How old are our grasslands: Determining the age of grassland using time series from Sentinel-2 and Landsat-5/8 imagery

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Permanent grassland: why age?

- grassland sustainability
- high ecological value, ecosystem services
- vital components of ecosystems, offering significant environmental, ecological, and socio-economic benefits
  - Bio-diversity hotspots, providing essential ecosystem services like carbon storage, water filtration, and nutrient cycling, and maintaining ecological balance.
  - Act as carbon sinks, mitigate climate change, and support diverse flora and fauna, and wildlife.
  - Crucial habitats for pollinators, safeguard water resources, and prevent soil erosion.
  - Additionally, they support global food production …
- Permanence is indicator of the stability of the grassland ecosystem

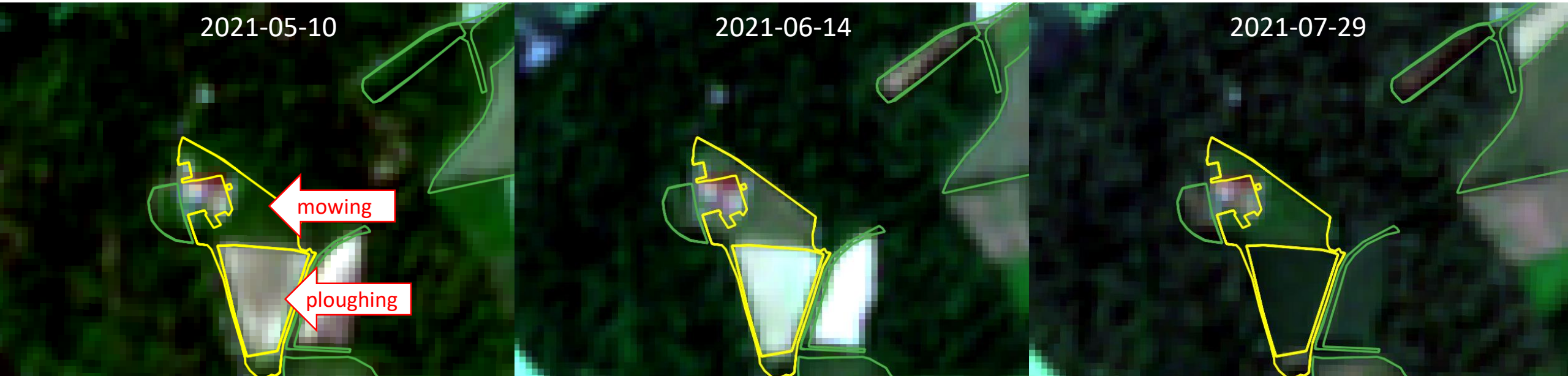
Threths and vulnerability

- Grasses are **resilient and adaptable species** known for their ability to recover after disturbance. However, they are **sensitive to climate variability** and will be affected by future changes in precipitation and temperature.
- Despite their widespread presence, grasslands are highly **endangered globally**, with nearly half degraded mainly due to climate change and human activities.
- Mapping grassland permanence, based on its age, serves as a **sustainability indicator**, reflecting the **long-term condition of the grassland**. It helps understand the relationship between grassland characteristics and ecosystem services, challenges in restoration, and landscape change patterns over time.

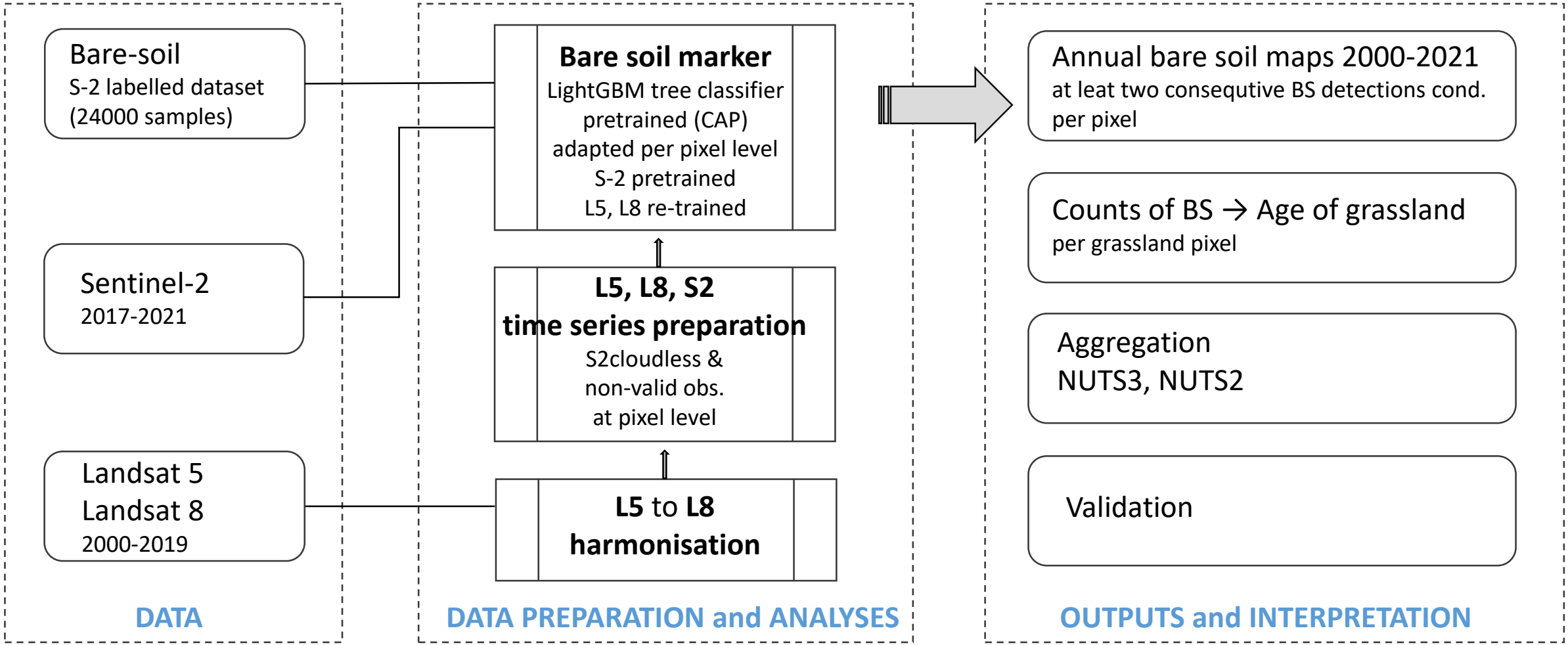
Our aim in this study was to determine the persistence of permanent grassland in Slovenia and to reveal **spatio-temporal patterns associated with conservation or signs of change**.

