Designing Monitoring Programmes

Henrik Hedenås
Department of Forest Resource Management
Swedish University of Agricultural Sciences

Designing Monitoring Programmes

Often in monitoring design

- We start with a question
- We carefully choose variables
- We design detailed field protocols

But …

We forget to design how the data should actually be sampled.

Designing Monitoring Programmes

Without a rigid sampling design

Our results may be meaningless.

- What do the data represent?
- Can we generalize?

=> Data does not guarantee good inference.

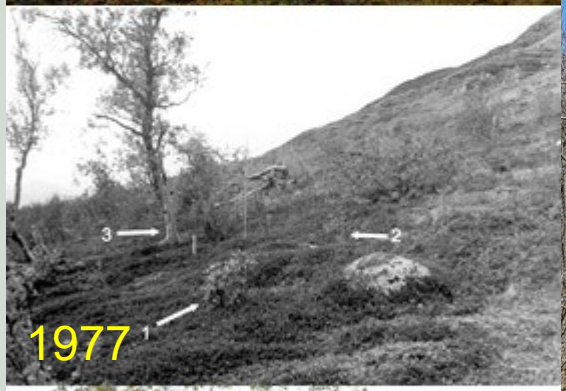
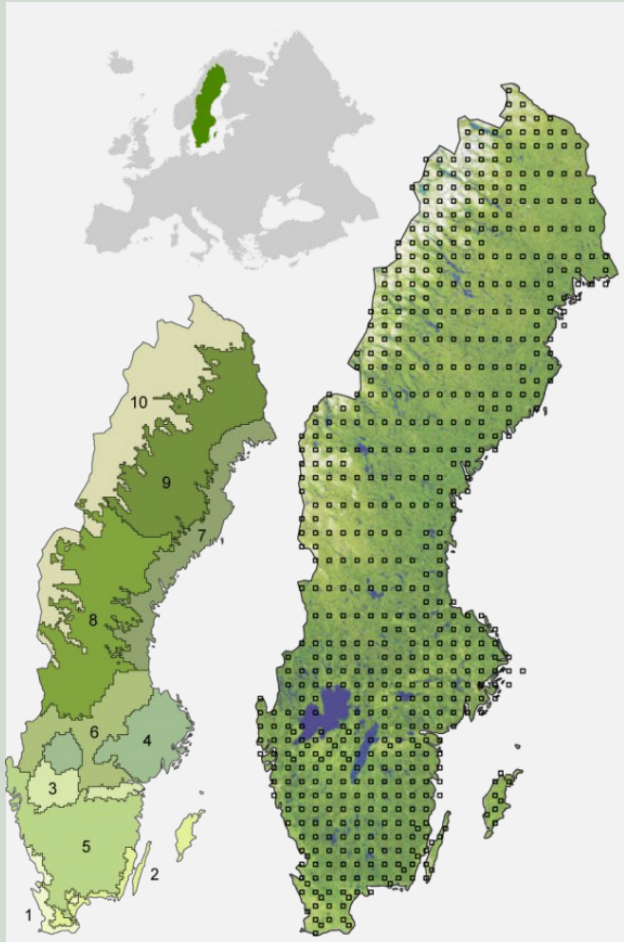


Photo 1977 N-Å Andersson
Photo 2009 H Hedenås

NILS 2003:2020

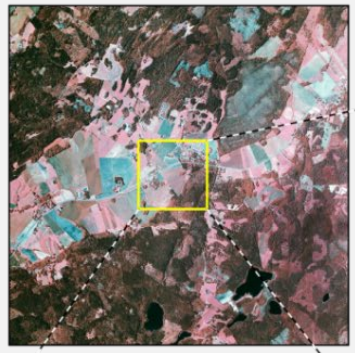
- **Sampling frame:**
  National 5×5 km grid covering Sweden
- **Probability-based sample:**
  639 squares (5×5 km) randomly selected
- **Stratified design:**
  10 geographic strata

Inference? *What population does this represent?*



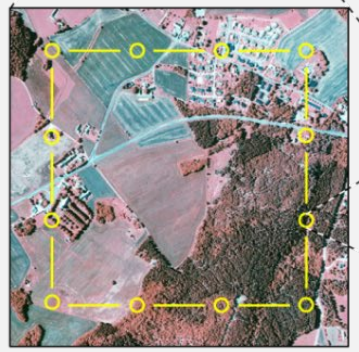
10 strata

639 sample units

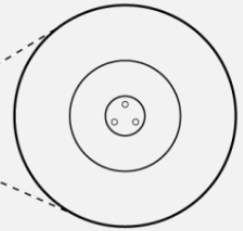


Sample unit
25 km² square

Aerial photo interpretation
1 km² square
- Polygons
- Lines
- Points



Field inventory
1 km² square
- Circular sample plots
- Sample lines



Circular sample plots
- 20 m radius
- 10 m radius
- 3,5 m radius
- 0,28 m radius

Citizen science/monitoring

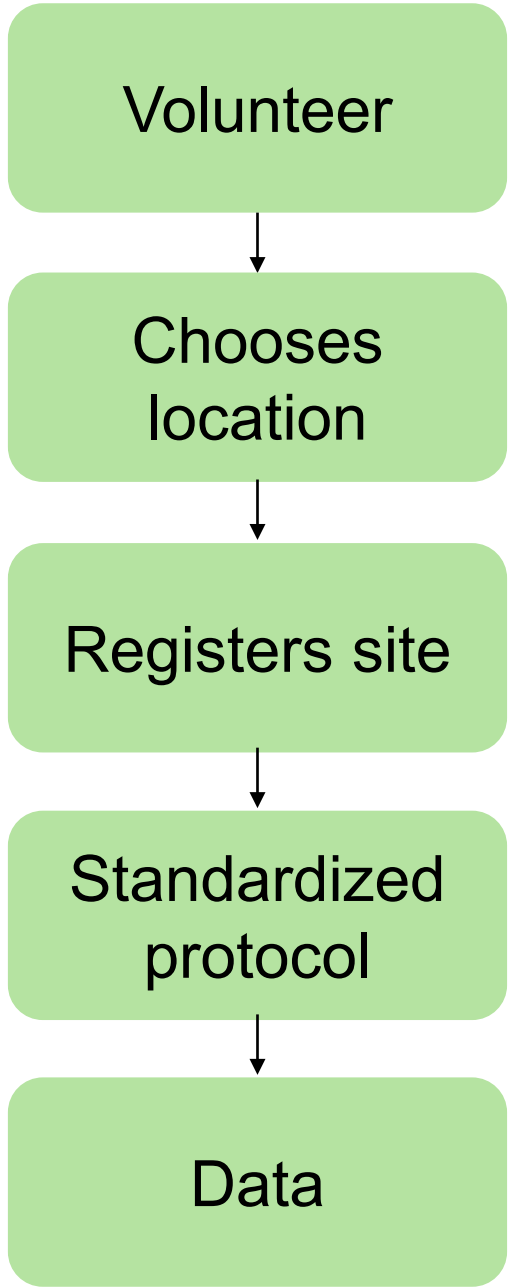
A citizen science program where volunteers select their own survey routes or sites.

This means:

- the observer decides *where* to sample i.e. no random selection of sites.

Inference? *What population does this represent?*

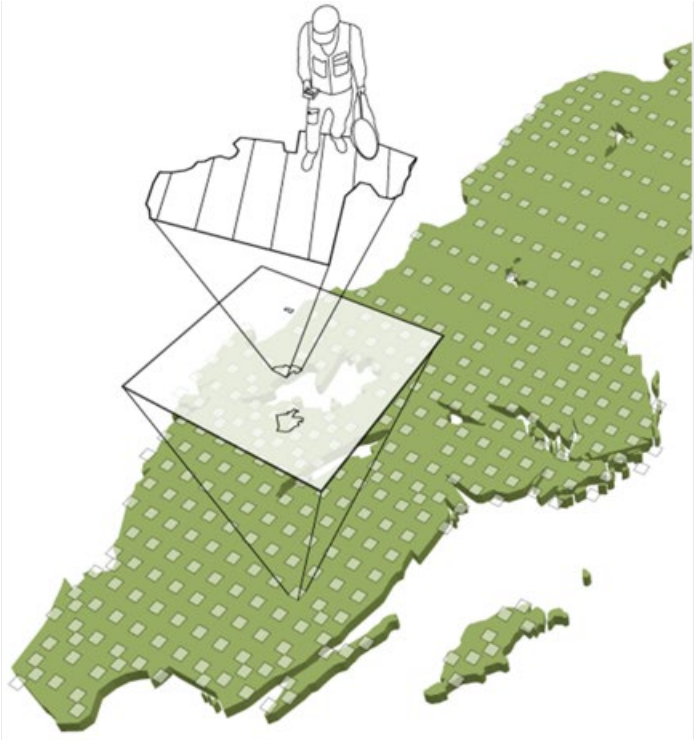
Citizen science

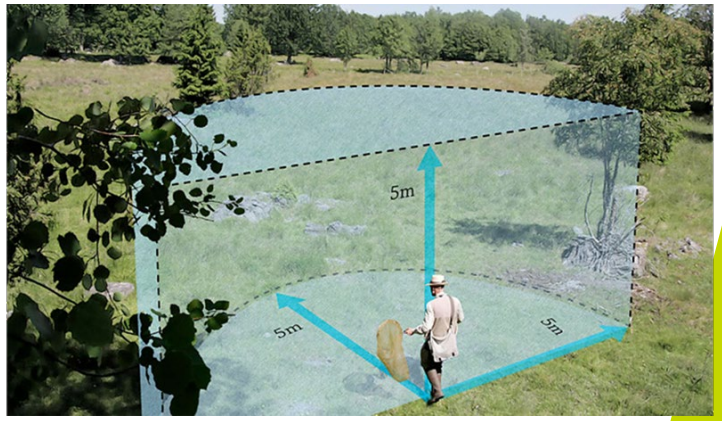


FHIN
Butterfly and Bumblebee Inventory

- **Sampling frame:**
  Registered semi-natural grasslands from the TUVA database
- **Probability-based sample:**
  Random selection of sites from the sampling frame
- **Spatial structure:**
  Sampling within NILS grid

Inference? *What population does this represent?*





EU pollinator monitoring

- **Sampling frame**
  Systematic LUCAS grid covering the landscape

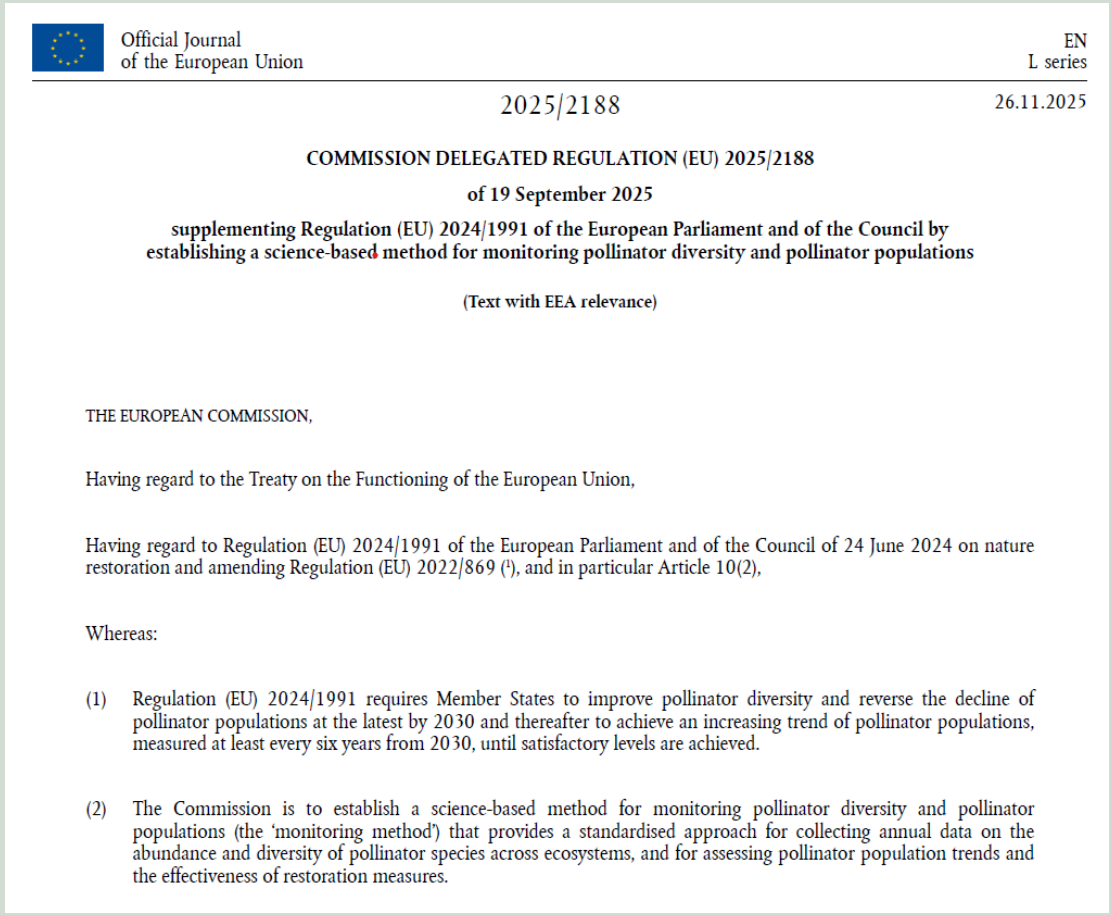
- **Probability-based**
  Random selection of monitoring stations

