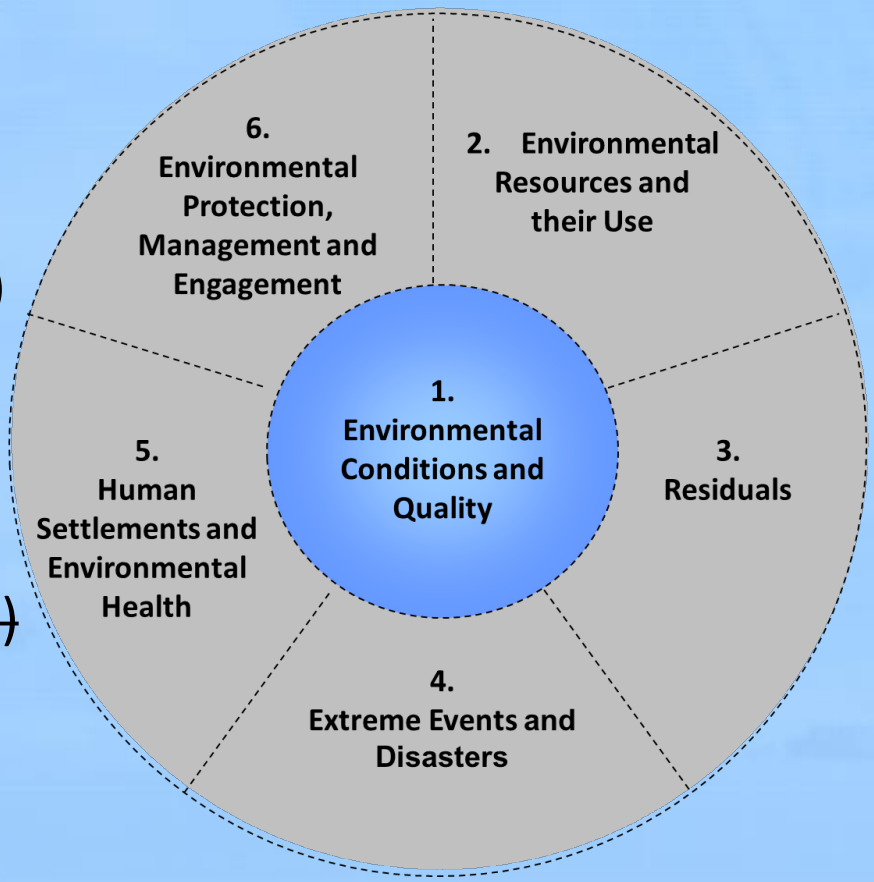
National Workshop on Environment Statistics and Climate Change Statistics

St. George's, Grenada, 12-14 November 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.

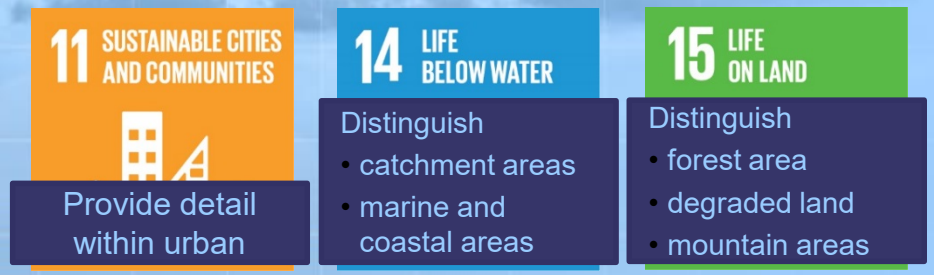
Statistics on land cover record systematically the areas by defined types (also termed extents with their characteristics). Land use statistics cover both land in use and land not in use.

Why are land statistics needed?