European permanent grassland

- grassland that has not been ploughed for at least 5 years or used for crop growing or depositing materials
- Questions:
  - How many such grasslands are there?
  - How can they be detected?
  - How can their age be determined?
- **age** is determined by the continuous presence of grass during the growing season over several years
  - monitoring/tracking the greeness, continuous presence of grass?
  - to identify the annual presence of exposed bare soil on grassland?



Overview of the concept and workflow



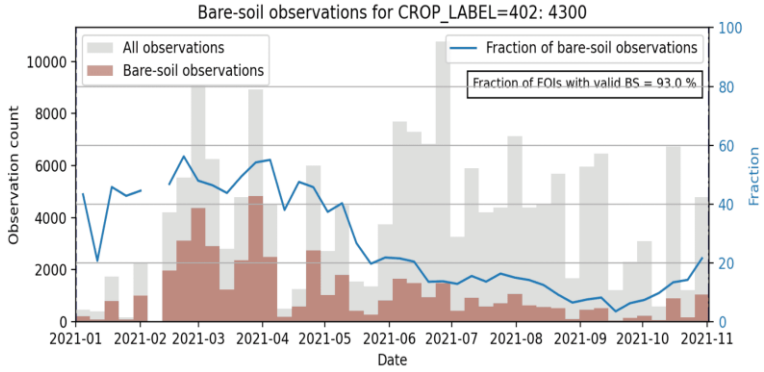
- to determine the age of each permanent grassland parcel in Slovenia using Sentinel-2 and Landsat 5/8 satellite data

Study area: Slovenia

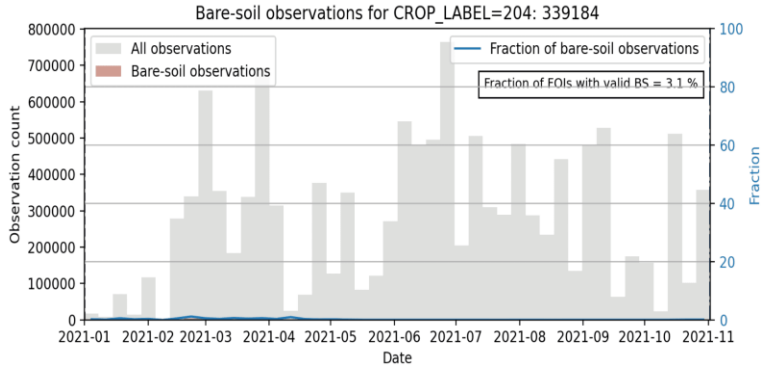
- 3060 km^2 of permanent grasslands
- grassland mask based on LPIS land use layer
- challenge: narrow, small and fragmented parcels
- BSM model adaptation:
  - from parcel to pixel level
  - pre-trained on S-2 2019 labelled data, re-trained for L8 and L5 using the same BS labelled sample

Bare soil marker

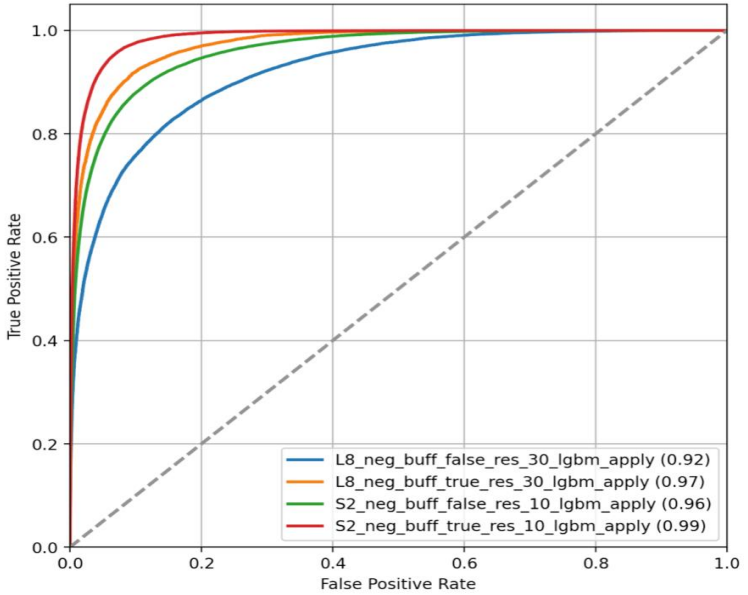
- developed within Area monitoring (EU CAP) activities
- used for plowing detection
- 24 000 S-2 based labelled samples (2019) for BS and non-BS, incl. crop and grassland fields
- LightGBM
- trained on Sentinel-2 NDVI, NBSI, NDVI Re3, CLRe (2019)
- adaptation for Landsat data
- Performance:
  - good accuracy for both Sentinel-2 and Landsat-8 (> 90%)



