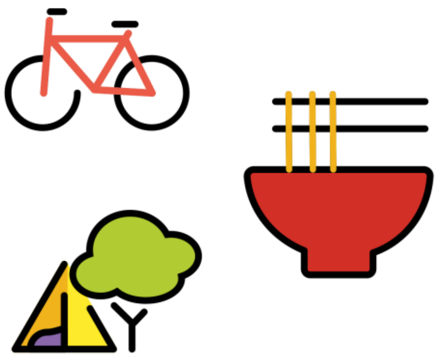
Land use/land cover change and data quality assessment

Who am I?

Macroecology and Society

iDiv

And in the free time?



Help me to learn your names

Something you really like  about your studies

Something you really don’t like  about your studies

Plan for today

Lecture | 10:00-10:30

Break | 10:30-10:40 

Exercise1 | 10:40-12:00

Lunch break | 12:00-13:00 

Exercise2 | 13:00-14:20

Break | 14:20-14:30 

What we learned | 14:30-15:00

What is land use/land cover (LULC) change?

‘Land cover change denotes a change in certain continuous characteristics of the land such as vegetation type, soil properties, and so on, whereas land-use change consists of an alteration in the way certain area of land is being used or managed by humans’ (Patel et al. 2019)

Patel, S.K., Verma, P., Singh, G.S., 2019. Agricultural growth and land use land cover change in peri-urban India. Environmental Monitoring and Assessment 191 (9), 600. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6366331/

What impacts does it have?

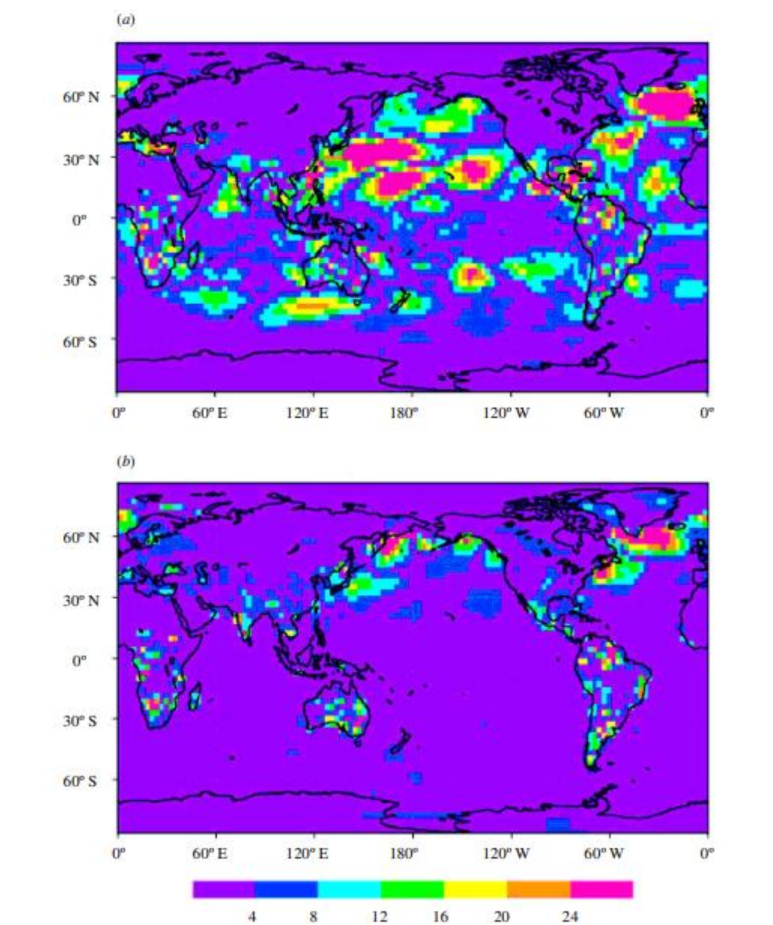


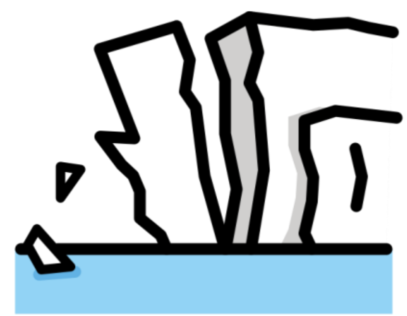
Figure 2. The 10-year average absolute-value change in surface latent turbulent heat flux in W m^{-2} worldwide as a result of the land-use changes: (*a*) January, (*b*) July. (Adapted from Chase *et al.* (2000).)

The influence of land-use change and landscape dynamics on the climate system: relevance to climate-change policy beyond the radiative effect of greenhouse gases

By Roger A. Pielke Sr[1], Gregg Marland[2], Richard A. Betts[3], Thomas N. Chase[4], Joseph L. Eastman[1], John O. Niles[5], Dev dutta S. Niyogi[6] and Steven W. Running[7]

[1]*Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523, USA*
[2]*Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6335, USA*
[3]*Met Office, Hadley Centre for Climate Prediction and Research, Bracknell, Berkshire RG12 2SY, UK*
[4]*Cooperative Institute for Research in Environmental Sciences and Department of Geography, CB 216, University of Colorado, Boulder, CO 80309, USA*
[5]*Energy and Resources Group, 310 Barrows Hall, University of California, Berkeley, CA 94720-2050, USA*
[6]*Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695-7236, USA*
[7]*Numerical Terradynamic Simulation Group, University of Montana, Missoula, MT 59812, USA*

Published online 25 June 2002



Pielke RA Sr, Marland G, Betts RA, Chase TN, Eastman JL, Niles JO, Niyogi DD, Running SW. The influence of land-use change and landscape dynamics on the climate system: relevance to climate-change policy beyond the radiative effect of greenhouse gases. Philos Trans A Math Phys Eng Sci. 2002 Aug 15;360(1797):1705-19. doi: 10.1098/rsta.2002.1027. PMID: 12460493.

What impacts does it have?

Global Consequences of Land Use

JONATHAN A. FOLEY, RUTH DEFRIES, GREGORY P. ASNER, CAROL BARFORD, GORDON BONAN, STEPHEN R. CARPENTER, F. STUART CHAPIN, MICHAEL T. COE, GRETCHEN C. DAILY, [...] PETER K. SNYDER +10 authors Authors Info & Affiliations

SCIENCE • 22 Jul 2005 • Vol 309, Issue 5734 • pp.570-574 • DOI: 10.1126/science.1111772