- Spatial foundation for all national administrative data and policies
- Land & resource management, conservation and restoration policies (biodiversity loss, desertification), land tenure
- Climate change: 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

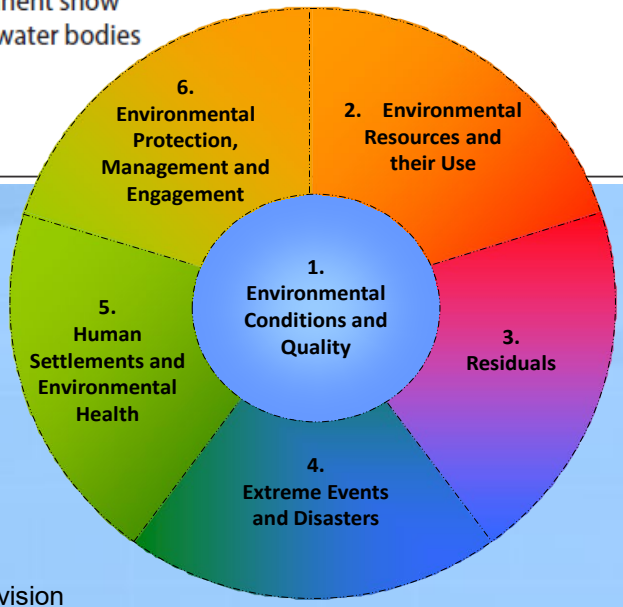


Land use

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 • 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] • National • Subnational	• FAO Land Cover Classification System • System of Environmental-Economic Accounting (SEEA) Central Framework (2012) land cover categories • 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)) • National • Subnational	• FAO • UNECE Standard Classification of Land Use (1989) • SEEA Central Framework (2012) Annex 1
b. Other aspects of land use		• National • 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 • National • Subnational	• FAO

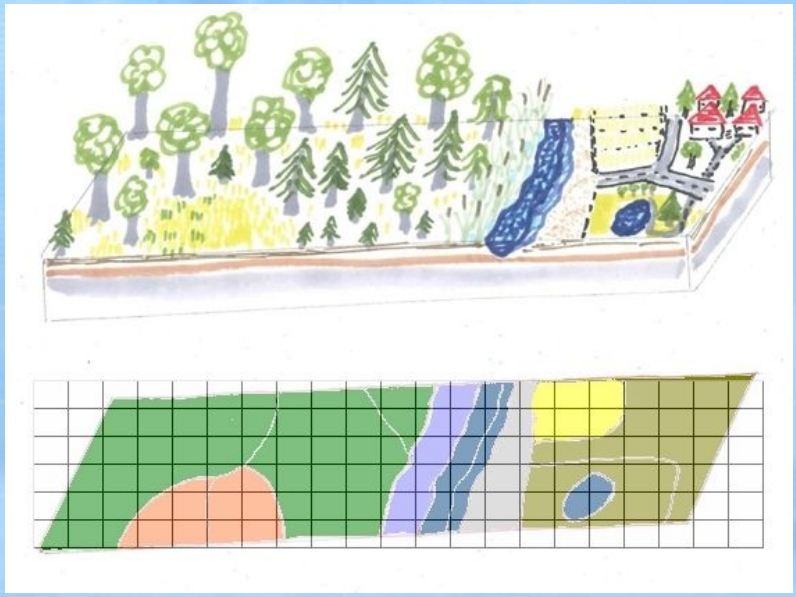
How do land cover and use statistics look like?

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

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

- Thinking spatially: maps to data to statistics
- Classifications: SEEA CF, LCCS, IGBP, CORINE
- Boundaries
- 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