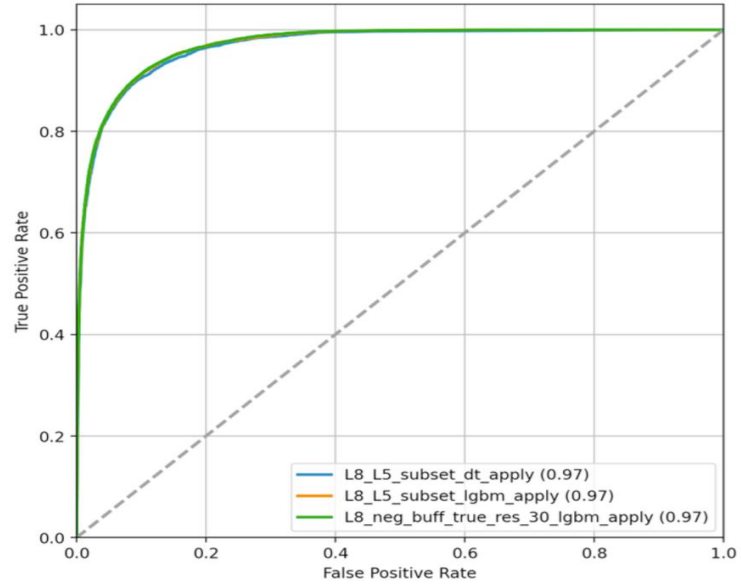
BS for crops



BS for grasslands

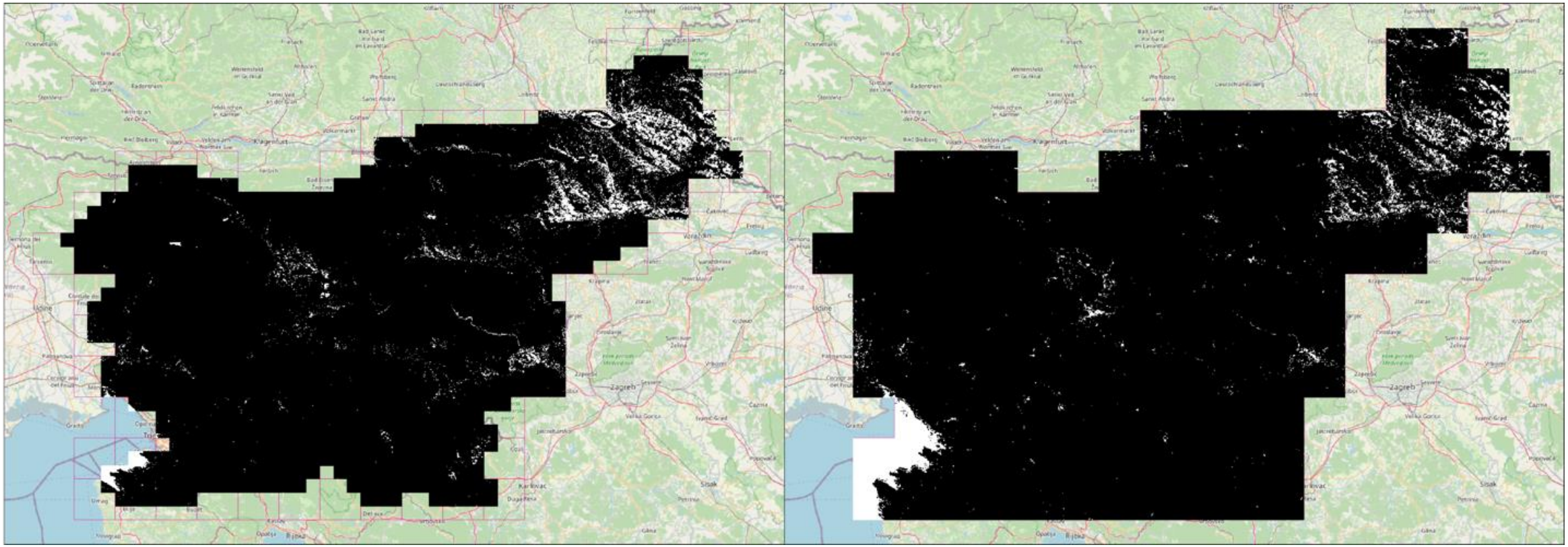


Landsat-8 vs. Sentinel-2 ROC curves



Landsat-8 vs. Landsat-5 ROC curves

Bare soil map 2019 for Sentinel-2 and Landsat-8

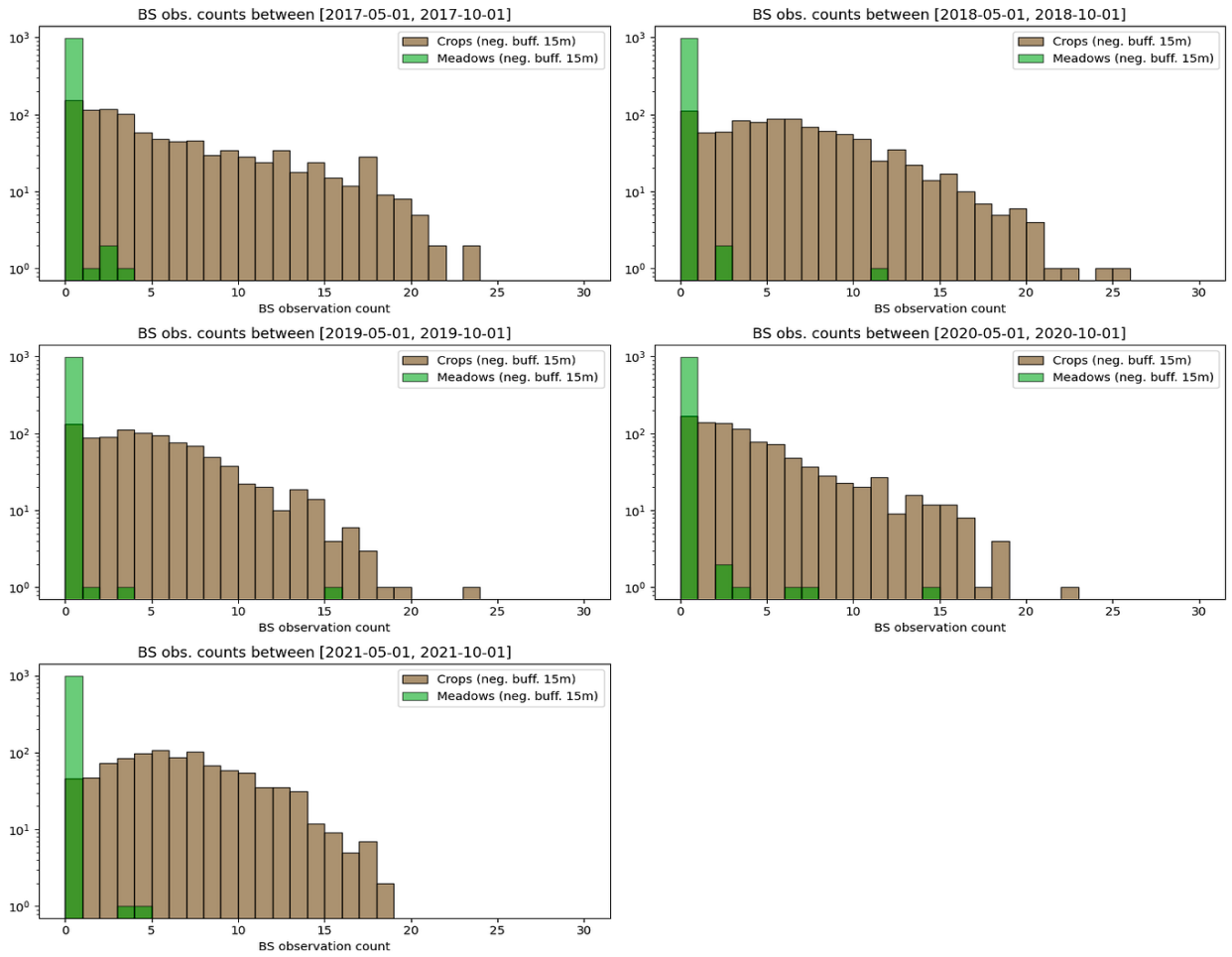


Sentinel-2