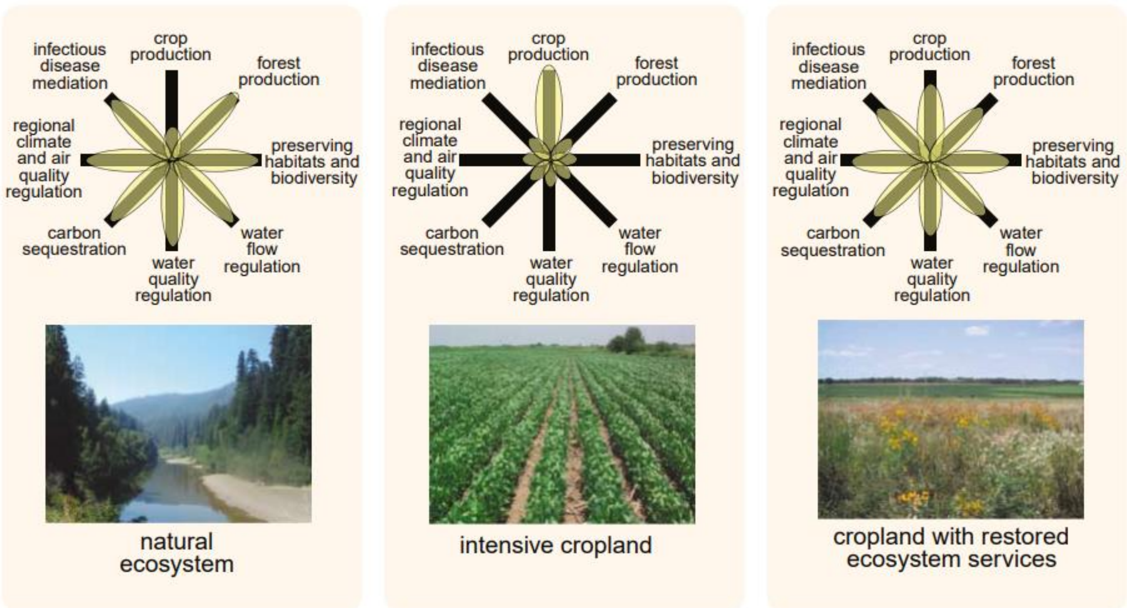
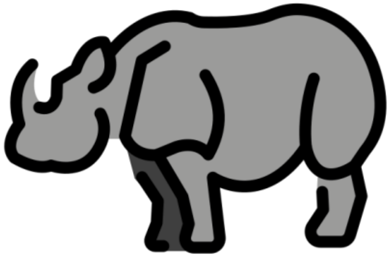


Fig. 3. Conceptual framework for comparing land use and trade-offs of ecosystem services. The provisioning of multiple ecosystem services under different land-use regimes can be illustrated with these simple "flower" diagrams, in which the condition of each ecosystem service is indicated along each axis. (In this qualitative illustration, the axes are not labeled or normalized with common units.) For purposes of illustration, we compare three hypothetical landscapes: a natural ecosystem (left), an intensively managed cropland (middle), and a cropland with restored ecosystem services (right). The natural ecosystems are able to support many ecosystem services at high levels, but not food production. The intensively managed cropland, however, is able to produce food in abundance (at least in the short run), at the cost of diminishing other ecosystem services. However, a middle ground—a cropland that is explicitly managed to maintain other ecosystem services—may be able to support a broader portfolio of ecosystem services.



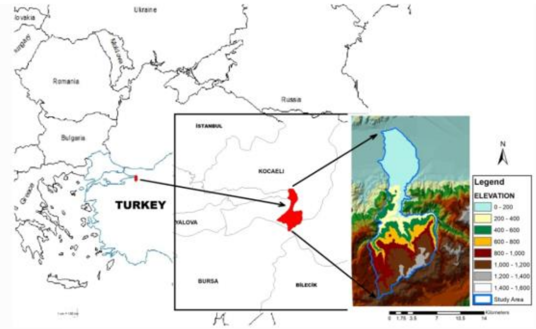
Foley JA, Defries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice IC, Ramankutty N, Snyder PK. Global consequences of land use. Science. 2005 Jul 22;309(5734):570-4. doi: 10.1126/science.1111772. PMID: 16040698.

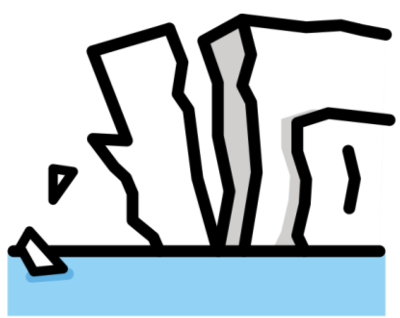
What impacts does it have?

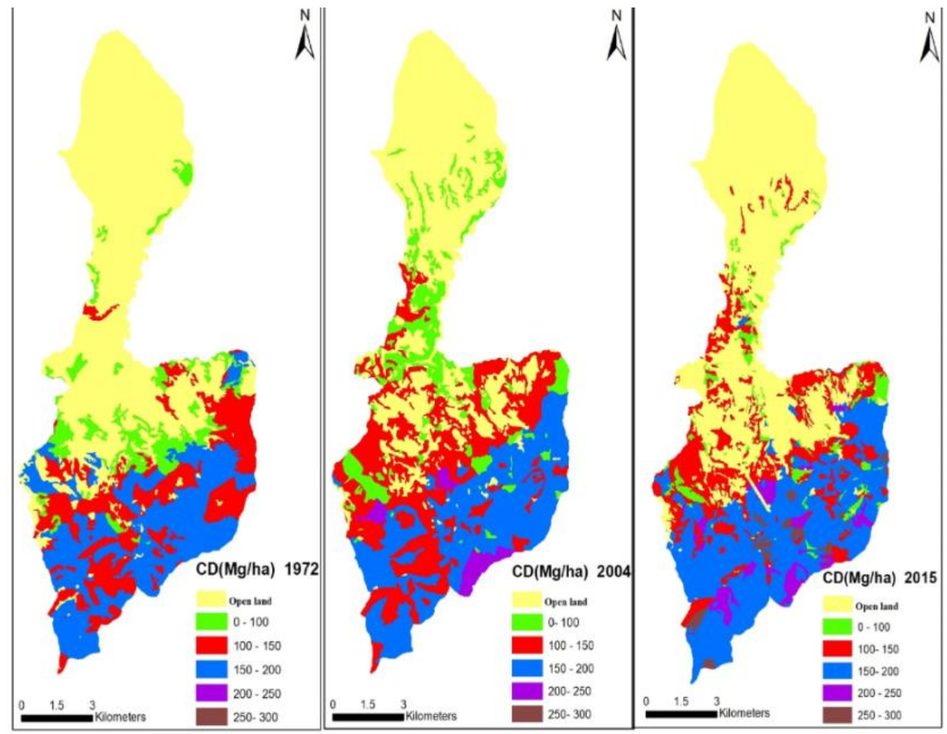
Investigating the spatiotemporal changes of land use/land cover and its implications for ecosystem services between 1972 and 2015 in Yuvacık

Raymond SAUTI & Uzay KARAHALİL

Environmental Monitoring and Assessment **194**, Article number: 311 (2022) | Cite this article