- **Stratified design**
  By biogeographic region and ecosystem type
  (forest, agriculture, others)

- **Proportional allocation**
  Sampling effort proportional to area of each stratum

- **Flexible transect placement (not specified)**
  Transects defined within stations, but placement rules are unclear → allows multiple implementation choices

Inference? *What population does this represent?*



Official Journal of the European Union — EN, L series

2025/2188 — 26.11.2025

COMMISSION DELEGATED REGULATION (EU) 2025/2188

of 19 September 2025

supplementing Regulation (EU) 2024/1991 of the European Parliament and of the Council by establishing a science-based method for monitoring pollinator diversity and pollinator populations

(Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 ([1]), and in particular Article 10(2),

Whereas:

(1) Regulation (EU) 2024/1991 requires Member States to improve pollinator diversity and reverse the decline of pollinator populations at the latest by 2030 and thereafter to achieve an increasing trend of pollinator populations, measured at least every six years from 2030, until satisfactory levels are achieved.

(2) The Commission is to establish a science-based method for monitoring pollinator diversity and pollinator populations (the 'monitoring method') that provides a standardised approach for collecting annual data on the abundance and diversity of pollinator species across ecosystems, and for assessing pollinator population trends and the effectiveness of restoration measures.

Current NILS 2020-
National Inventories of Landscapes in Sweden

- **Target population** e.g. grasslands
- **Sampling frame**

National 1×1 km grid covering all land and freshwater

Two-phase sampling design

Phase 1: Selection of tracts using coordinated balanced sampling

Phase 2: Selection of plots within tracts

- **Stratified random subsampling for fieldwork**

Higher sampling intensity of rare/priority habitats

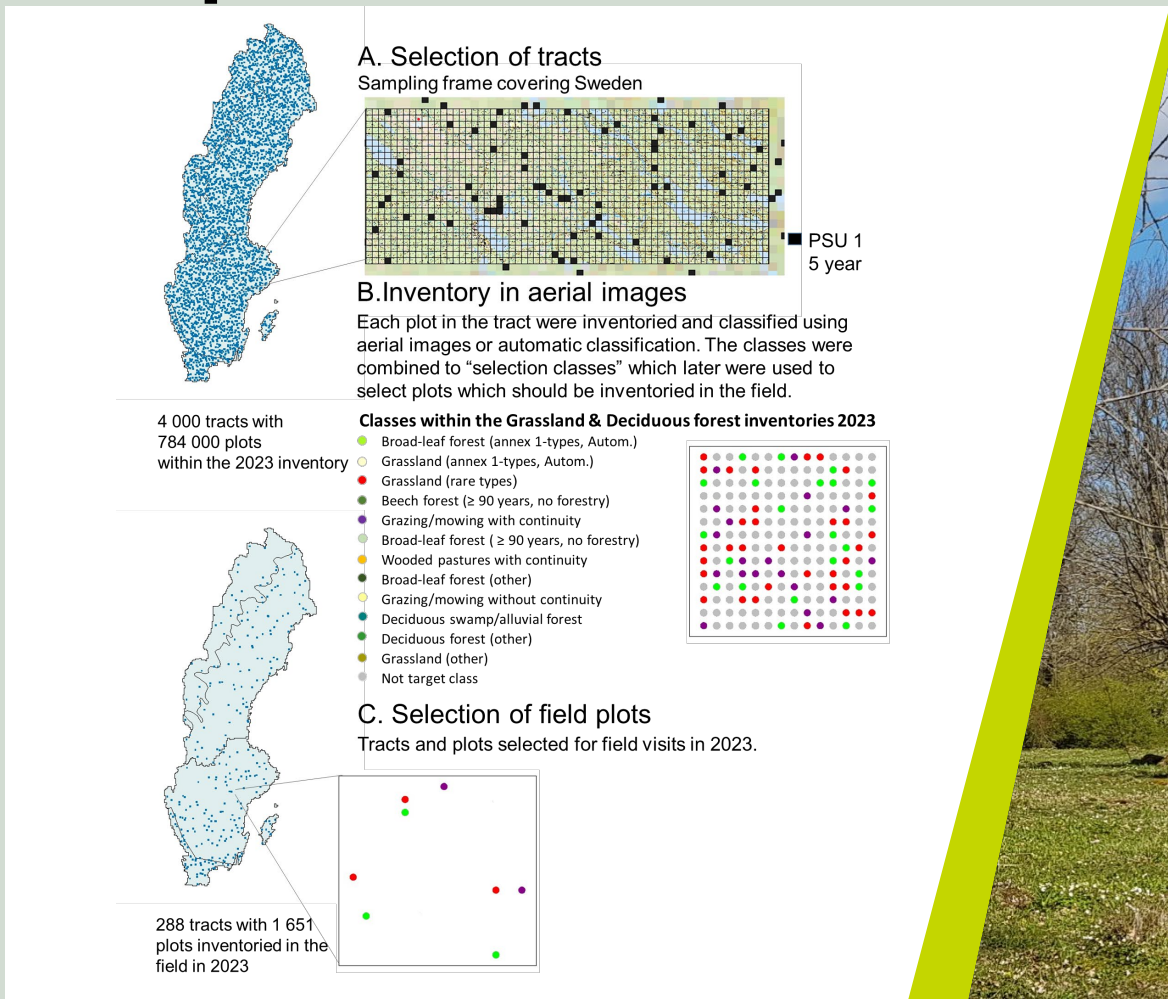
- **Non-visited units retained in sample**

Plots/tracts without target habitats contribute as zero observations

- **Spatially balanced sampling**

Ensures coverage across environmental gradients

Inference? *What population does this represent?*



Importance of randomness

- Every location gets a **known** chance of being selected
- Captures the **full variation** in the landscape
- **Reduces risk of systematic bias**
- Enables **statistically valid inference**

=> Randomness is what allow us to generalise

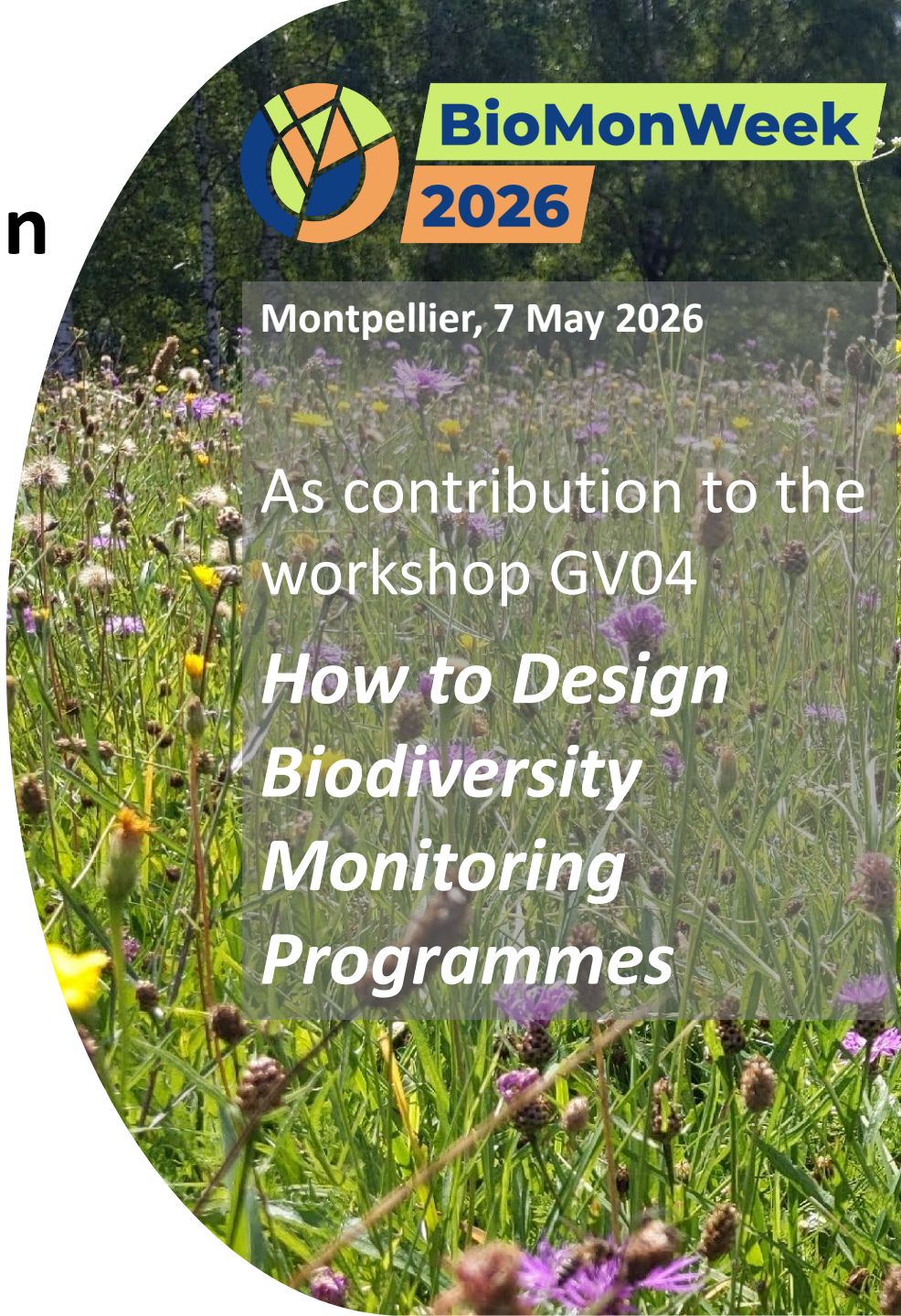
However,

- Stratification/ weighting needed to capture rare habitats

European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL)

Laura Sutcliffe, Rainer Oppermann:
Institute for Agroecology and Biodiversity (IFAB), Mannheim

Luca Kleinewillinghöfer, **Dirk Lindemann**, Lars Roggon, Carsten Haub:
EFTAS-Fernerkundung Technologietransfer GmbH, Münster