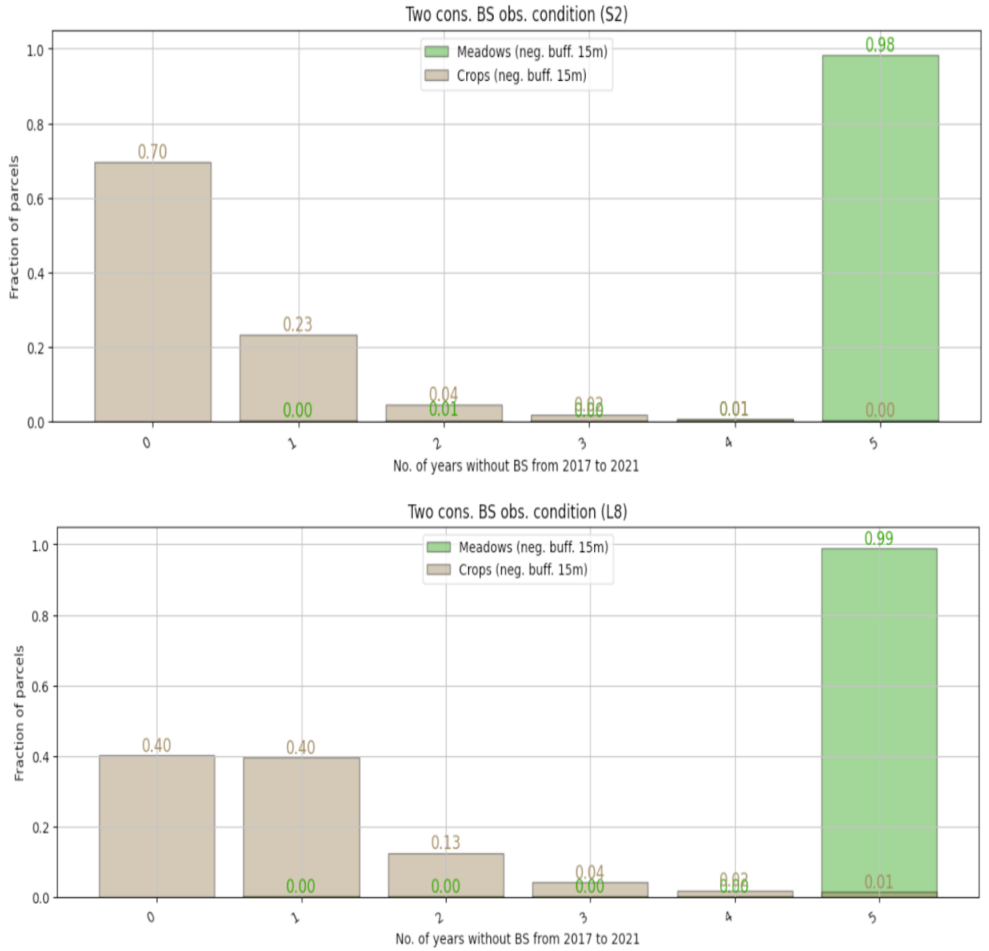
Landsat-8

Annual base soil layers → age of grassland

S-2



The yearly distribution of bare soil observation counts per parcel for Sentinel-2 data.
Green represents grassland parcels, while brown represents arable land parcels.
The y-axis is on a logarithmic scale.