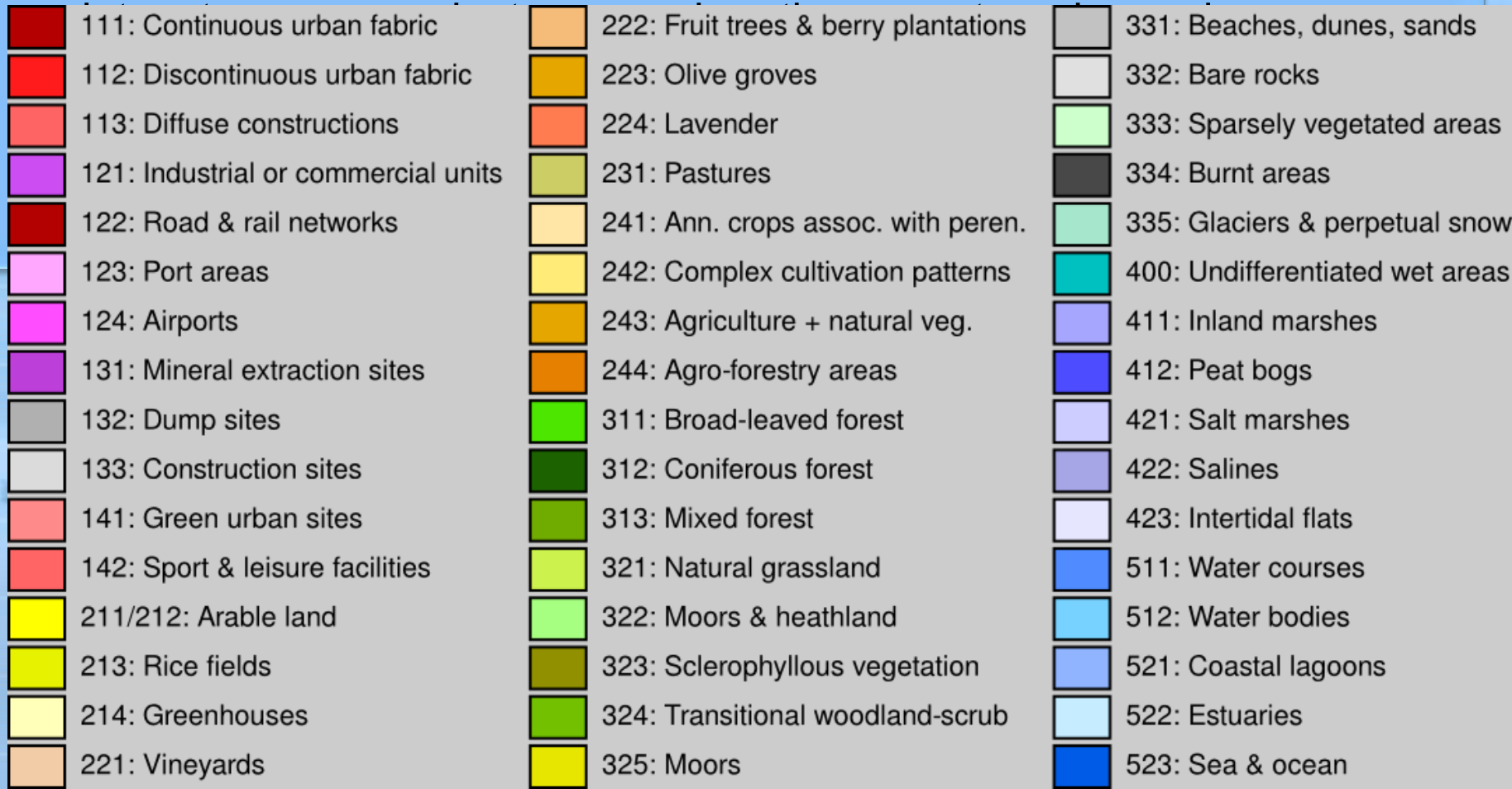
Classifications and legends

- 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

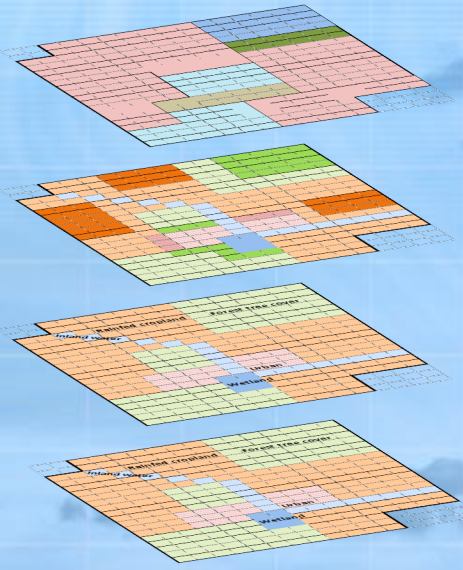


Input data, EO and GIS