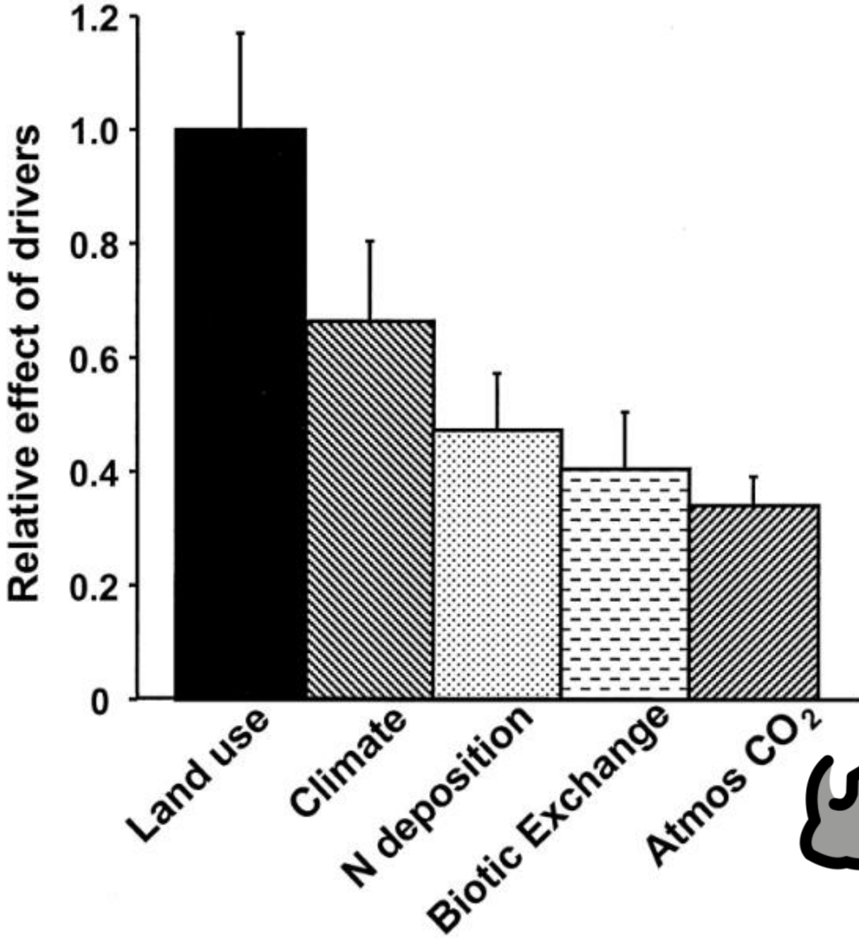


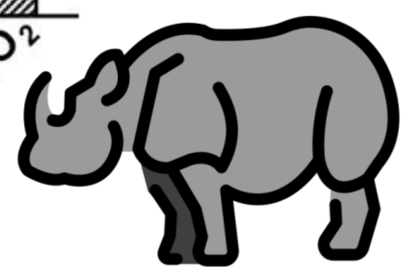
SAUTI, R., KARAHALİL, U. Investigating the spatiotemporal changes of land use/land cover and its implications for ecosystem services between 1972 and 2015 in Yuvacık. *Environ Monit Assess* 194, 311 (2022). https://doi.org/10.1007/s10661-022-09912-x

What impacts does it have?

Global Biodiversity Scenarios for the Year 2100

OSVALDO E. SALA, F. STUART CHAPIN , III, JUAN J. ARMESTO, ERIC BERLOW, JANINE BLOOMFIELD, RODOLFO DIRZO, ELISABETH HUBER-SANWALD, LAURA F. HUENNEKE, [...] DIANA H. WALL +11 authors Authors Info & Affiliations





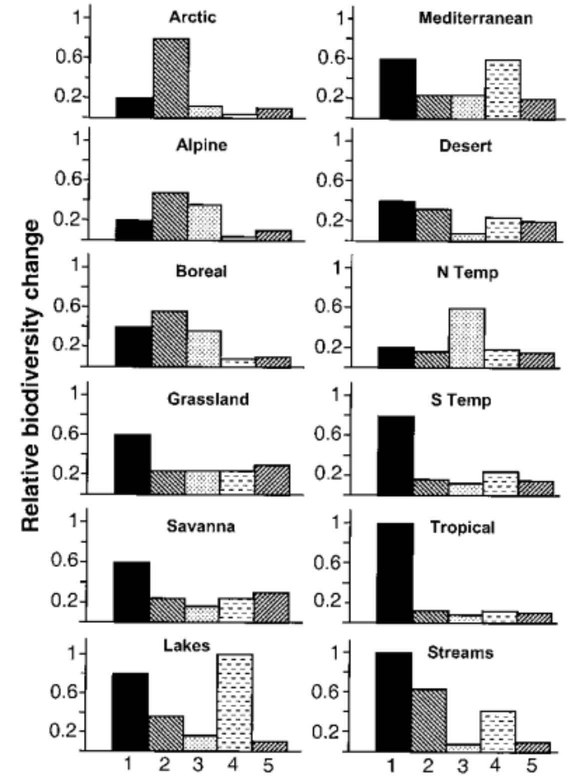


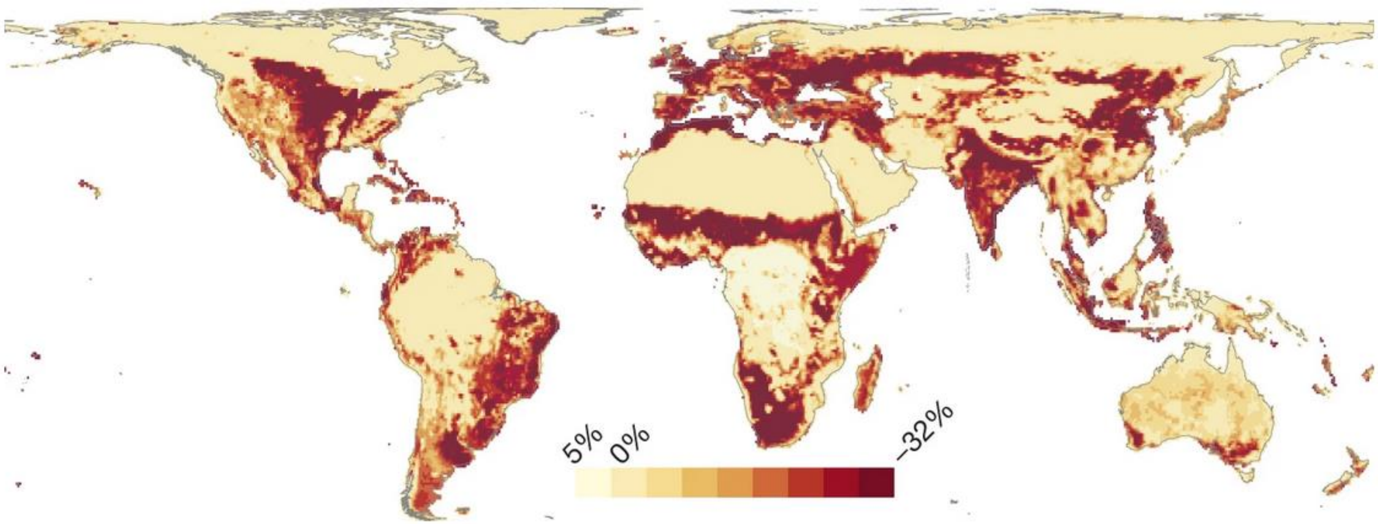
Fig. 2. Effect of each driver on biodiversity change for each terrestrial biome and freshwater ecosystem type calculated as the product of the expected change of each driver times its impact for each terrestrial biome or freshwater ecosystem. Expected changes and impacts are specific to each biome or ecosystem type and are presented in Tables 1 to 4. Values are relative to the maximum possible value. Bars: 1, land use; 2, climate; 3, nitrogen deposition; 4, biotic exchange; 5, atmospheric CO_2.