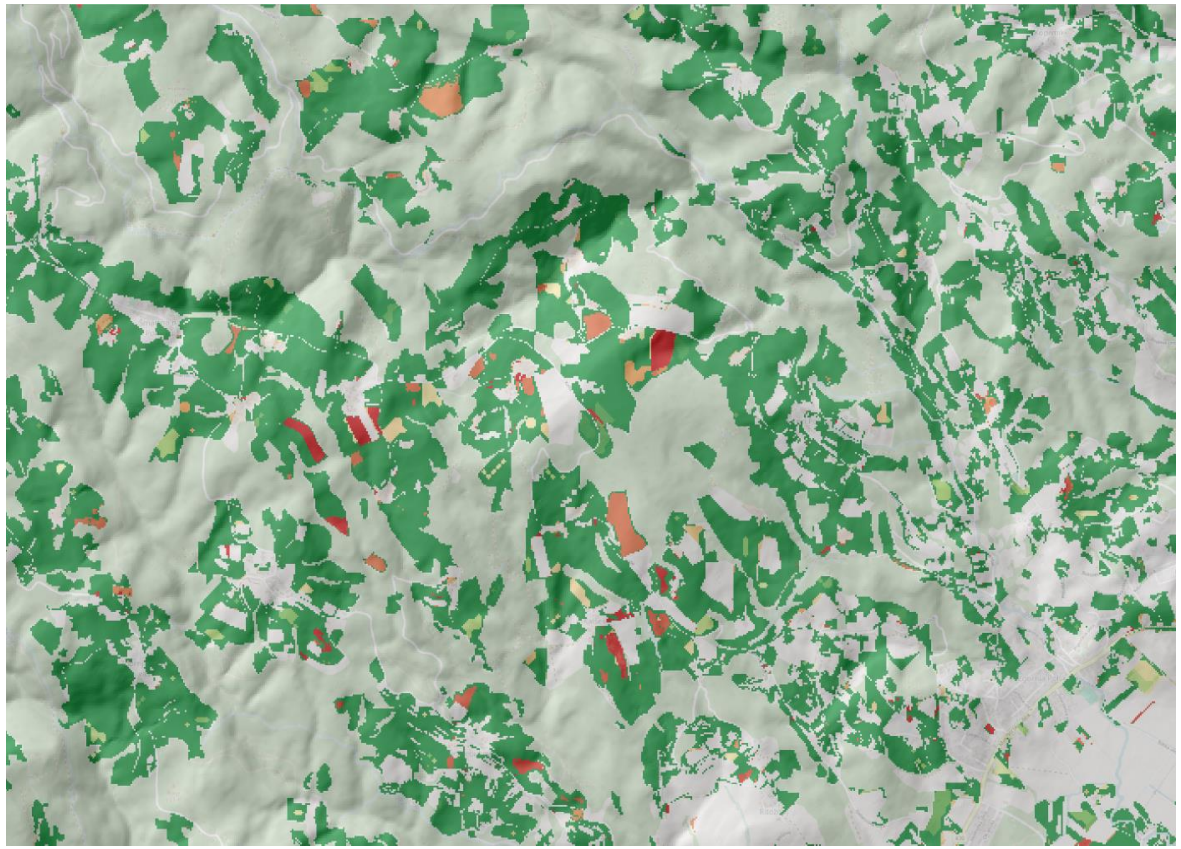


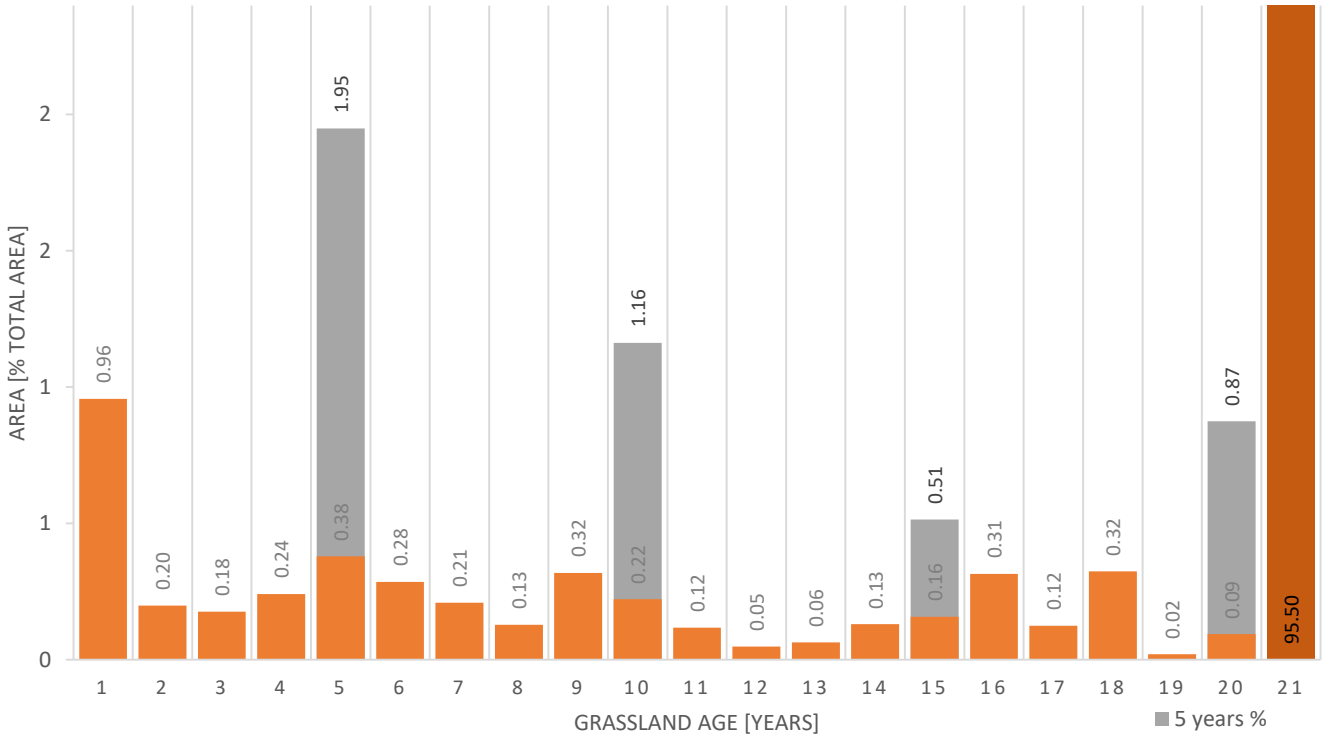
S-2

L-8

The **number of consecutive years without detected bare soil** for **grassland** parcels (green) and **arable land** parcels (brown) from 2017 to 2021.
Detection required at least two consecutive observations of bare soil.
Results, based on Sentinel-2 (top) and Landsat 8 (bottom) data, show good agreement between the two data sources.