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

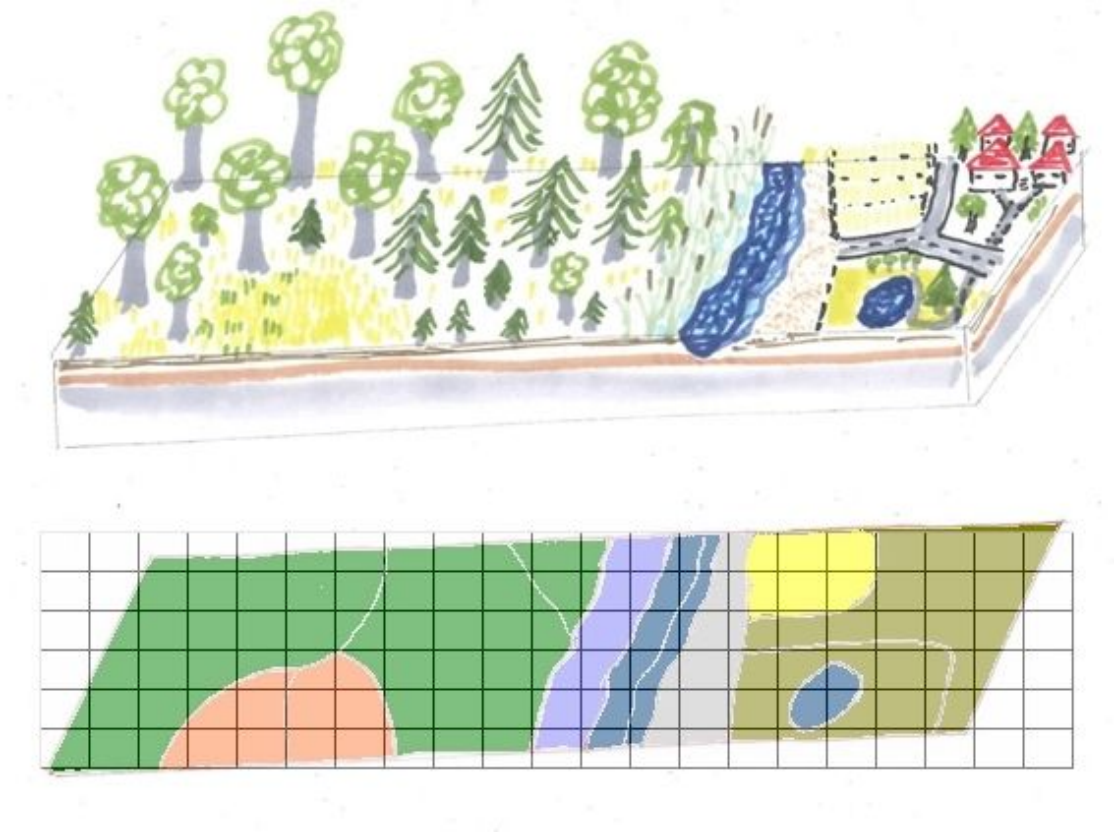
Use and ownership: cadastre, urban plans, public/private land

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)