Funded by the European Union

Farmland biodiversity monitoring in the EU

Funded by the European Union

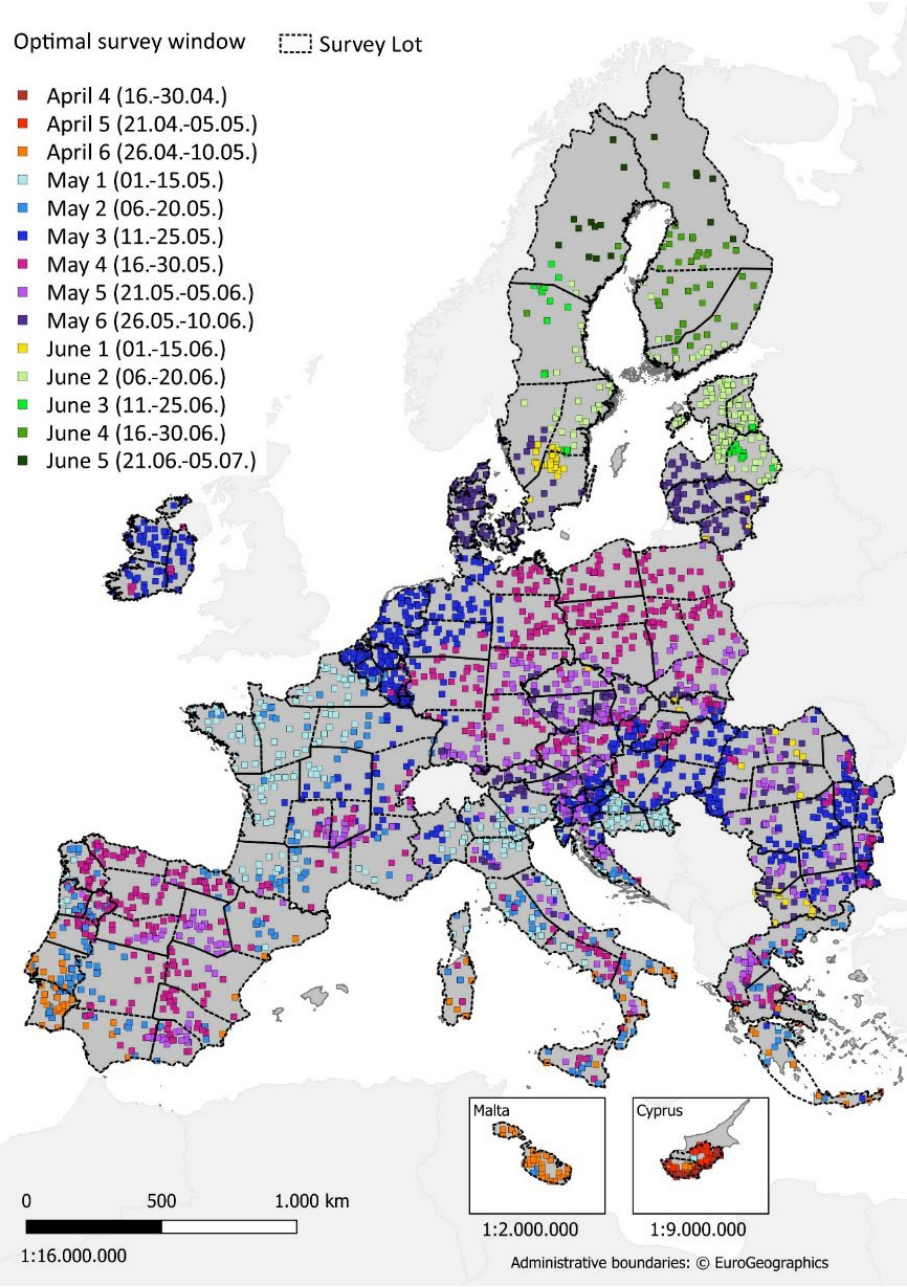
- There are many approaches to monitor farmland biodiversity, but these are either limited to a national scale (e.g., HNVF monitoring in Germany) or limited to a single species group (e.g., Farmland Bird Index)
- Challenge: to develop a methodology that is
  - **rapid** (creating a large sample size)
  - **in-situ** (and **in-depth)**
  - **focussed on general agricultural biodiversity**, not single species groups or specific habitats
  - capable of **detecting meaningful changes over time**
  - **standardised and comparable** across the EU-27

EMBAL Methodology

- 25 ha plots: pre-processing using orthophotos
- Fieldwork: three observation levels
  - **Plot** (e.g, number of parcels, area of landscape elements…)
  - **Parcel** (all parcels; land cover and rapid parameters such as crop density, number of flower colours)
  - **Transect** (up to 9 per plot; detailed parameters, e.g. indicator species)
  - Also photo documentation of features

EMBAL Roll-out 2022/23

- Survey of 3,000 plots in 2022 and 2023: between 30 (MT) and 250 (FR) plots per country
- Stratified random sampling based on **LUCAS master grid** (2x2 km) to create representative sample (NUTS0/Biogeographic region/elevation class)
- Including >110,000 parcels and >23,000 transects
- Specified timeframe for each plot
- ~75 surveyors coordinated per season
- On average roughly 1 - 2 plots per surveyor and day



Biodiversity parameters and indices

- > 60 parameters recorded in the field
- Many indices can be derived from the raw data, e.g., number of crop types per plot…

Measured parameter/**derived index**	Level of observation
Landcover 1	Parcel / Transect
Landcover 2	Parcel / Transect
Number of indicator species	Transect
Flower density (all flowers)	Parcel / Transect
Colours of flowering forbs	Parcel / Transect
Number of different flower colours	Parcel / Transect
Agricultural Nature Value Index (ANVI)	Parcel/Plot
Agricultural Land Use intensity Index (ALUI)	Parcel/Plot
Agricultural Landscape Connectivity Index (ALCI)	Plot
Agricultural Pollinator Resource Index (APRI)	Parcel/Plot
Proportion of woody landscape features	Plot
Proportion of high-diversity landscape features	Plot
Crop diversity	Plot
Crop coverage in %	Parcel
Wild plant coverage in %	Parcel
Graminoid:forb ratio	Parcel / Transect
Height herbaceaous layer (cm)	Transect
Height of crop (cm)	Transect
Woody layer coverage	Transect
Total cover of legumes (%)	Transect
EUNIS Grass habitat / complex	Transect
Grassland age	Transect

etc…

EMBAL Stratification and parameter design

1. How can European biodiversity monitoring programmes be designed to be scalable and representative across local, national, and European levels?

EMBAL Stratification

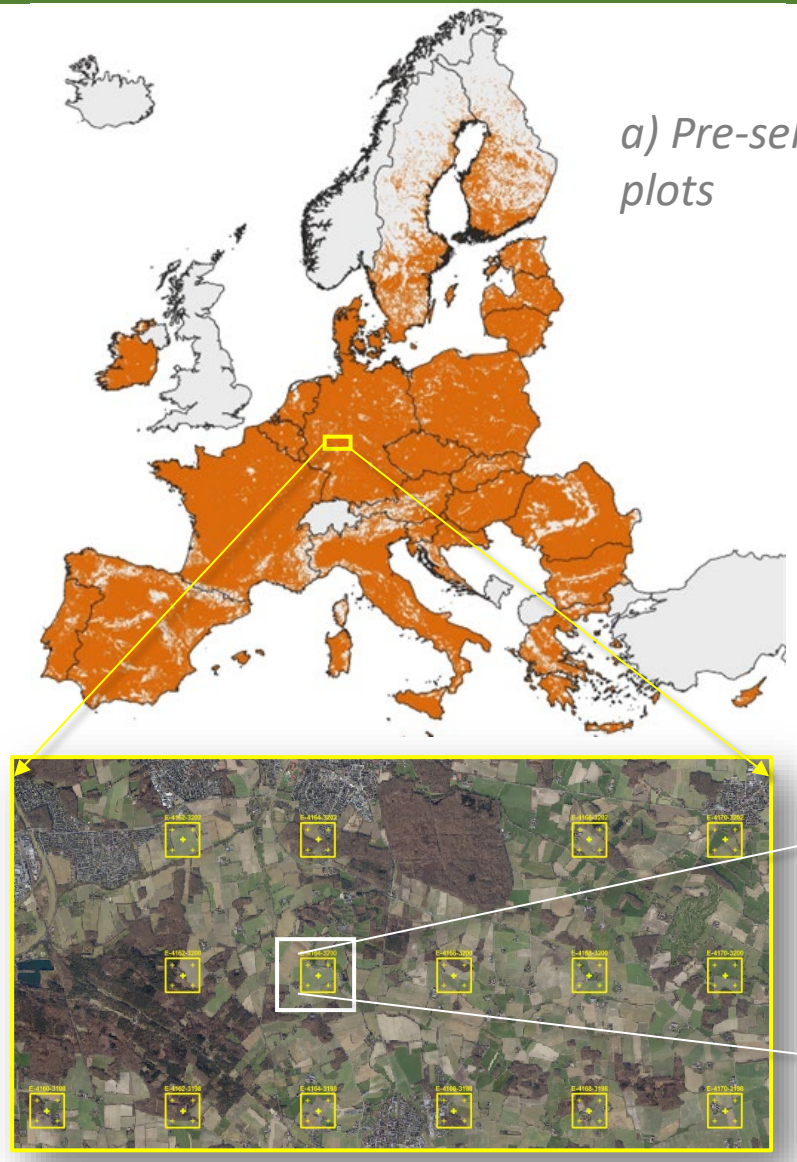
Funded by the European Union

EMBAL sampling strategy

(1) EMBAL Master Sample frame
(> 1.000.000 plots regular grid based on LUCAS master frame)

(2) Pre-Selection of EMBAL plots with at least 10% agricultural use
(approx. 600.000 plots)
based on Copernicus CLC & HRL intersections

(3) Random stratified sample for field survey



a) Pre-selected 600.000 plots

b) Close-up: Plot allocation within the 2x2 km grid

c) Standardised plot dimension (500 x 500 m)

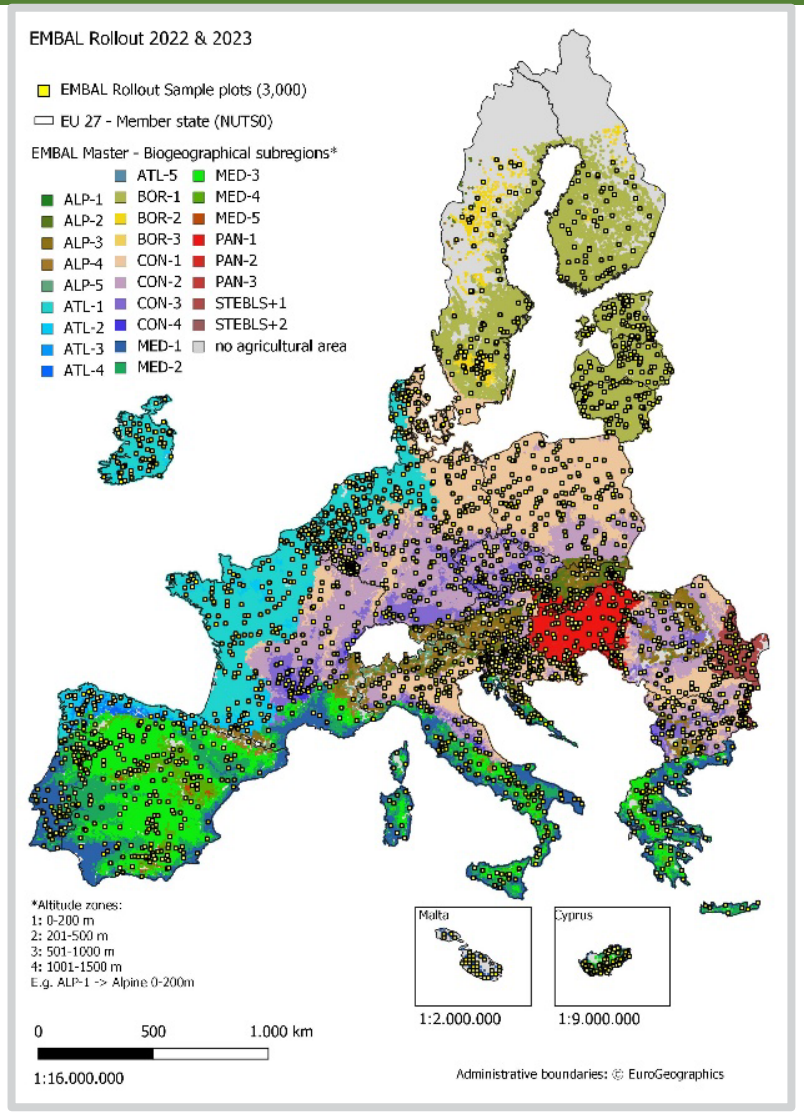
EMBAL Stratification

Funded by the European Union

EMBAL Survey 2022 & 2023

- 3,000 plots across EU27 *(visited in 2022 and 2023)*
- **Stratified Random Sampling** based on
  - **Member States**
    No. of plots depending on the size of Member State (min. 30, max. 250) and its share of agricultural land
  - **Biogeographic Regions**
    (aggregated regions
  - **Altitude zones**
    4 zones per Biogeographic Region:
    1: 0-200 m
    2: 200-500 m
    3: 500-1000 m
    4: 1000-1500 m