Age of grassland 2000-2021



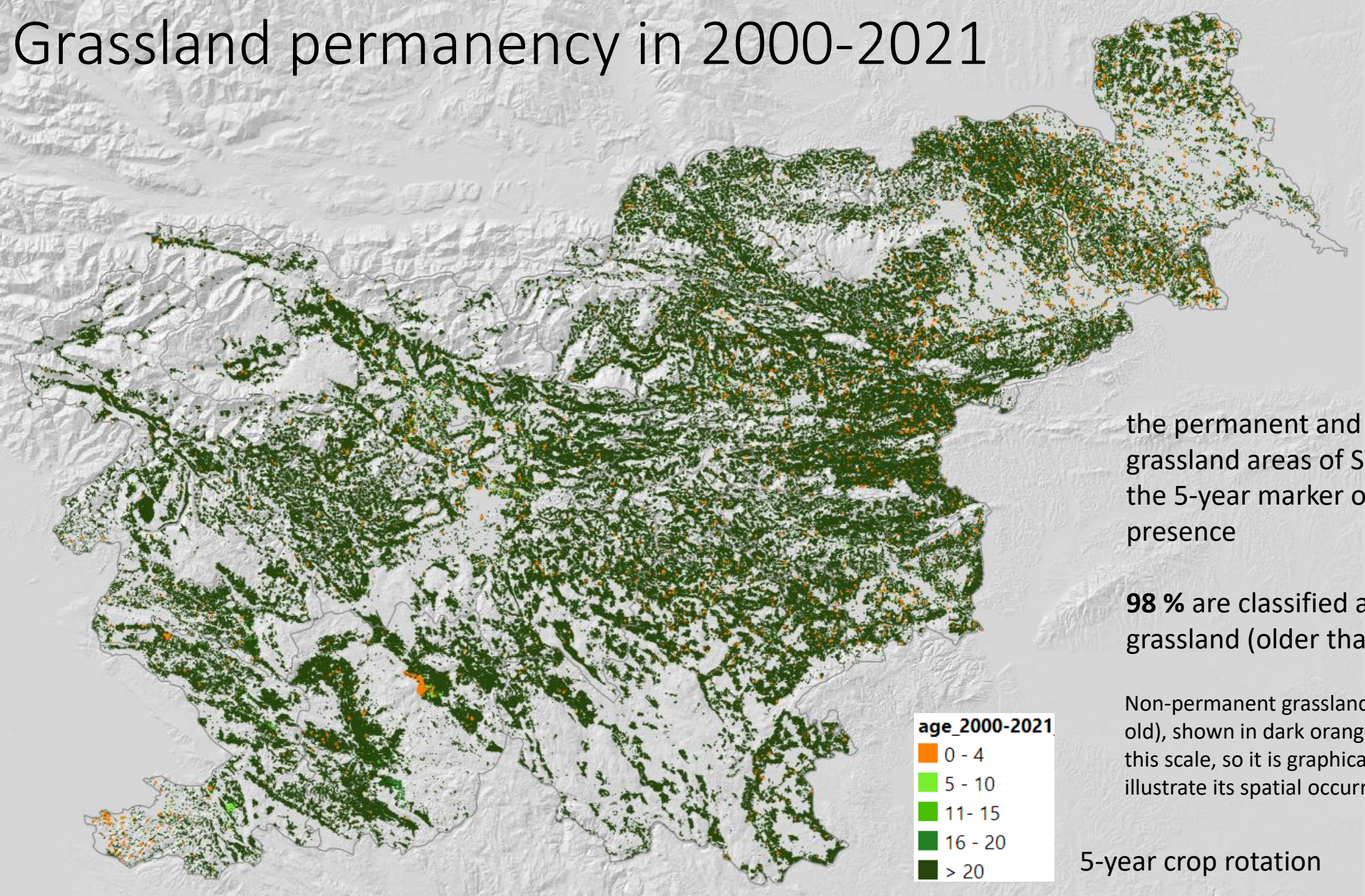


→

0 years 21 years

95.5 % grassland area is 21 years old

Grassland permanency in 2000-2021



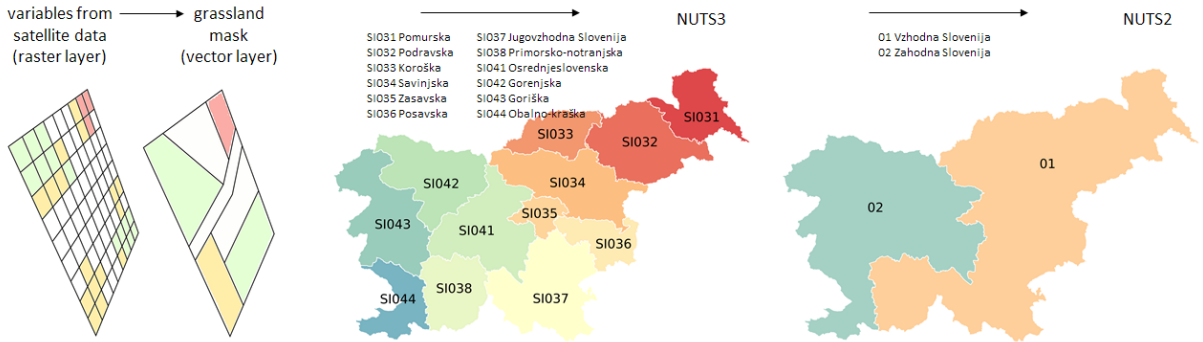
the permanent and non-permanent grassland areas of Slovenia, based on the 5-year marker of the bare soil presence