Sala, O. E. et al. Science 287, 1770–1776 (2000)

What impacts does it have?

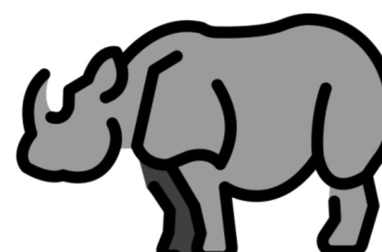
Figure 3: Net change in local richness caused by land use and related pressures by 2000.

From: Global effects of land use on local terrestrial biodiversity



Global effects of land use on local terrestrial biodiversity

Tim Newbold, Lawrence N. Hudson, ... Andy Purvis + Show authors



Newbold, T., Hudson, L., Hill, S. *et al.* Global effects of land use on local terrestrial biodiversity. *Nature* 520, 45–50 (2015). https://doi.org/10.1038/nature14324

Who needs information about LULC change? – Data users

Probabilistic forecasting of remotely sensed cropland vegetation health and its relevance for food security

Ahmed T. Hammad [a], Giacomo Falchetta [b,c,*]

[a] Decatab Pte Ltd., Singapore
[b] International Institute for Applied Systems Analysis,Schlossplatz, 1, Laxenburg A-2361, Austria
[c] Centro Euro-Mediterraneo sui Cambiamenti Climatici, Università Ca'Foscari Venezia, RFF-CMCC European Institute on Economics and the Environment, Italy

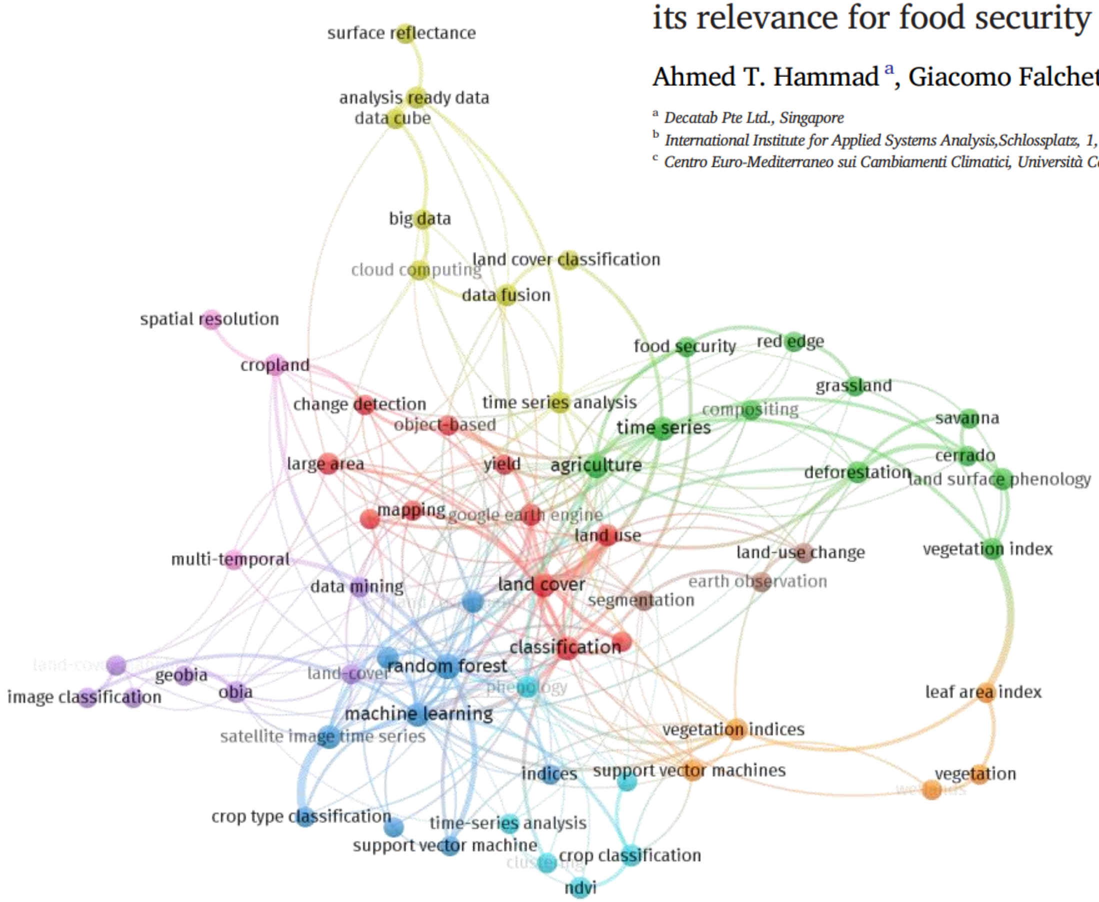
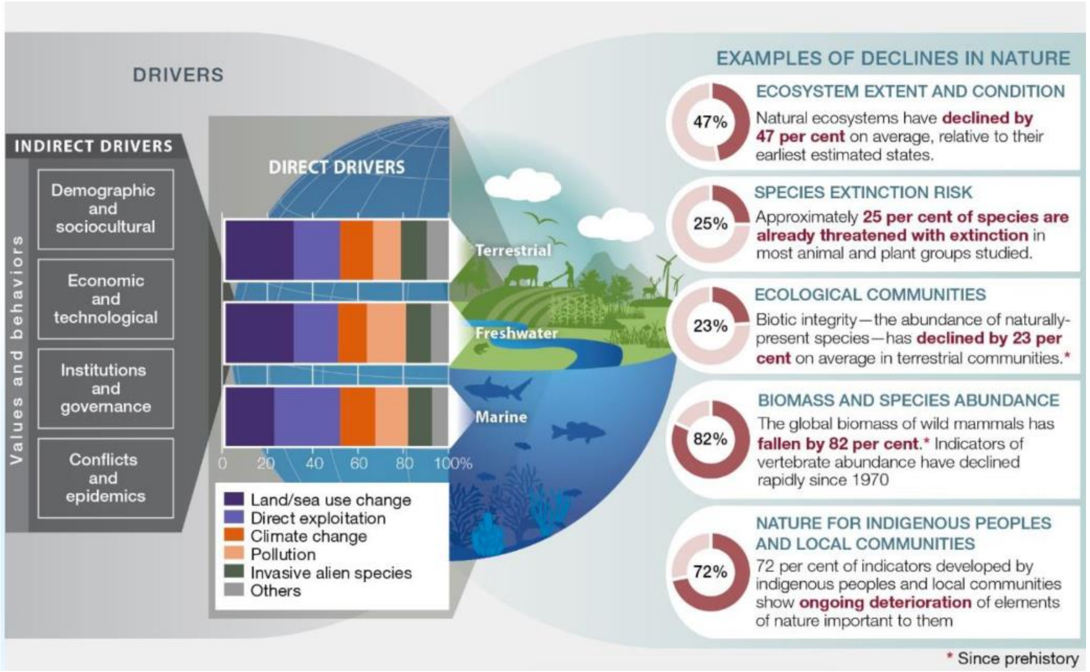


Figure from Chaves et al. 2020

Hammad AT, Falchetta G. Probabilistic forecasting of remotely sensed cropland vegetation health and its relevance for food security. Sci Total Environ. 2022 May 23;838(Pt 2):156157. doi: 10.1016/j.scitotenv.2022.156157. Epub ahead of print. PMID: 35618127.