➢ Targeting estimates at Member State and Biogeographical region

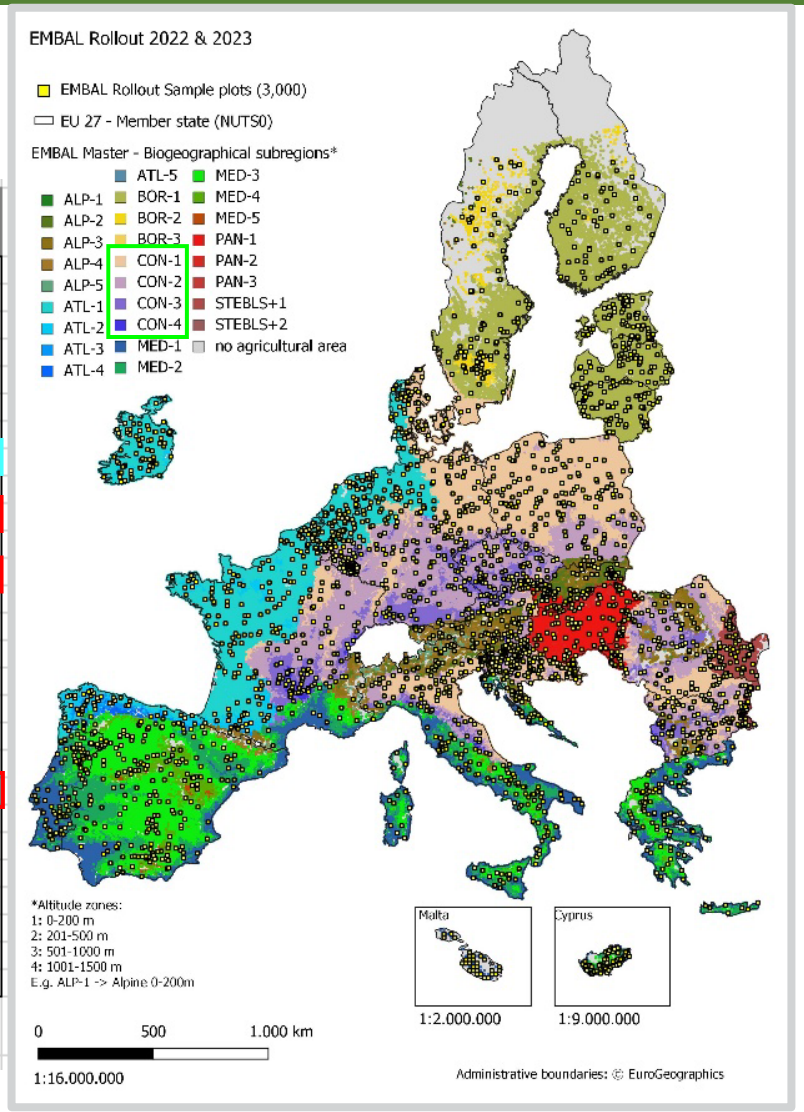


EMBAL Stratification

Funded by the European Union

Allocation of 3,000 plots to EU-27 and BIOGEO subregions

REGION	ALP-1	ALP-2	ALP-3	ALP-4	ATL-1	ATL-2	ATL-3	BOR-1	BOR-2	CON-1	CON-2	CON-3	CON-4	MED-1	MED-2	MED-3	MED-4	PAN-1	PAN-2	STEBLS +1	STEBLS +2	Sum per country
AT		8	35	25						6	20	12	1									107
BE					56	1				4	15	2										78
BG		1	5	8						34	29	13	8							9	30	137
CY														25	19	11	5					60
CZ										2	42	29	1					7	20			101
DE		1	1	1	52	1				63	58	33	2									212
DK					21					39												60
EE								56	4													60
FI														30	25	28	6					89
ES		1	1	1	2	8	44							9	31	101	52					250
FI								54	6													60
FR	1	1	3	3	99	33	7			11	30	17	32	4	4	4	1					250
HR		4	14	1						67	10	1		9	12	2						120
HU																		53	16			69
IE					63	7																70
IT	8	5	7	11						42	15	7	5	31	44	34	7					216
LT								60	8	1												69
LU										2	54	4										60
LV								48	12													60
MT														27	3							30
NL					59	1																60
PL		2	6	1						128	30	1										168
PT					4	2	2							29	40	32	3					112
RO		3	16	6						30	29	9	1					35	4	48	26	207
SE		1	1					43	51	3	1											100
SI	7	12	25	4						9	33	11	2									103
SK	34	13	8	1														23	13			92
Sum per BioGeo	50	52	122	62	356	53	53	261	81	441	366	139	52	164	178	212	74	118	53	57	56	3000



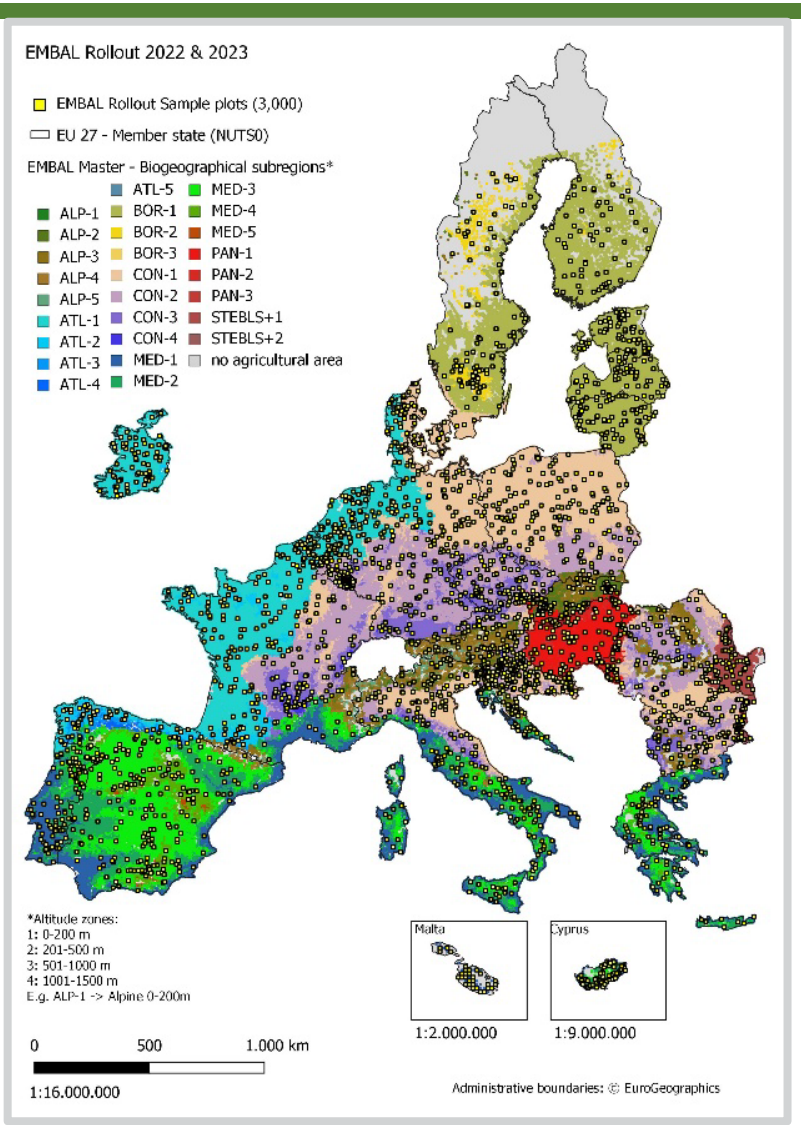
Parameter design - Timeframing

- Vegetation parameters (and many/most biodiversity parameters) are variable according to the time of year
  - Affected by weather and climate: e.g., flower density peaking in June/July in northwestern Europe, but May(/June) in southeastern Europe
  - Affected by management: e.g. first cut in moderately intensive meadows end of May in northwestern Europe

Parameter design - Timeframing

Funded by the European Union

Region			Altitude m above s.l.	Subregion CODE	Altitude	April 1	2	3	4	5	6	May 1	2	3	4	5	6	June 1	2	3	4	5	6	July 1	2	3	4
1	Atlantic - Northwest	England	0-200	1sa																							
			200-500	1sb																							
			500-1000	1sc																							
			1000-1500																								
		Scotland	0-200	1na																							
			200-500	1nb																							
			500-1000	1nc																							
			1000-1500																								
						1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4
2	Boreal- Scandinavia	South	0-200	2sa																							
			200-500	2sb																							
			500-1000	2sc																							
			1000-1500	2sd																							
		Middle	0-200	2ma																							
			200-500	2mb																							
			500-1000	2mc																							
			1000-1500	2md																							
		North	0-200	2na																							
			200-500	2nb																							
			500-1000	2nc																							
			1000-1500	2nd																							
						1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4
3	Atlantic - South +	South	0-200	3sa																							
			200-500	3sb																							
			500-1000	3sc																							
			1000-1500	3sd																							
		North	0-200	3na																							
			200-500	3nb																							



Parameter design - Timeframing

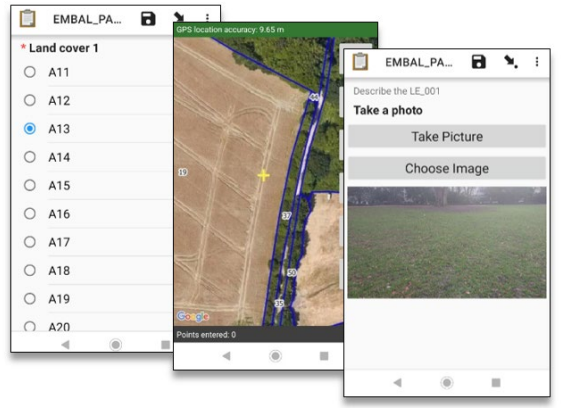
- Vegetation parameters (and many/most biodiversity parameters) are variable according to the time of year
  - Affected by weather and climate: e.g., flower density peaking in June/July in northwestern Europe, but May(/June) in southeastern Europe
  - Affected by management: e.g. first cut in moderately intensive meadows end of May in northwestern Europe
- This leads to a narrow window to collect phenologically comparable results: a logistical challenge, that was mostly met, but not always.
- Records were flagged for the analysis according to
  - Time frame (early-optimal-late)
  - Vegetation stage (unmown/ungrazed-mown a while ago-recently mown)

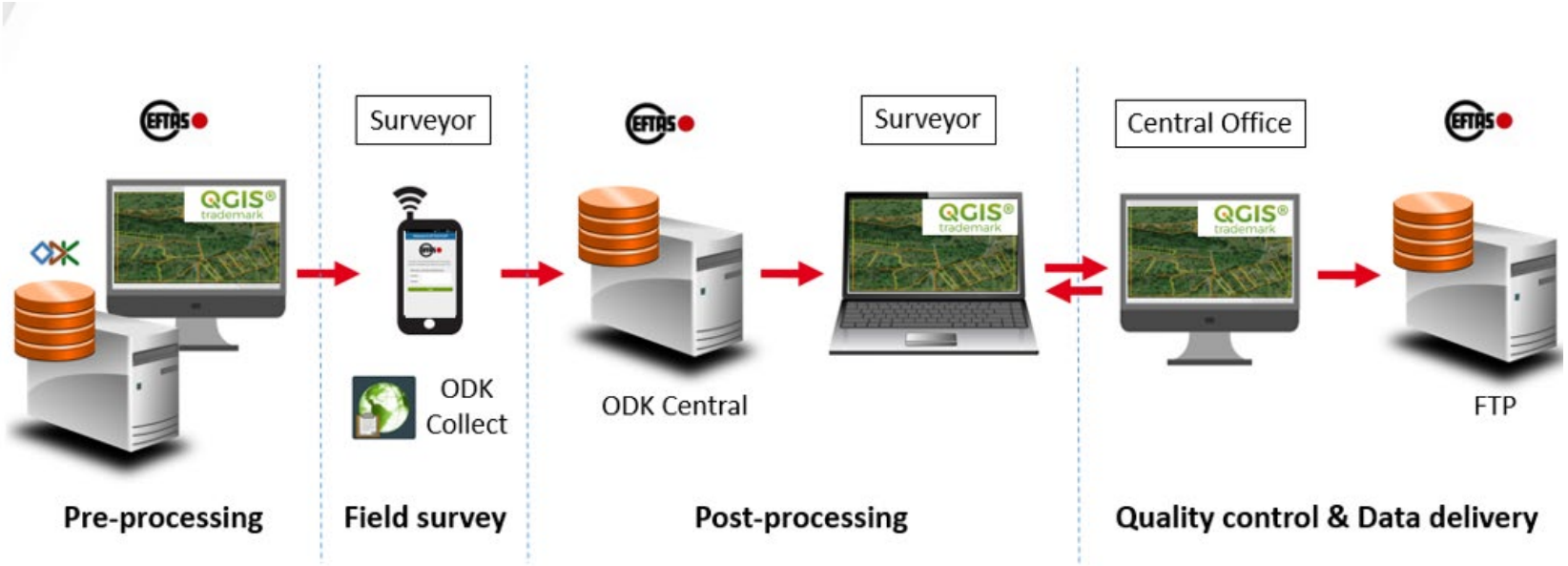
EMBAL Data Management

2. How can data from biodiversity monitoring be organised, shared, and governed effectively across European countries?

EMBAL internal data workflow

1. Pre-processing of the plots using digital orthophotos
2. Field survey
3. Post-processing of recorded data
4. Data exchange & Quality control