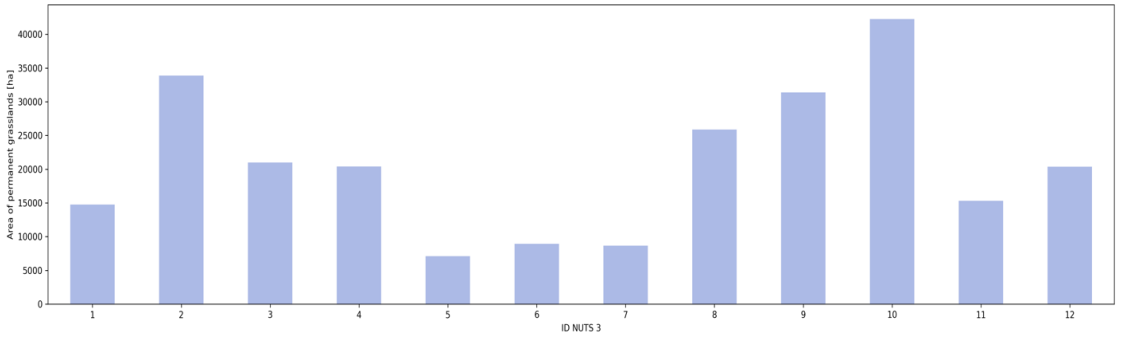
98 % are classified as permanent grassland (older than 5 years)

Non-permanent grassland (less than 5 years old), shown in dark orange, is barely visible at this scale, so it is graphically highlighted to illustrate its spatial occurrences.