E. D. Chaves M, C. A. Picoli M, D. Sanches I. Recent Applications of Landsat 8/OLI and Sentinel-2/MSI for Land Use and Land Cover Mapping: A Systematic Review. *Remote Sensing*. 2020; 12(18):3062. https://doi.org/10.3390/rs12183062

Who needs information about LULC change? – Policy makers



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Convention on Biological Diversity

CBD

UNEP

Convention on Biological Diversity

Distr.
GENERAL

CBD/POST2020/PREP/1/1
25 January 2019

ORIGINAL: ENGLISH

PREPARATIONS FOR THE POST-2020
GLOBAL BIODIVERSITY FRAMEWORK

POST-2020 GLOBAL BIODIVERSITY FRAMEWORK: DISCUSSION PAPER

Note by the Executive Secretary

30 by 30 (or **30x30**) is a worldwide initiative for governments to designate 30% of Earth's land and ocean area as protected areas by 2030.[1][2] The target was proposed by a 2019 article in *Science Advances* "A Global Deal for Nature: Guiding principles, milestones, and targets", highlighting the need for expanded nature conservation efforts to mitigate climate change.[3][4] Launched by the High Ambition Coalition in 2020, more than 50 nations had agreed to the initiative by January 2021[5] which had expanded to over 70 by October the same year. 30 by 30 was promoted at the COP15 meeting of the Convention on Biological Diversity.[6] This includes the G7[7] and European Union.

$5b funding called the "Protecting Our Planet Challenge" was announced for the initiative in September 2021.[8]

The initiative has attracted controversy over indigenous rights issues.[1]

Wikipedia

How can we quantify LULC change?

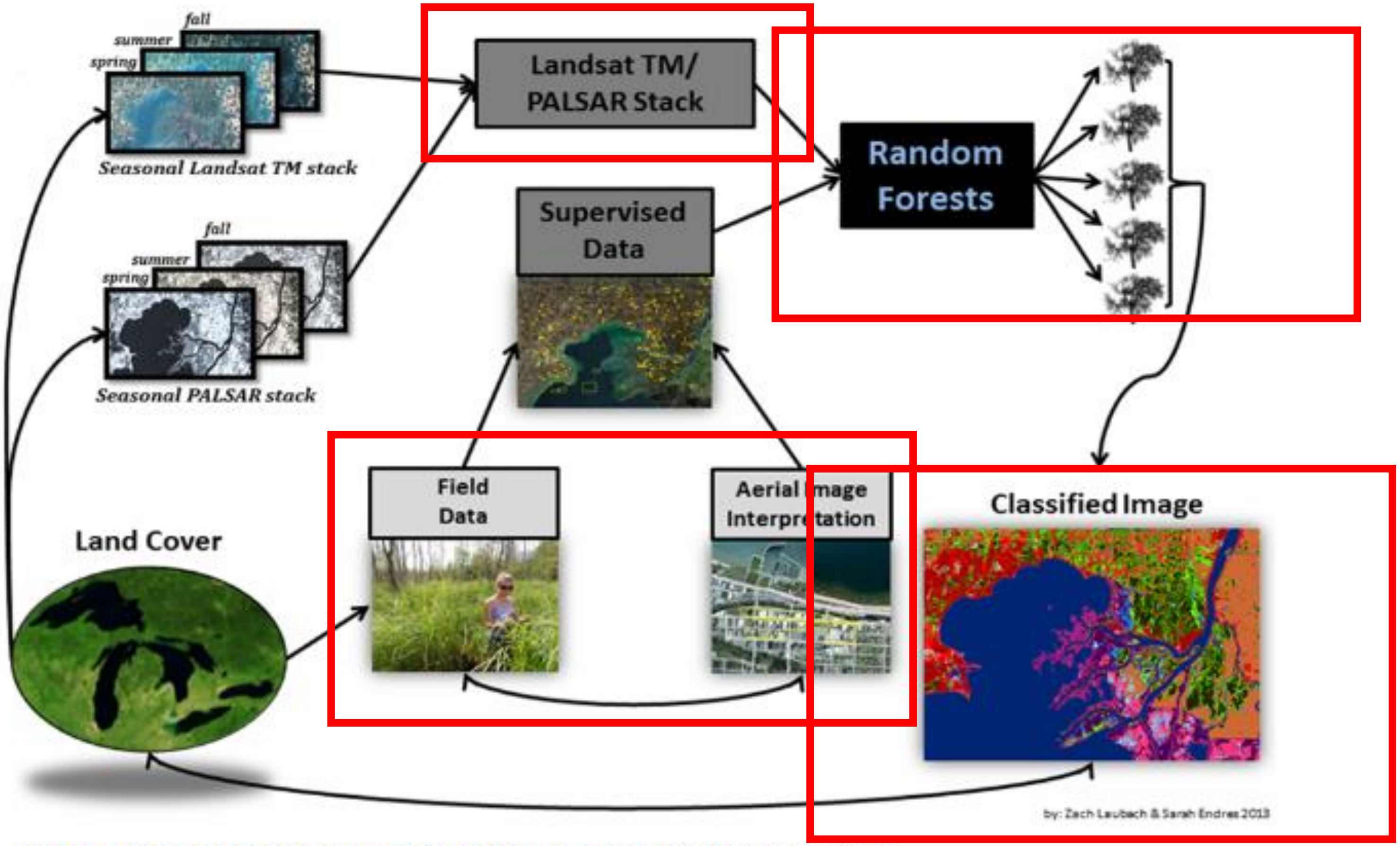
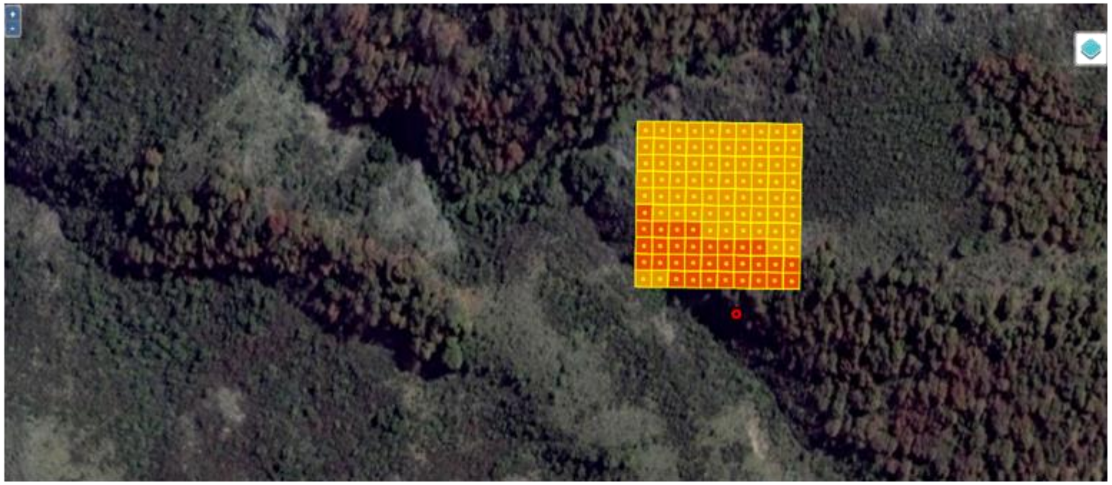
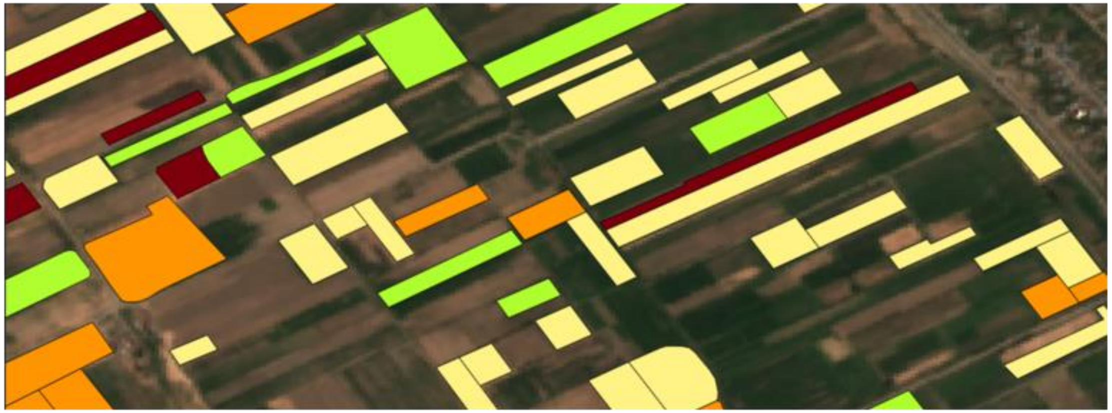