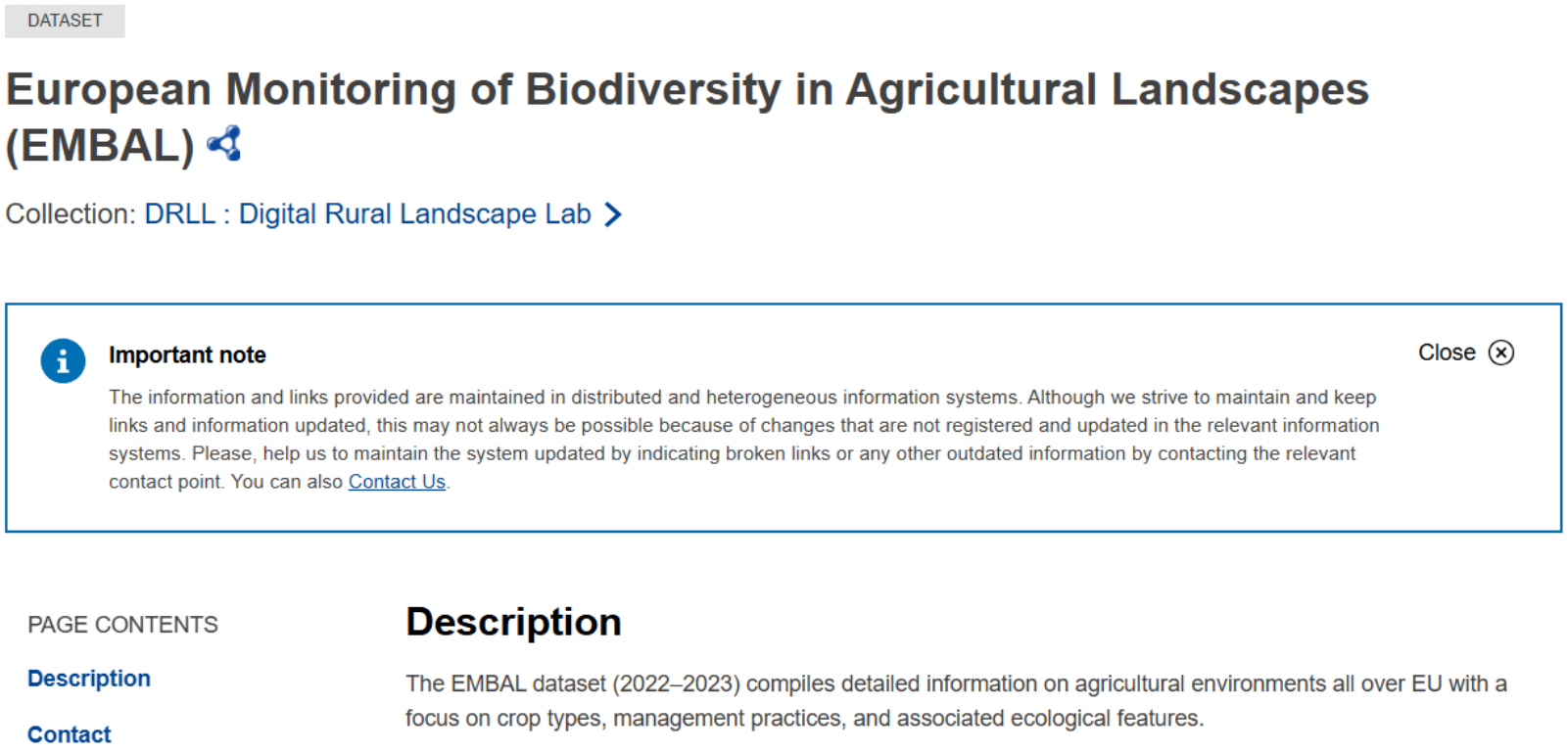




EMBAL on JRC Data Catalogue

Funded by the European Union

- [Joint Research Centre Data Catalogue - European Monitoring of Biodiversity in Agricultura... - European Commission]



DATASET

European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL)

Collection: DRLL : Digital Rural Landscape Lab >

Important note Close

The information and links provided are maintained in distributed and heterogeneous information systems. Although we strive to maintain and keep links and information updated, this may not always be possible because of changes that are not registered and updated in the relevant information systems. Please, help us to maintain the system updated by indicating broken links or any other outdated information by contacting the relevant contact point. You can also Contact Us.

PAGE CONTENTS

Description

Contact

Description

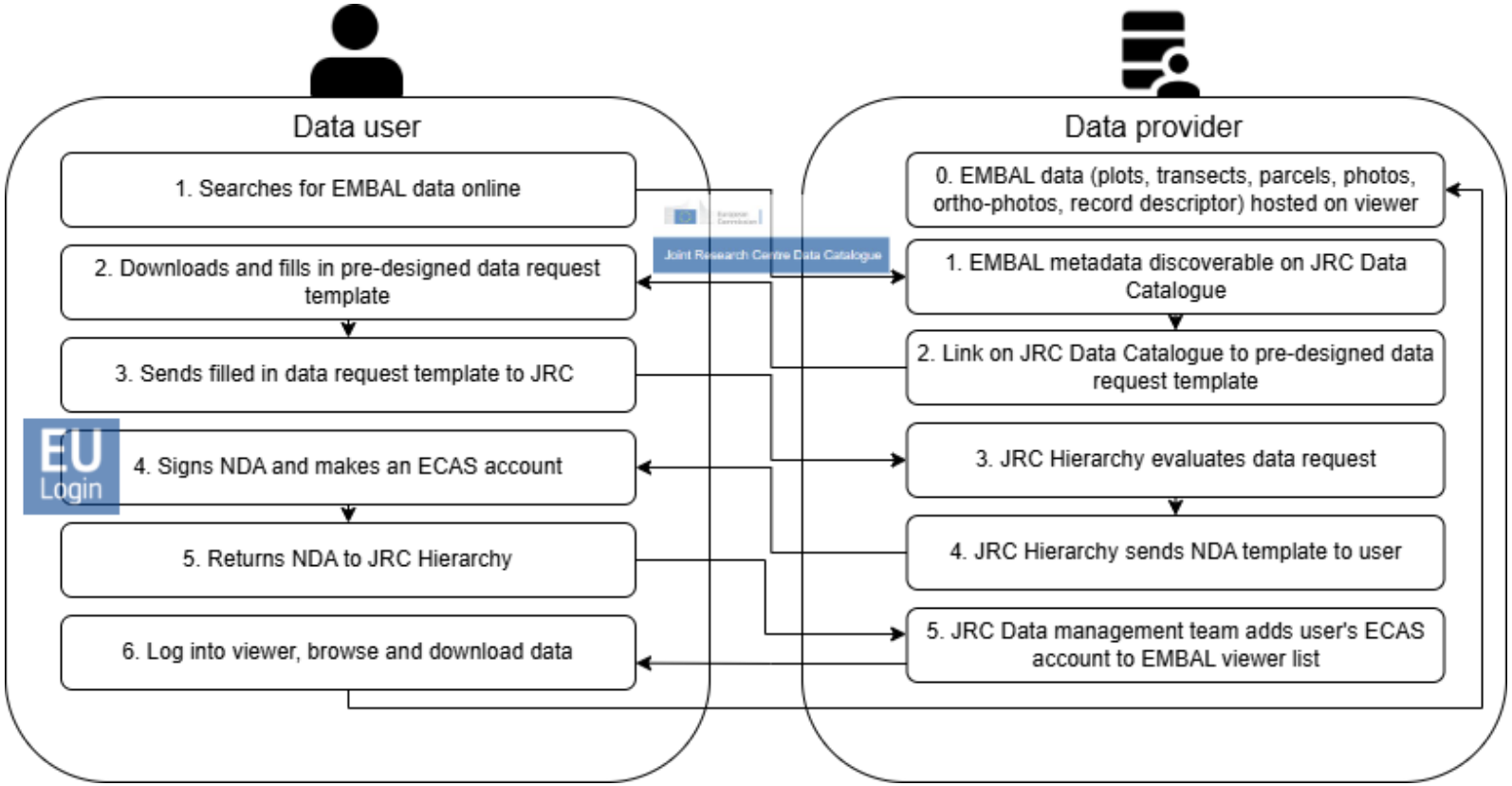
The EMBAL dataset (2022–2023) compiles detailed information on agricultural environments all over EU with a focus on crop types, management practices, and associated ecological features.

*Slides provided by **Andrea Hagyo**, Joint Research Centre*

Workflow for EMBAL data sharing

1. JRC publishes discoverable entry for **geo-anonymized** EMBAL data on **JRC Data Catalogue**
2. <u>Upon approval</u> of **research proposal** and signature of **Non-disclosure agreement**

→Access to, viewing, exploring, and **downloading** EMBAL data with **geo-location**

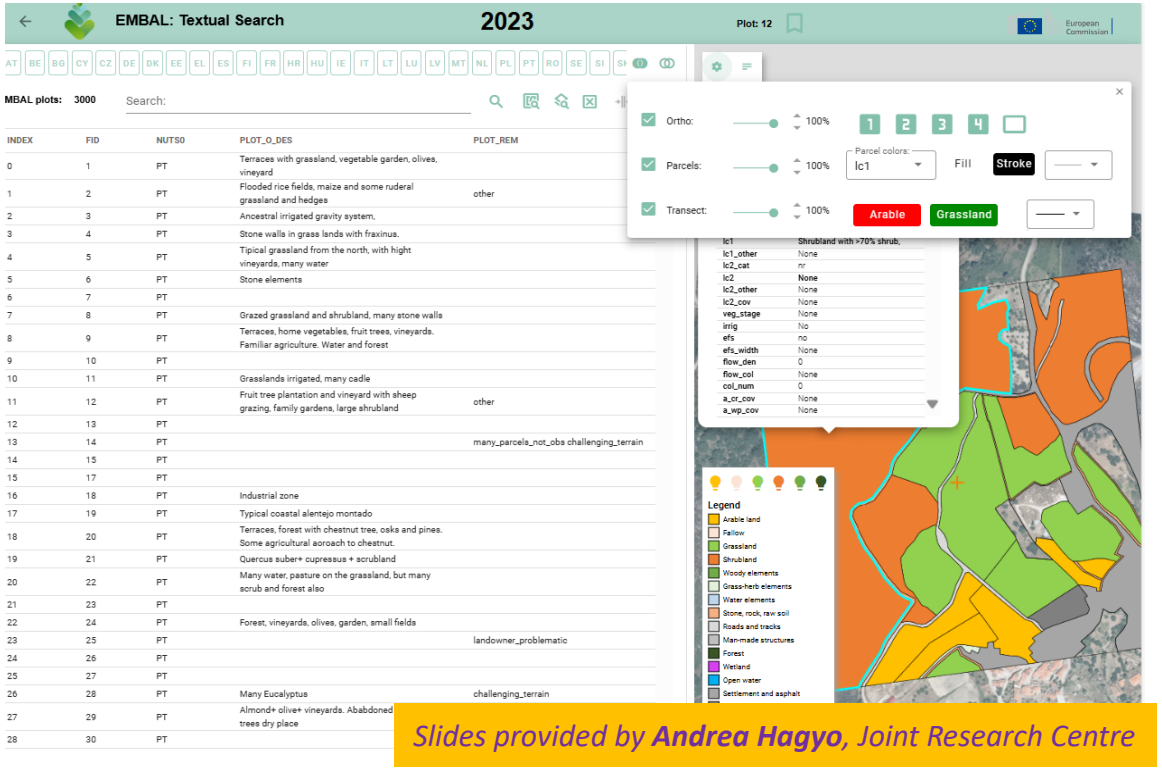


*Slides provided by **Andrea Hagyo**, Joint Research Centre*

EMBAL geo-anonymised viewer

Funded by the European Union

- Access with **ECAS account**
- Available in JRC Data Catalogue
- GPS coordinates not available
- Attribute fields with location deleted
- **No EMBAL_id** available
- Photos are not available