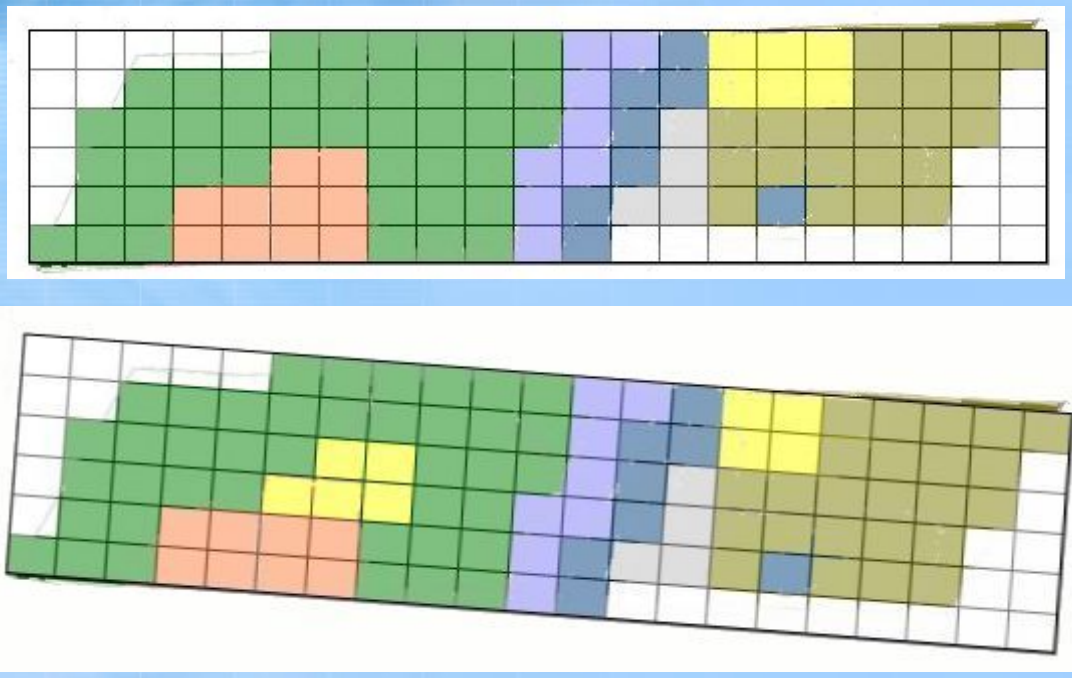
Think Spatially: maps to data



- 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 …

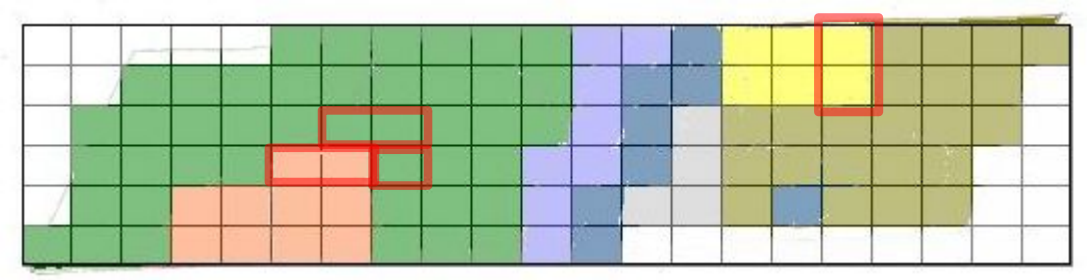


- …don't always match because of different:
  - projections
  - scales
  - sources
  - methods

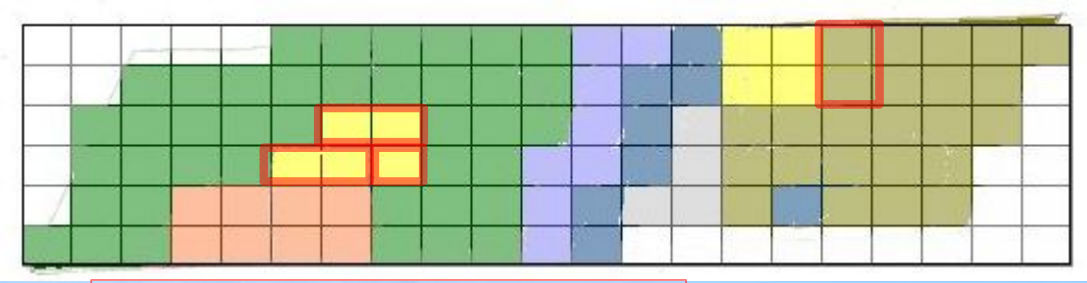
- and need some adjustment before overlaying

Land cover change

•2ha Crops to artificial



•Now we can compare the two!



•What has changed?

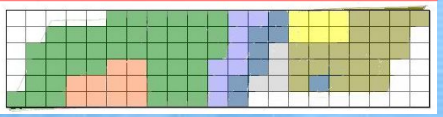
•2ha Grassland to crops

•3ha Tree covered to crops

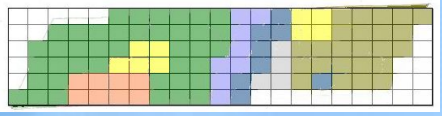
	LEGEND
	Artificial Surfaces
	Crops
	Grassland
	Tree covered areas
	Regularly flooded
	Inland waters
	Barren land

Land cover timeseries – basic statistics

Land cover 2000



Land cover 2018

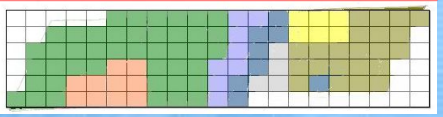


LEGEND
Artificial Surfaces
Crops
Grassland
Tree covered areas
Regularly flooded
Inland waters
Barren land

	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

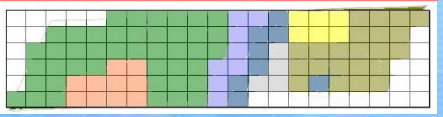
$$A(Degraded)_{i,n} = \sum_{j=1}^{n} Arecent_{i,n} + Apersistent_{i,n}$$