Figure 2: Radar-optic imagery land cover classification workflow

How can we quantify LULC change?

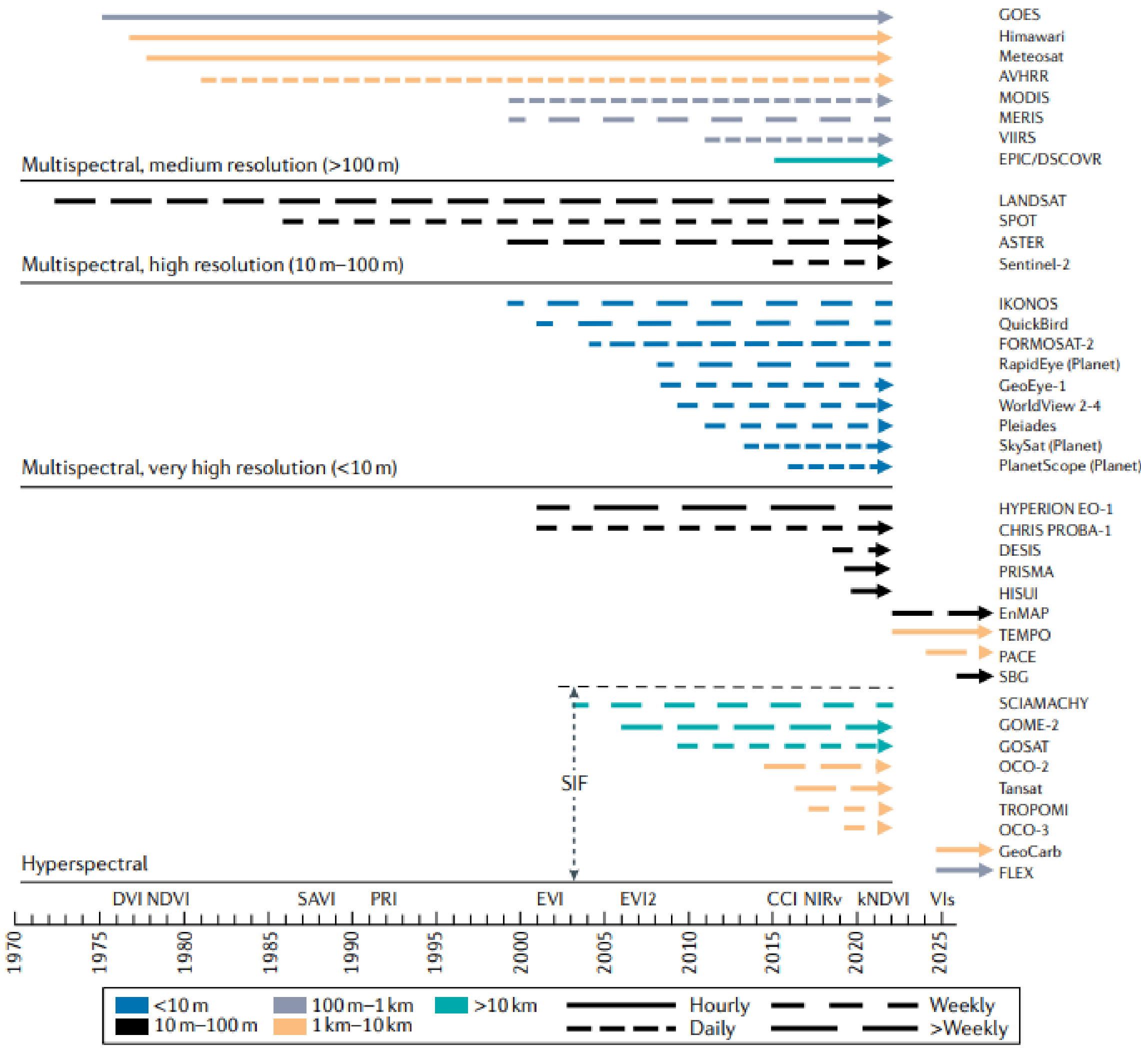
How can we quantify LULC change?





GeoWiki
https://www.sinergise.com/en/solutions/land-cover-monitoring-system

How can we quantify LULC change?



Zeng, Y., Hao, D., Huete, A. *et al.* Optical vegetation indices for monitoring terrestrial ecosystems globally. *Nat Rev Earth Environ* (2022). https://doi.org/10.1038/s43017-022-00298-5

How can we quantify LULC change?

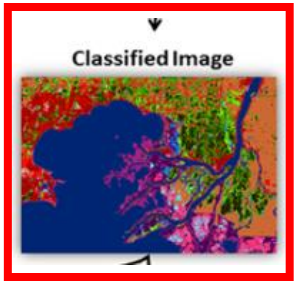


Table 1. Global datasets used for producing the fused land cover dataset.