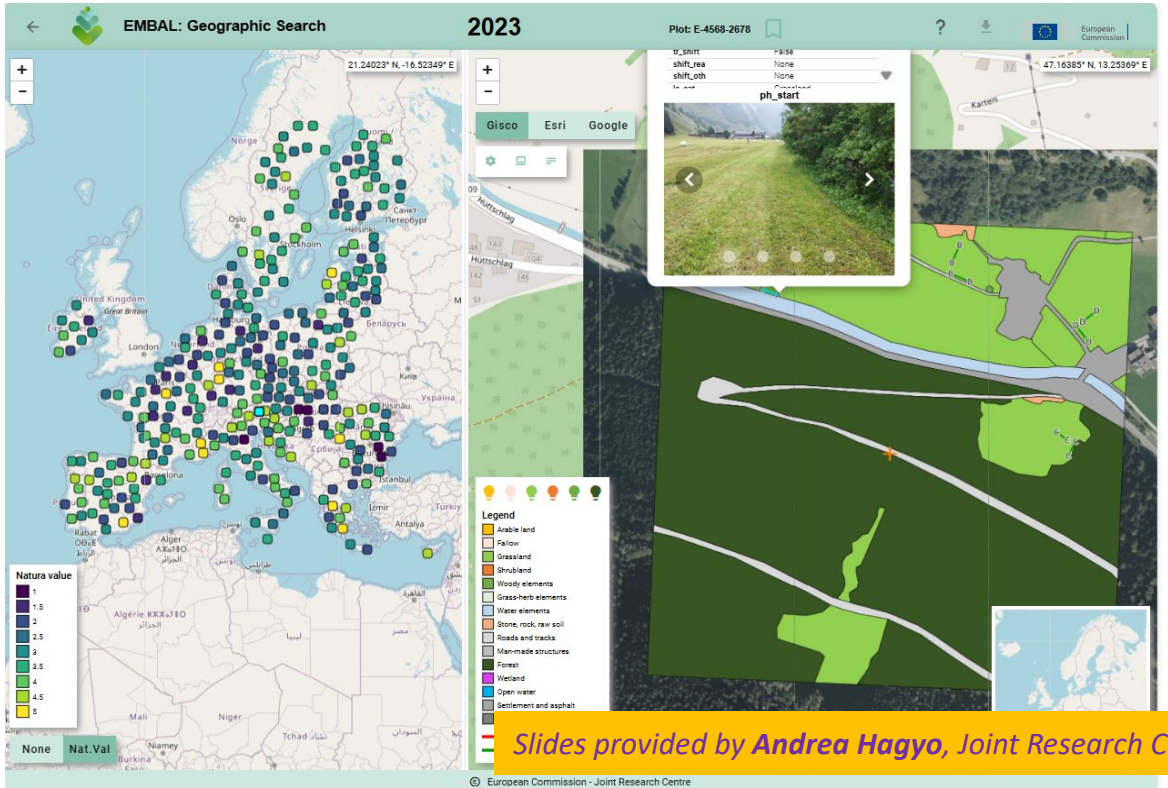


*Slides provided by **Andrea Hagyo**, Joint Research Centre*

EMBAL full dashboard

- **Full version** of the data (plots, transects, photos, …)
- Accessible after **approved research proposal** and **NDA** signature

- Has textual and geographical search across all fields
- Access to the photos taken during the survey
- **Orthophoto pairing** (new Eurostat GISCO service!)



*Slides provided by **Andrea Hagyo**, Joint Research Centre*

Question for discussion (II)

c) *What governance **structures**, **standards** and **sharing infrastructure** are needed for coordinated, long-term monitoring?*

With regard to "2nd Main Question of the Workshop"

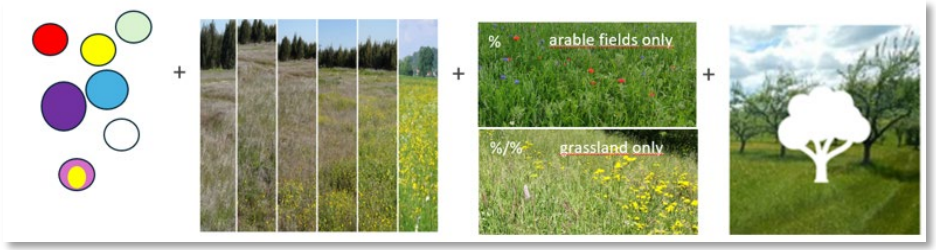
*How can **data** from biodiversity monitoring be **organised, shared, and governed** effectively across European countries?*

EMBAL Supporting policy

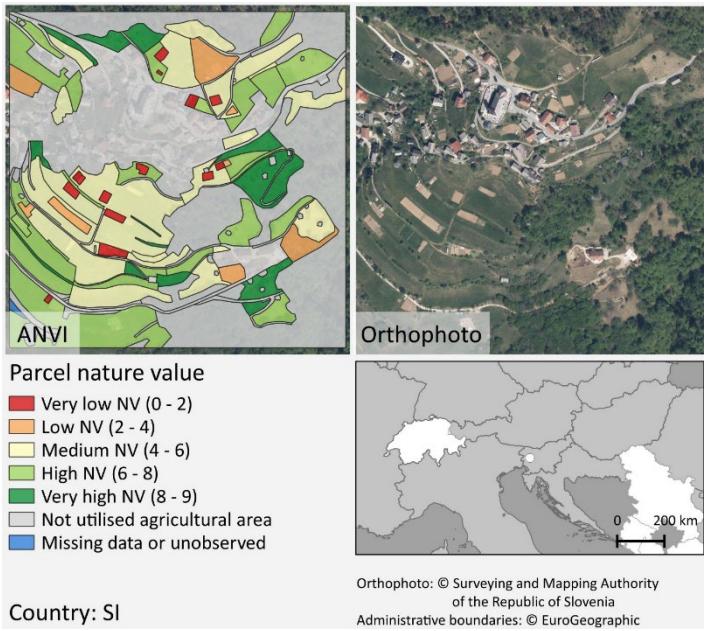
3. How can monitoring data be translated into formats that effectively support decision making and policy processes?