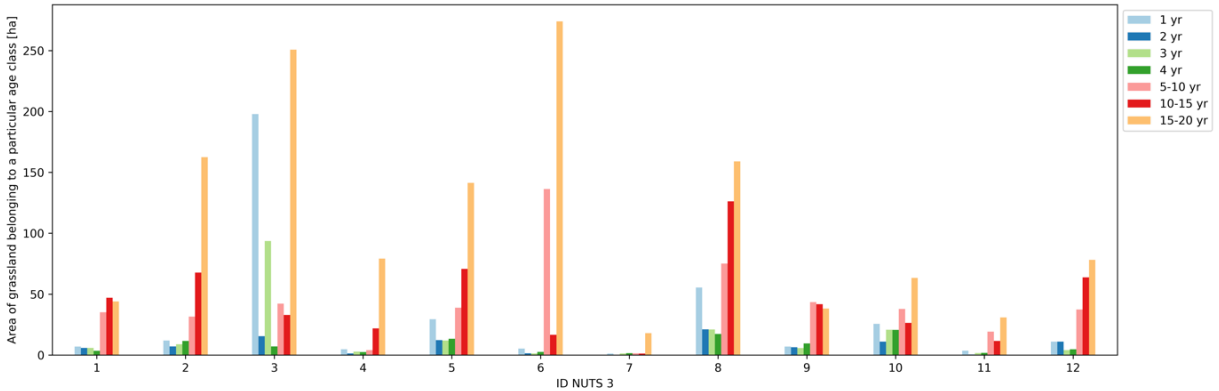
5-year crop rotation

Aggregation to NUTS3 and NUTS2

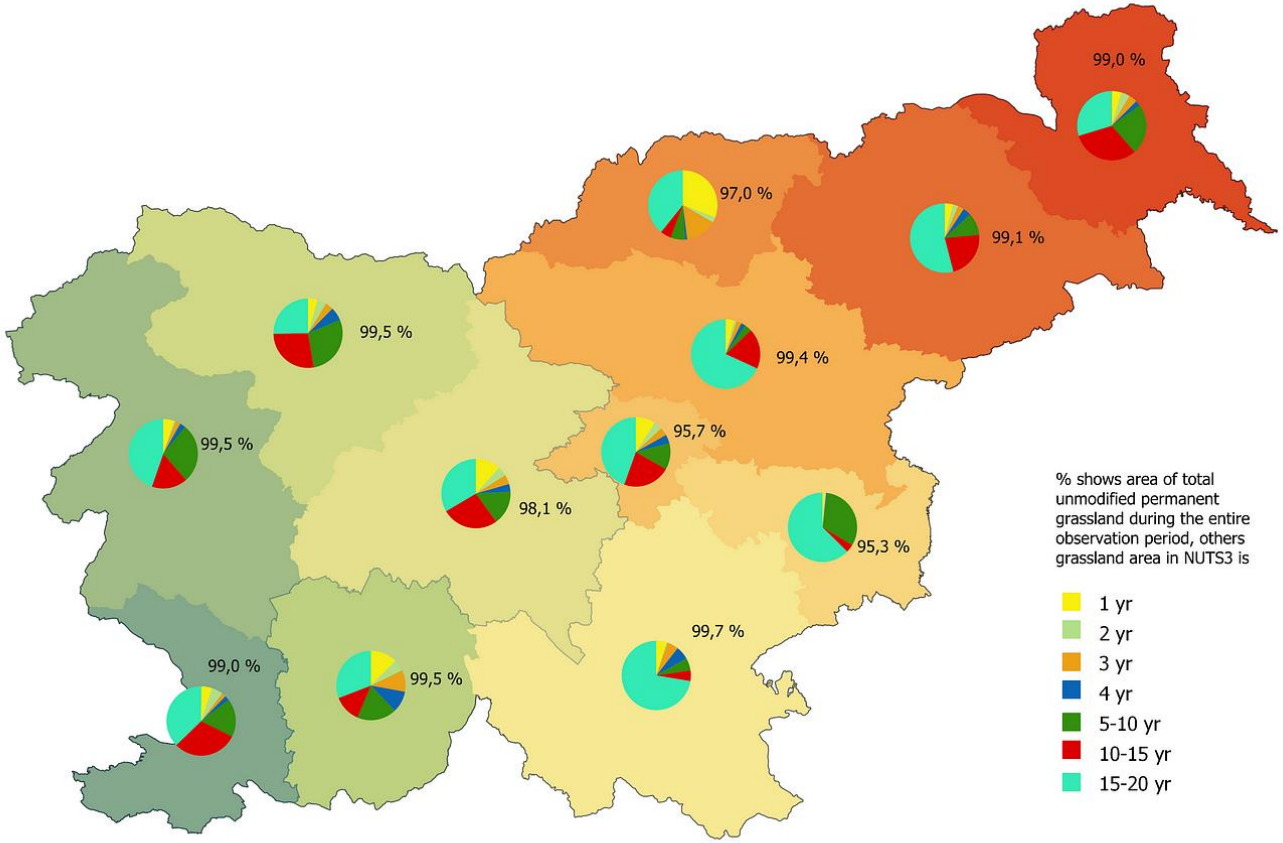




Area of total unmodified permanent grassland during the entire observation period.



Area of changed grassland parcels belonging to a particular age class.



Aggregation of the age of grassland parcels in Slovenia from 2000 per NUTS-3 region level.

Validation

- direct reference data on the age of individual grassland at the national level are not available
- indirect data collected by government agencies
- can only be used as general trend indicators, a direct comparison (per polygon) is not possible

- MKGP land use data
  - In the last 15 years, there are 244 km² less permanent grassland, a loss of almost 7%.
- SiSTAT
  - 1.5 % loss in 20 years.
  - The comparison of the loss trends between the SURS indicator and the aggregated data on the age of grassland shows a match in three regions (SI033 Koroška, SI035 Zasavska and SI041 Osrednjeslovenska), but a mismatch in SI036 Posavska. Other regions are considered stable.

Conclusions

- National-level assessment of grassland permanency is crucial for evaluating the quality of ecosystem conservation.
- Informs national statistics, agricultural policy and environmental protection.
- First large-scale monitoring of grassland longevity in Slovenia.
- The performance of the method to determine the age of grasslands can only be trusted by carefully designing the workflow and testing the BSM algorithm.

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