Data set	Sensor	Date	Resolution	Classification approach
GLCC	AVHRR	April 1992-March 1993	1 km	Unsupervised classification with post-classification refinement
UMd	AVHRR	April 1992-March 1993	1 km	Supervised classification decision tree
MODIS LC	MODIS	January 2001-December 2002	500 m	Supervised decision tree, neural networks
GLC2000	SPOT-4	November 1999-December 2000	1 km	Unsupervised classification
GlobCover	MERIS	December 2004-June 2006	300 m	Unsupervised classification
MODIS VCF	MODIS	2000	250 m	Regression tree
MODIS Cropland Probability	MODIS	2000	250 m	Decision tree
AVHRR CFTC	AVHRR	April 1992-March 1993	1 km	Spectral unmixing

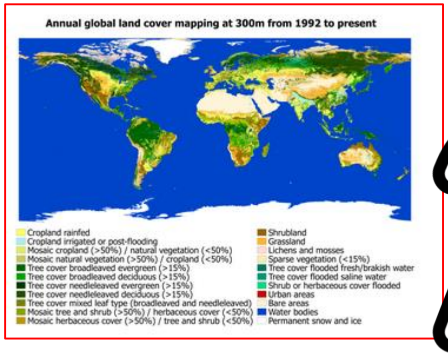
Table 1. Inventory and comparison of existing land cover data products at finer spatial resolutions ($\leq$300 m) available for the continental Europe.

Product / reference	Time span	Spatial resolution	Mapping accuracy	Classification system	Uncertainty / Probability
CLC	1990, 2000, 2006, 2012, 2018	100 m (25 ha)	$\leq$85%	44 classes	N / N
ESA CCI-LC		300-m		22 classes	N / N
(Batista e Silva et al., 2013)	2006	100-m			
S2GLC (Malinowski et al., 2020)	2017	10 m		15 classes	
Pflugmacher et al. (2019)	2014-2016	30 m	75%	12 classes	N / N
GLC FCS30 (Zhang et al., 2020)	2015, 2020	30-m			N / N
Buchhorn et al. (2020)	2015, 2016, 2017, 2018	100 m		??	N / Y
ESA WorldCover	2020	10 m	>75%	12+	N / N
ELC10 (Venter and Sydenham, 2021)	2020	10 m	>90%	8 classes	N / N
ODSE-LULC (our product)	2000, 2001, . . . , 2019	30 m		33 classes	Y / Y

Feng, M. and Bai, Y. (2019). A global land cover map produced through integrating multi-source datasets. Big Earth Data, 3(3):191–219.

Martijn Witjes et al. 2021. A spatiotemporal ensemble machine learning framework for generating land use / land cover time-series maps for Europe (2000 – 2019) based on LUCAS, CORINE and GLAD Landsat

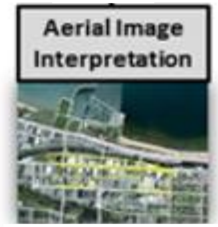
How to decide which map to use?



Site-specific metric	Reference	Equation
Error Matrix	Olofsson et al. (2014)[a] [4]	$p_{ij} = W_i \frac{n_{ij}}{n_i}$
Overall Accuracy (OA)	Olofsson et al. (2014) [1]	$O = \sum_{j=1}^{q} p_{jj}$
User's Accuracy (UA)	Olofsson et al. (2014) [2]	$U_i = p_{ii}/p_{i\cdot}$
Producer's Accuracy (PA)	Olofsson et al. (2014) [3]	$P_j = p_{jj}/p_{\cdot j}$
Standard Error (SE) of OA	Olofsson et al. (2014) [5]	$\hat{V}\left(\hat{O}\right) = \sum_{j=1}^{q} W_i^2 \hat{U}_i\left(1-\hat{U}_i\right)/(n_{i\cdot}-1)$
Standard Error (SE) of UA	Olofsson et al. (2014) [6]	$\hat{V}\left(\hat{U}_i\right) = \hat{U}_i\left(1-\hat{U}_i\right)/(n_{i\cdot}-1)$
Standard Error (SE) of PA	Olofsson et al. (2014) [7]	$\hat{V}\left(\hat{P}_j\right) = \frac{1}{\hat{N}_{\cdot j}^2}\left[\frac{N_{j\cdot}^2\left(1-\hat{P}_j\right)^2\hat{U}_j\left(1-\hat{U}_j\right)}{n_{j\cdot}-1} + \hat{P}_j^2\sum_{i\neq j}^{q} N_{i\cdot}^2 \frac{n_{ij}}{n_{i\cdot}}\left(1-\frac{n_{ij}}{n_{i\cdot}}\right)/(n_{i\cdot}-1)\right]$
Quantity Disagreement (QD)	Pontius and Millones (2011)[b] [3]	$Q = \frac{\sum_{g=1}^{J} q_g}{2}$ $q_g = \lvert(\sum_{i=1}^{J} p_{ig}) - (\sum_{j=1}^{J} p_{gj})\rvert;\ a_g = 2\ \min\ \lvert(\sum_{i=1}^{J} p_{ig}) - p_{gg}, (\sum_{j=1}^{J} p_{gj}) - p_{gg}\rvert$
Allocation Disagreement (AD)	Pontius and Millones (2011) [5]	$A = \frac{\sum_{g=1}^{J} a_g}{2}$
Ratio of AD/QD	–	$\frac{A}{Q}$
Linguistic Scale of Fuzzy Measures	Gopal and Woodcock (1994), Woodcock and Gopal (2000)	See text description.
Non-site specific metric	**Reference**	**Equation**
Error matrix	Olofsson et al. (2014) [4]	$P_{ij} = W_i \frac{n_{ij}}{n_i}$
Class Area	Olofsson et al. (2014) [9]	$\hat{p}_{\cdot k} = \sum_{j=1}^{q} W_i \frac{n_{ik}}{n_{i\cdot}}$
Standard Error (SE) of Area Estimate	Olofsson et al. (2014) [10]	$\hat{S}\left(\hat{p}_{\cdot k}\right) = \sqrt{\sum_i W_i^2 \frac{\frac{n_{ik}}{n_{i\cdot}}\left(1-\frac{n_{ik}}{n_{i\cdot}}\right)}{n_{i\cdot}-1}} = \sqrt{\sum_i \frac{W_i \hat{p}_{ik} - \hat{p}_{ik}^2}{n_{i\cdot}-1}}$
Spatial distribution metric	**Reference**	**Equation**
Kolmogorov-Smirnov statistic (KS)	Riemann et al. (2010)[c] [1]	$D_{KS} = \max\lvert F(x) - G(x)\rvert$
Agreement Coefficient (AC)	Riemann et al. (2010) [5]	$AC = 1 - \frac{SSD}{SPOD}$ $SSD = \sum_{i=1}^{n}(X_i - Y_i)^2$ $SPOD = \sum_{i=1}^{n}\left(\lvert\overline{X}-\overline{Y}\rvert + \lvert X_i - \overline{X}\rvert\right)\left(\lvert\overline{X}-\overline{Y}\rvert + \lvert Y_i - \overline{Y}\rvert\right)$
Systematic AC (AC_{sys})	Riemann et al. (2010) [9]	$ACsys = 1 - \frac{SSD_s}{SPOD}$ $SPD_s = SPD - SPD_u$
Unsystematic AC (AC_{uns})	Riemann et al. (2010) [10]	$ACuns = 1 - \frac{SSD_u}{SPOD}$ $SPD_u = \sum_{i=1}^{n}\left(\lvert X_i - \hat{X}_i\rvert\right)\left(\lvert Y_i - \hat{Y}_i\rvert\right)$

Mark D. Nelson, James D. Garner, Brian G. Tavernia, Stephen V. Stehman, Rachel I. Riemann, Andrew J. Lister et al. Assessing map accuracy from a suite of site-specific, non-site specific, and spatial distribution approaches., Remote Sensing of Environment, 2021

How to decide which map to use?