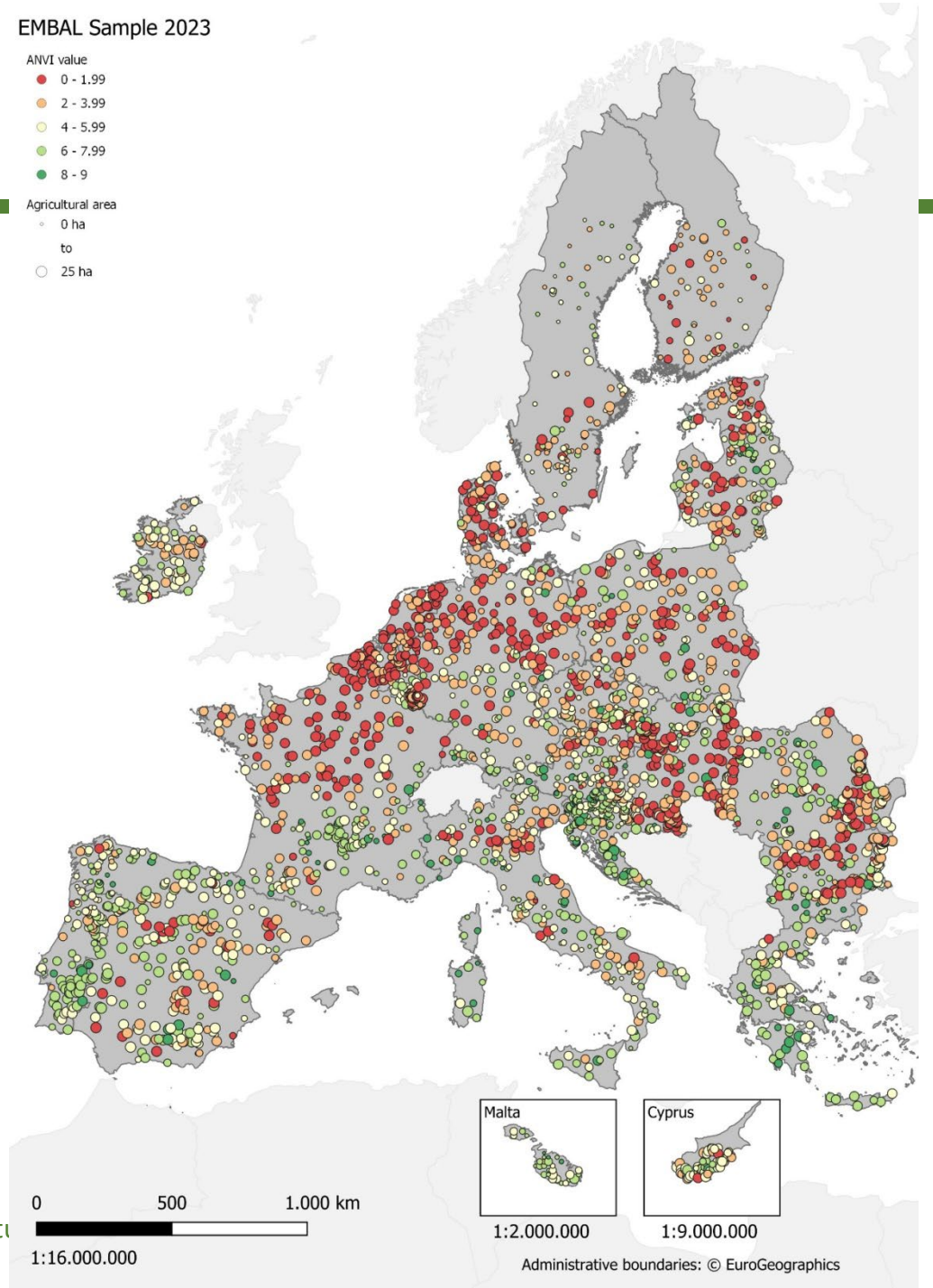
Agricultural Nature Value Index

Parcel NV calculated from individual parameters



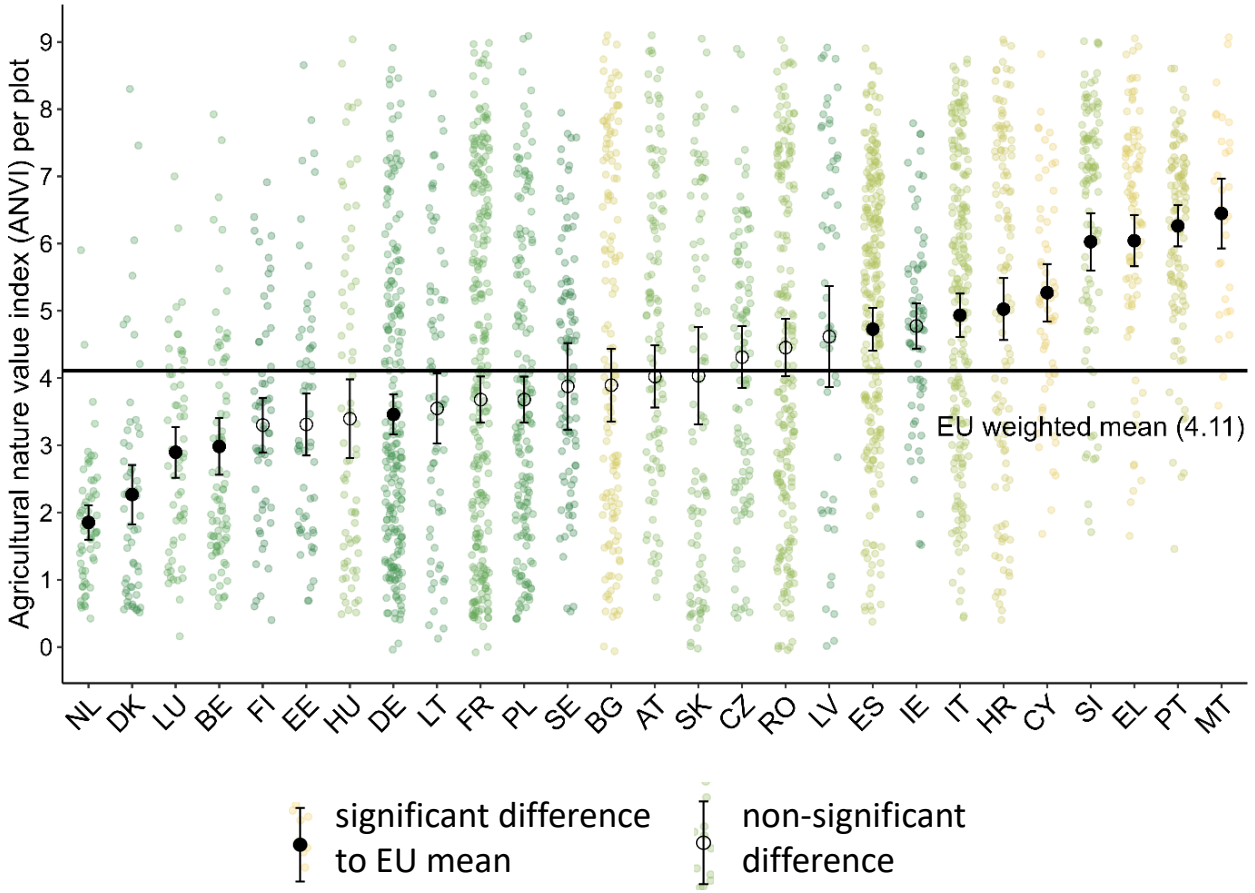
Plot ANVI scored between 0-9



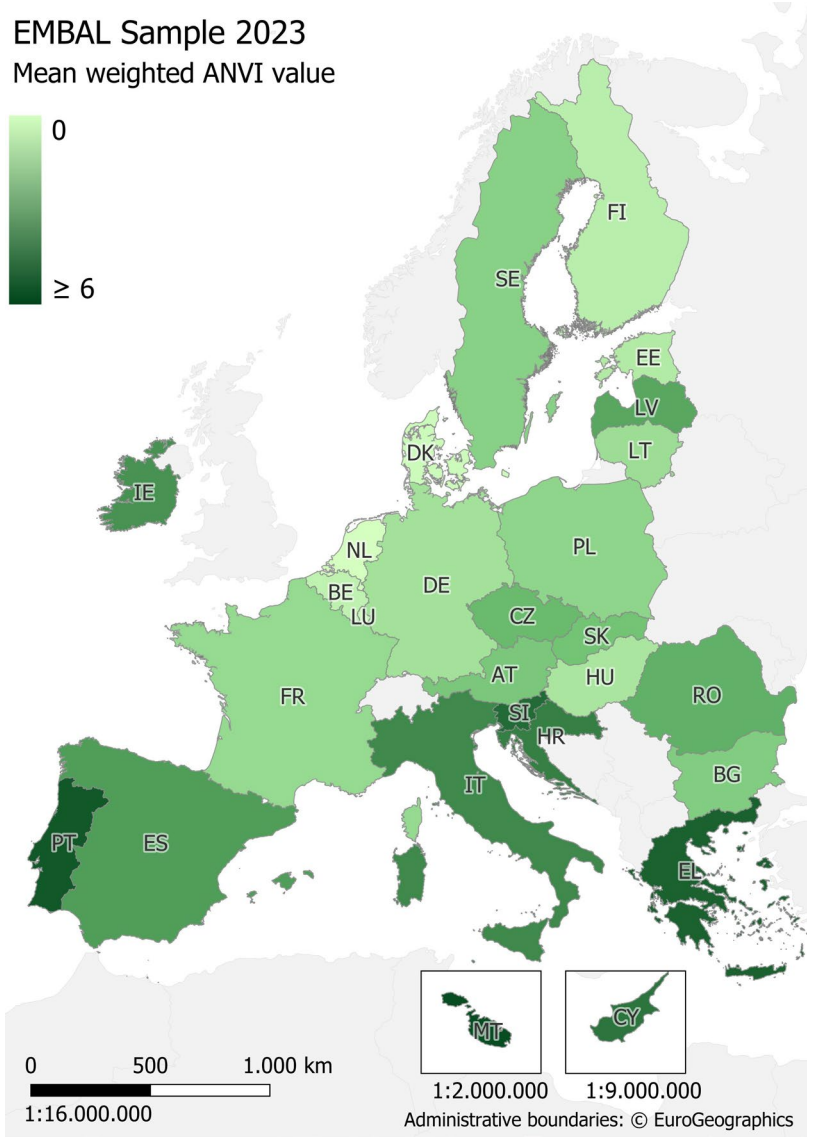


Agricultural Nature Value Index

Funded by the European Union



Applying plot weights for representativeness at Member State level. Significance according to permutation test with 10,000 permutations and Bonferroni correction. Showing 95% confidence intervals



Thank you for your attention!

How to design biodiversity monitoring programmes

How can monitoring data be translated into formats that effectively support decision-making and policy processes?

BioMonWeek 2026 7/5/2026

Andrea Hagyo, Joint Research Centre

European Commission

How biodiversity monitoring data can support policy?

- Monitor biodiversity
  - to underpin why biodiversity conservation and restoration are needed
  - evidence to design effective policies
  - to track policy impact and performance

- Monitor biodiversity/ proxies AND management/actions
  - What human activities, pressures have an impact on biodiversity?
  - What actions can lead to positive changes, halt and reverse biodiversity loss?
  - Where, how, how much?

<u>Clear links between biodiversity and actions regulated or incentivised by the policy</u>

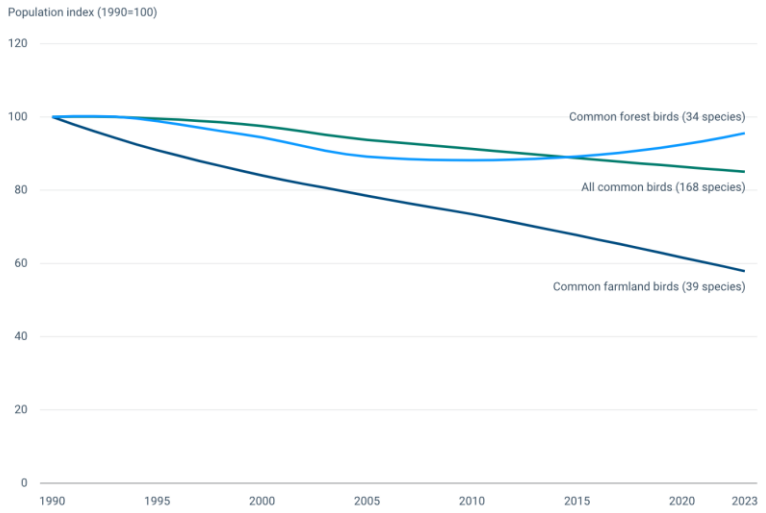
- Biodiversity targets
  EU Biodiversity Strategy
- Protected areas
  Natura 2000

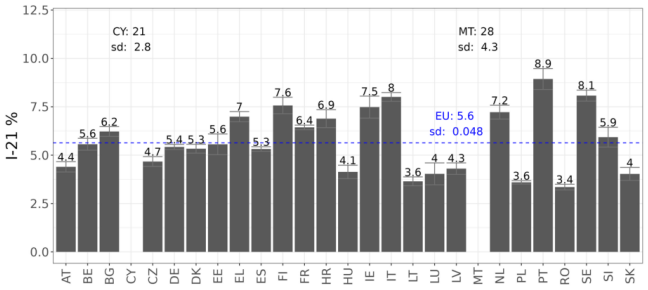
- Conservation/restoration policies
  Nature Restoration Law

- Sectoral policies with biodiversity objectives
  Common Agricultural Policy

How can monitoring data be translated into formats that effectively support decision-making and policy processes?

- Cost-effective and robust indicators, reliable in a legal context
- Detect changes at a comparable timescale with policies, comparability across time
- Statistical representativeness
- Well-documented, open data





From design to policy-relevant data and indicators

Land Use and Cover Area frame Survey, LUCAS

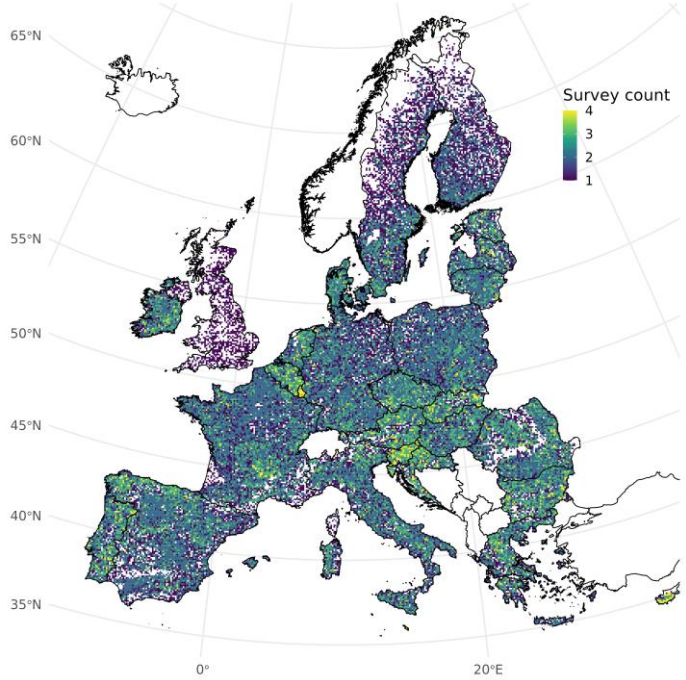
- Multiannual planning
- Align pogramming with policy and implementation cycles
- Implementation of robust data governance principles
- Data quality, interoperability
- Identification of user needs
- Survey design, data collection, processing, analysis, dissemination, and post-survey evaluation

Soil biodiversity 2018, 2022

Landscape Features 2022

LUCAS Grassland 2018, 2022

Co-location



LUCAS grassland
LUCAS Landscape features
LUCAS soil biodiversity
EMBAL

Monitoring landscape features

Clear objective

Common Agricultural Policy (CAP) supports maintaining landscape features since 1992

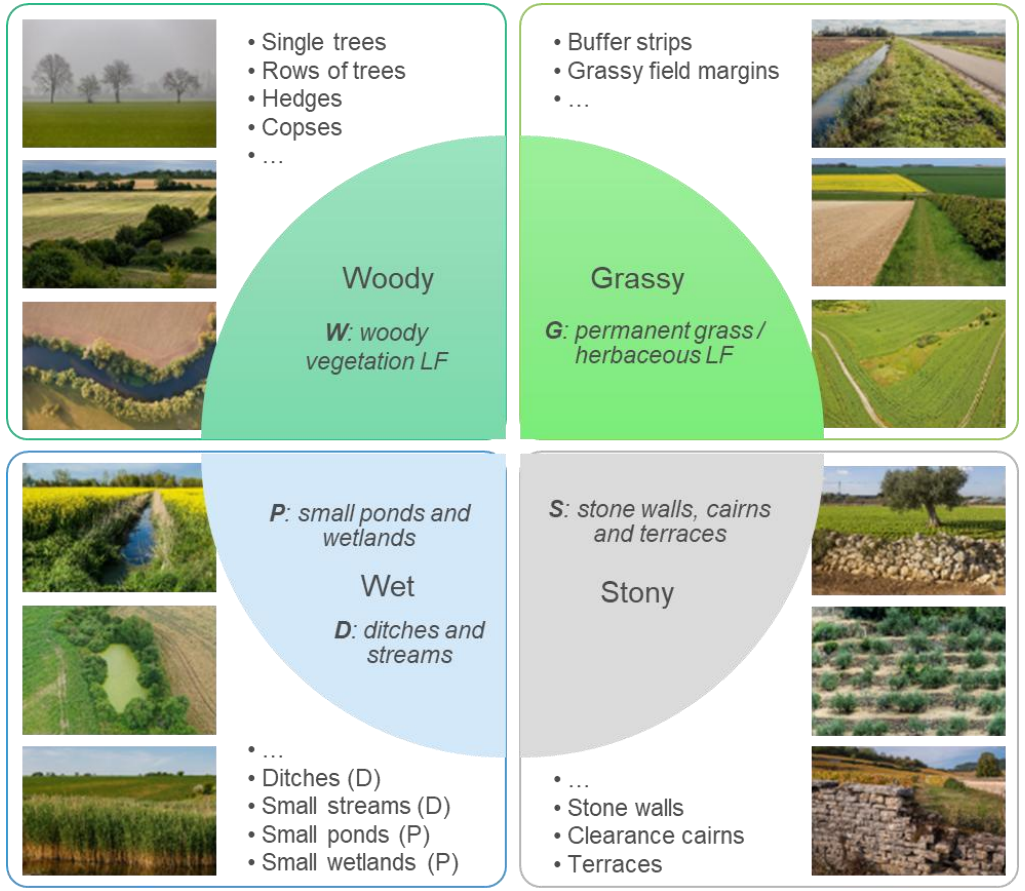
Impact indicator I-21

‘share of agricultural land covered with landscape features’

developed by JRC at the request of DG-AGRI

A European Union typology of landscape features

Clear and simple definitions for cost-efficient sampling and robust data



Indicator: The ratio (%) between the area covered by LF and the area covered by agricultural land at Member State (and possibly at NUTS2) level

LF definition: small fragments of non-productive and typically, but not only, semi-natural vegetation present in, or adjacent to, agricultural land.