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

		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

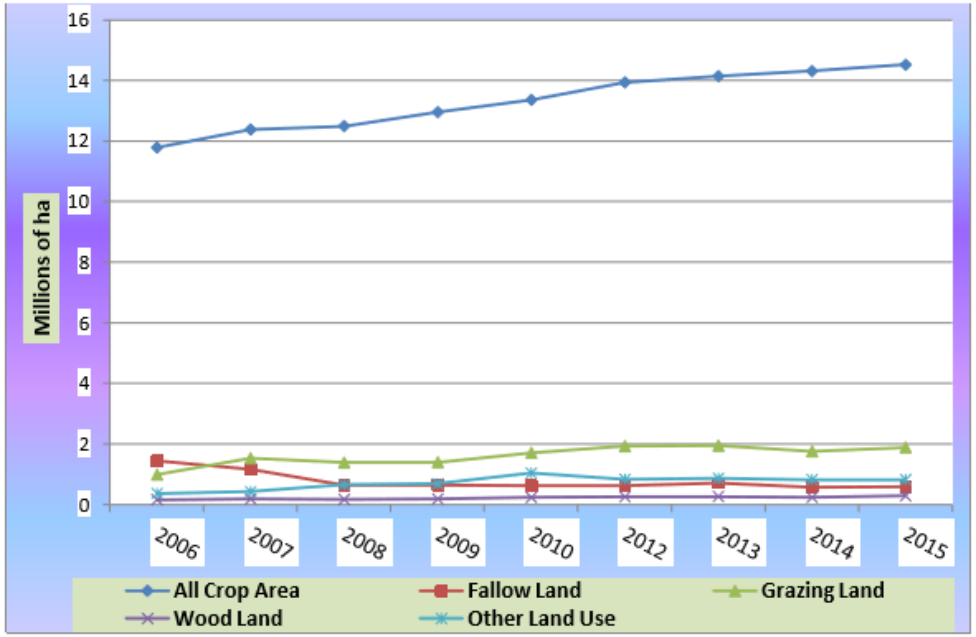


Figure 17: Land Use Area and Category by Year
Source: AgSS main season reports of CSA 2006/07-2015/16

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

LAND USE/LAND COVER MAP FOR GRENADA

eoworld 2
Earth Observation for Development

Location

Legend

- Town or village
- River or stream
- Road
- Water
- Wetland
- Mangrove
- Buildings
- Roads and other built-up surfaces (e.g. concrete, asphalt)
- Bare ground (e.g. sand, rock)
- Quarry
- Semi-deciduous forest
- Drought Deciduous open woodland
- Evergreen and seasonal Evergreen forest
- Deciduous, coastal Evergreen and mixed forest or shrubland
- Elfin and Sierra Palm tall cloud forest
- Nutmeg and woody agriculture (e.g. cacao, coconut, banana)
- Pastures, cultivated land and herbaceous agriculture
- Golf course

Interpretation

This product shows a 2 m resolution land use/land cover map of Grenada. Land use/land cover was predominantly mapped through a combination of automated classification and visual interpretation of high-resolution Pleiades satellite imagery acquired in 2013 and 2014. RapidEye satellite imagery (2011-2014) and existing land use/land cover data were used to map areas obscured by significant cloud cover in the Pleiades imagery.

Local projection: WGS84 UTM Zone 20 North
Geographical system: WGS84 Geographic (DMS)

0 2 4 8 km

N

Data sources

This product was derived from Pleiades satellite data acquired between 2013-2014 (Includes material © CNES 2014, Distribution Astrium Services / Spot Image S.A., France, all rights reserved) and RapidEye satellite data acquired between 2011-2014 (Includes material © (2014) BlackBridge S.àr.l. All rights reserved). The product also builds upon the 2001 land cover map developed by The Nature Conservancy's Mesoamerica and Caribbean Region project.

The aim of EOWORLD is to produce, deliver and assess the benefits of EO-based geo-information services in support of on-going World Bank project activities. This work forms part ESA's efforts to raise awareness within the World Bank of European and Canadian EO missions (both ESA and national), and the capabilities of EO service providers to provide information customised to the needs of individual projects. The World Bank together with ESA have identified 12 specific EOWORLD Actions for which EO-based information has significant potential.

This product was produced by the British Geological Survey as part of Annex 3 of the EOWORLD 2 project: Risk information services in the Caribbean.

British Geological Survey

esa

THE WORLD BANK

Input data options and sources

- International data: FAO data, Deforestation map
- 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

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- 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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