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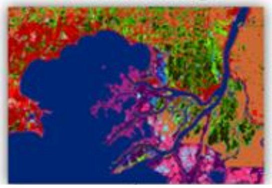
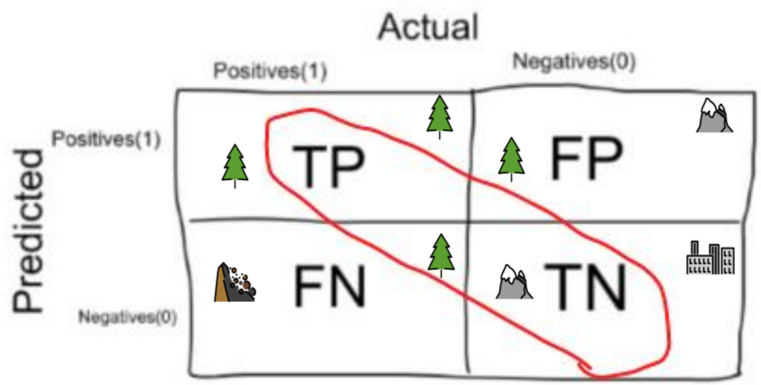




$$Precision = \frac{\#\ of\ True\ Positives}{\#\ of\ True\ Positives + \#\ of\ False\ Positives}$$

$$F1\ score = 2 * \frac{Precision\ * Recall}{Precision + Recall}$$

$$Recall = \frac{\#\ of\ True\ Positives}{\#\ of\ True\ Positives + \#\ of\ False\ Negatives}$$

Question time

Where are we?

Lecture | 10:00-10:30

Break | 10:30-10:40 

Exercise1 | 10:40-12:00

Lunch break | 12:00-13:00 

Exercise2 | 13:00-14:20

Break | 14:20-14:30 

What we learned | 14:30-15:00

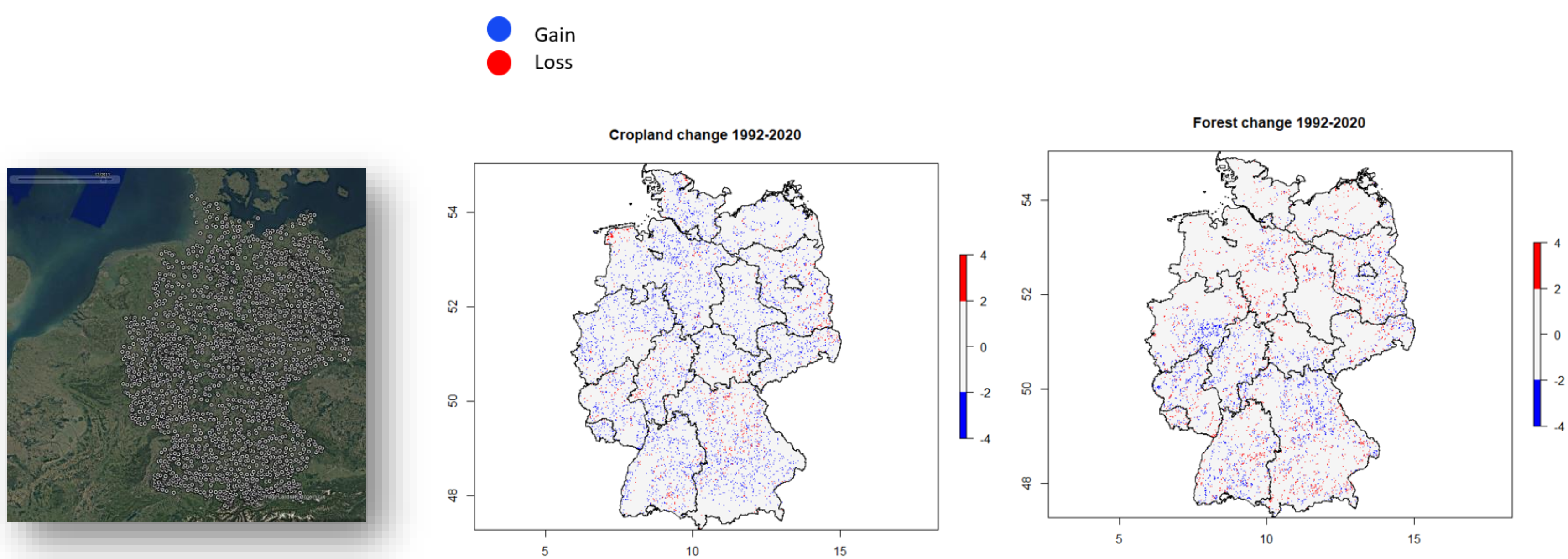
Exercise 1 – morning_exercise.R

Intro

In this first exercise we will look at forest and cropland changes in Germany during the period 1992-2020 by using the ESA-CCI time-series (see https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-land-cover?tab=form). This is a global product at 300 m spatial resolution that includes also other land-use and land-cover classes as: shrubland, wetland, water body, urban and built-up area, permanent snow and ice, grassland and bare land. You can find all the classes in Appendix A of this documentation https://datastore.copernicus-climate.eu/documents/satellite-land-cover/D5.3.1_PUGS_ICDR_LC_v2.1.x_PRODUCTS_v1.1.pdf.

Specifically we will do the following:

- A. Visual changes: Look if changes can be visually identified
- B. Numerical changes: Look at the changes numerically
- C. Spatial visual changes: Look visually at the forest and cropland changes per state in Germany
- D. Spatial numerical changes: Look at the spatial changes numerically
- E. Distribution ground-truth samples: Select and plot a subset of the available samples to quantify accuracy in 2020
- F. F1: measure F1 score for forest and cropland, and plot the correct and wrong locations
- G. Questions



Where are we?

Lecture | 10:00-10:40

Break | 10:40-10:50

Exercise1 | 10:50-12:00

Lunch break | 12:00-13:00

Exercise2 | 13:00-14:20

Break | 14:20-14:30

What we learned | 14:30-15:00

Exercise 2

Afternoon_questions

2022-06-10

Intro

This time you will have to work the code your-self to answer the questions. This time we are going to add another time-series compared to the ESA-CCI. This is the GLASS, a 5 km spatial resolution time-series between 1982 and 2015 (see https://essd.copernicus.org/preprints/essd-2019-23/essd-2019-23.pdf). The purpose of this exercise is to find out if cropland and forest changes in Germany are differing between the two products (ESA-CCI and GLASS), and if yes you will need to look at the F1 score to decide which you can trust most. Because ESA-CCI time-series is between 1992-2020, while GLASS is between 1982-2015, this time you will look at the changes in the period **1992-2015**.

Specifically you will have to answer the following questions:

- A. Are the numerical changes of forest and cropland in Germany different between the two products?
- B. Are the F1 scores of cropland and forest different between the two products?
- C. If they are different, which product can you trust the most to say how much cropland and forest change happened in Germany between 1992-2015?

Where are we?

Lecture | 10:00-10:40

Break | 10:40-10:50

Exercise1 | 10:50-12:00

Lunch break | 12:00-13:00

Exercise2 | 13:00-14:20

Break | 14:20-14:30

What we learned | 14:30-15:00