- 4 main LF types
- Geometry

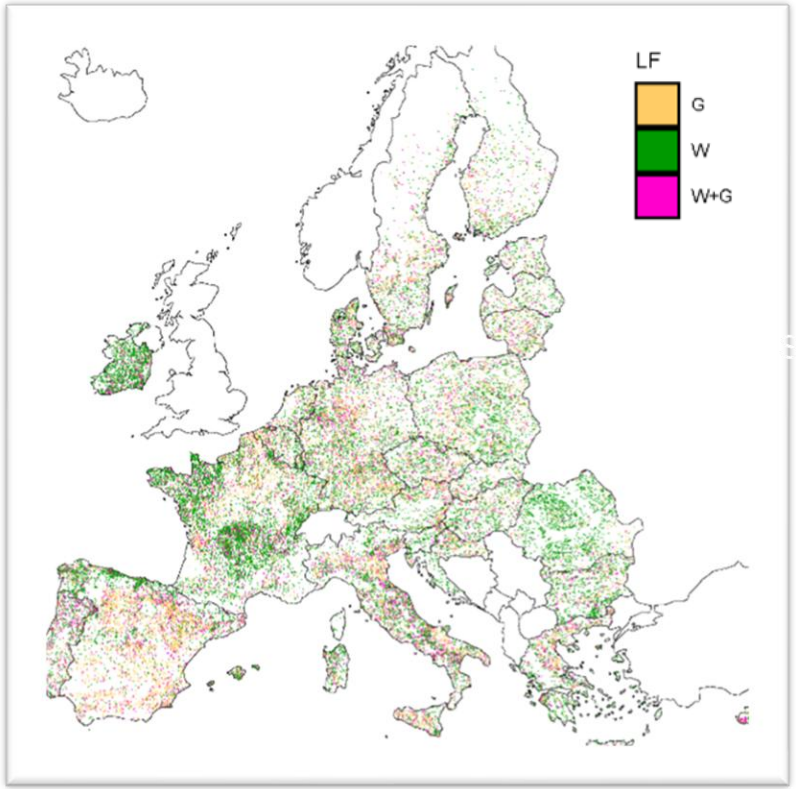
< 20m wide OR
< 0.5 ha size (area)

LUCAS Landscape Features 2022

- Clear methodology
- Robust area estimation

in collaboration

Policy
Research
Statistics

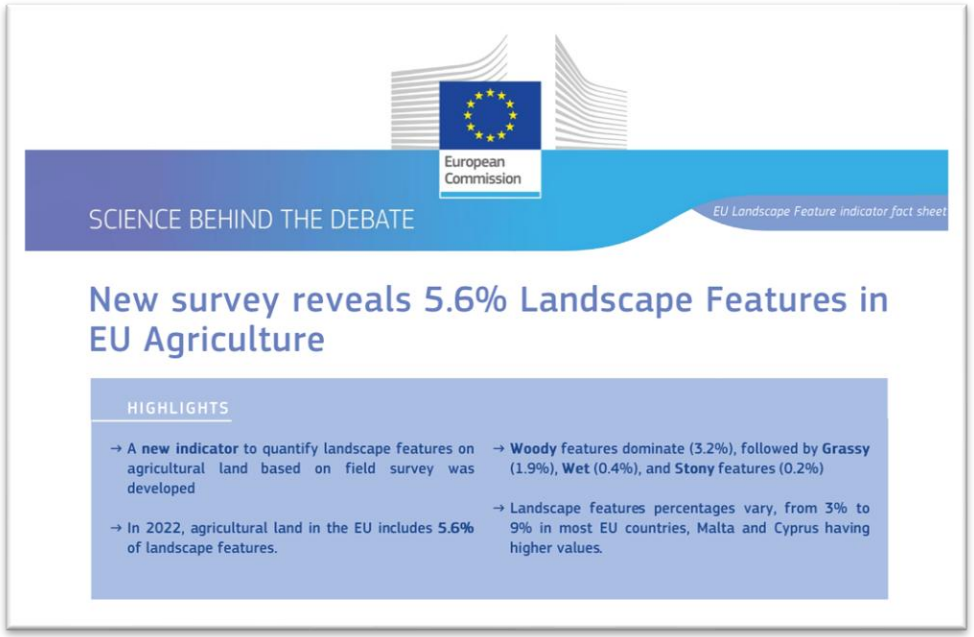


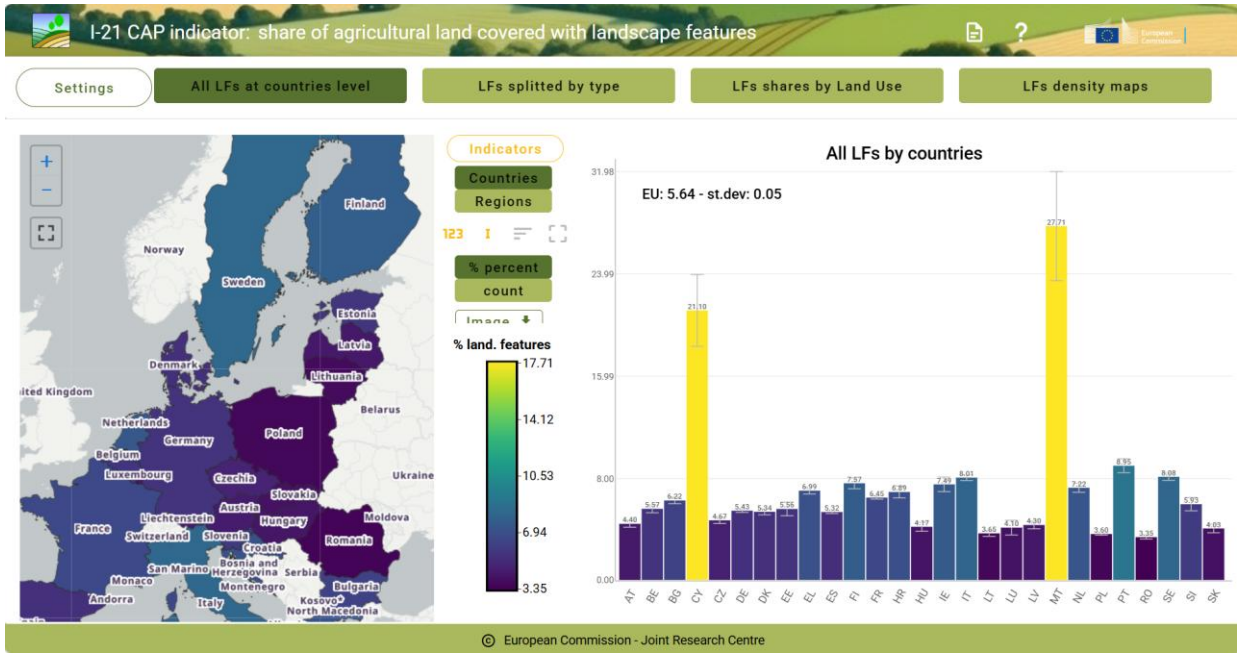
- Nested point sampling
- Agricultural land

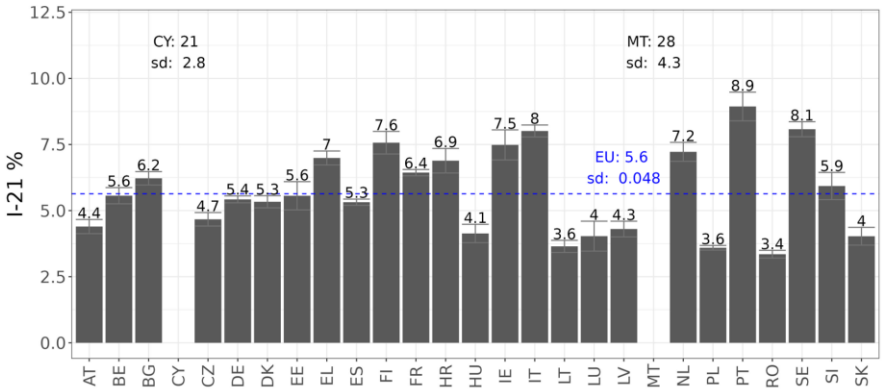
93,000 quadrats of 100x100m

x 41 sub-points-> 3.8 million

I.21 CAP indicator





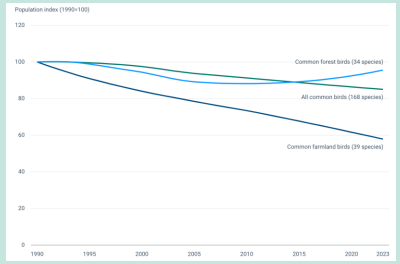


Setting a baseline

Change detection?

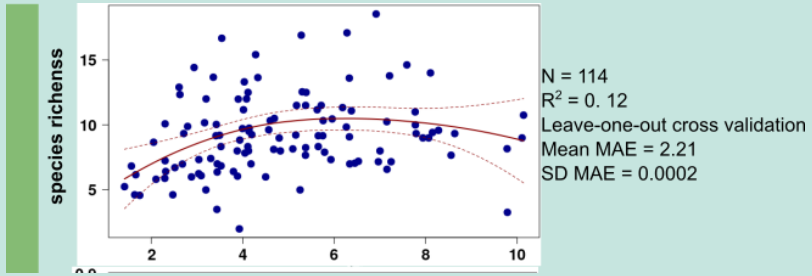
Evidence on links between biodiversity, proxies and management

A. Combining data from different monitoring programs

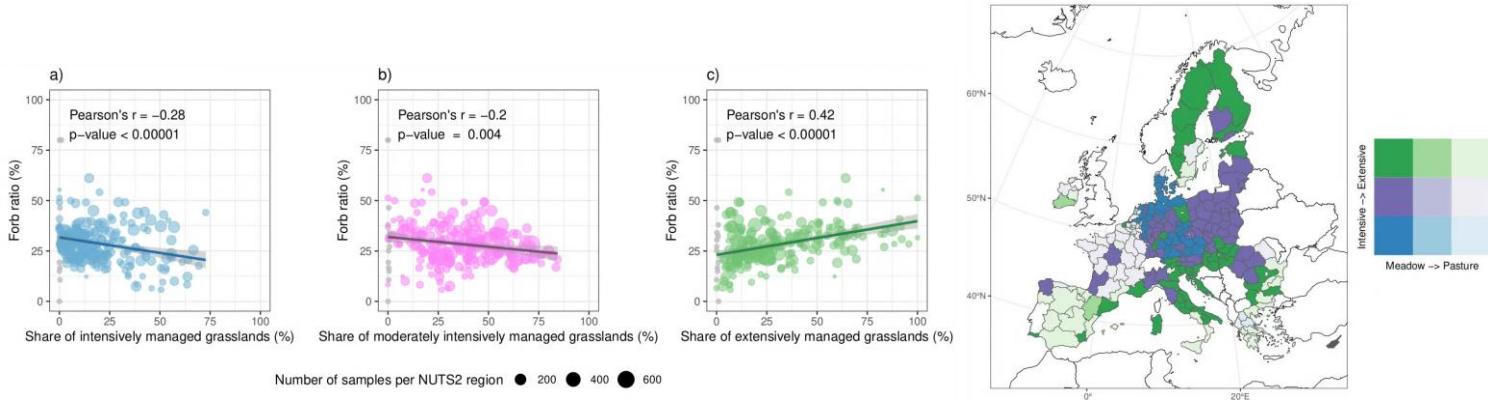


Gridded data from the Pan European Common Bird Monitoring scheme (PECBMS) site-level data, 2018-2023

Mean species richness and abundance, weighted by sampling effort



B. Monitoring multiple biodiversity and management metrics - LUCAS Grassland



C. Knowledge synthesis from multiple studies

- JRC Farming practices evidence library: Systematic review of meta-analyses

Thank you