European Commission

JRC TECHNICAL REPORT

Getting the most of Land Parcel Identification Systems (LPIS) and GeoSpatial Aid Application (GSAA) datasets

Investigating on the benefits for Member States to use and reuse their LPIS/GSAA data

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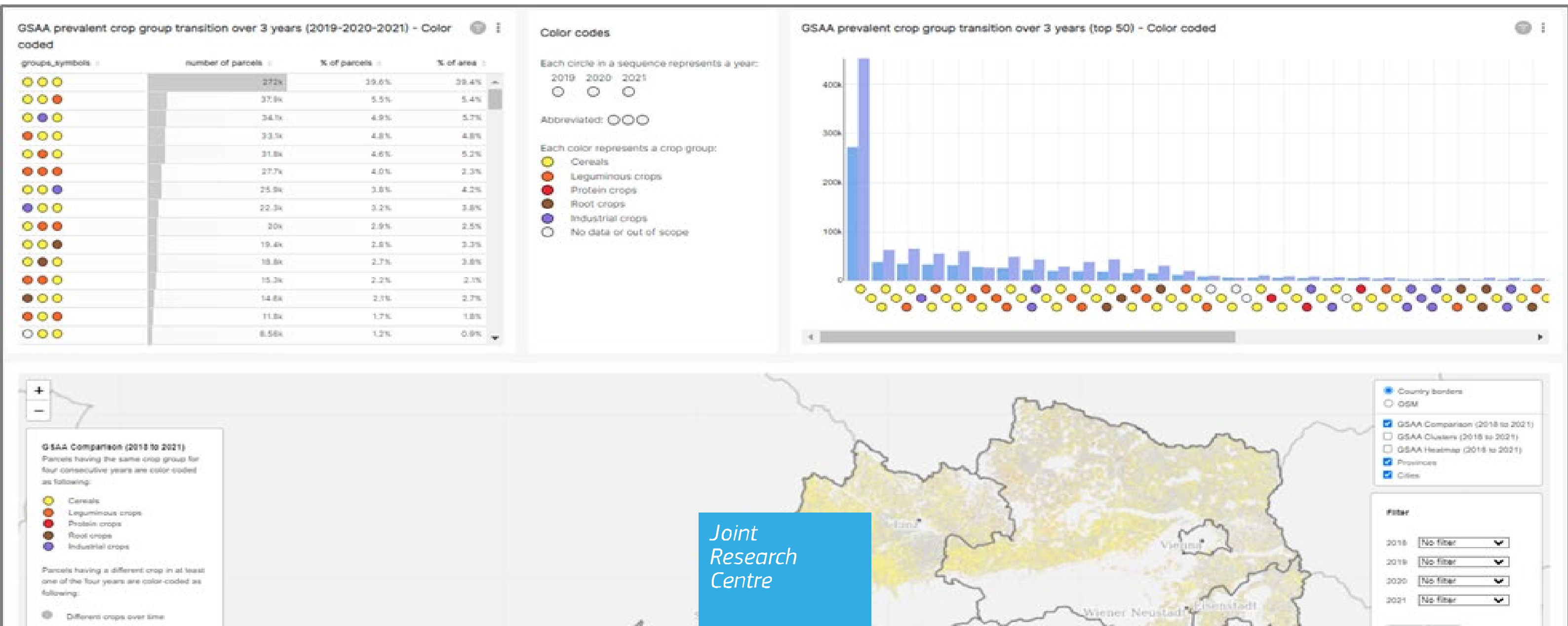

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Abstract

Land Parcel Identification Systems (LPIS) and GeoSpatial Aid Application (GSAA) are two major components of any Integrated Administration and Control System (IACS) as they explicitly record and track land use (LU) and land cover (LC) of agricultural areas.

The authors explored methods to extract agriculture land information from (publicly available) LPIS and GSAA data.

Methods and tools have been established to evaluate the stability over time of the parcels recorded in the GSAA and/or LPIS. Stability criteria include the persistence of parcel physical boundaries, land cover (LC) and/or land use (LU) content, considered over a time period ranging from 3 to 5 years. Additional analyses were done to extract information on crop rotation, land cover and land use patterns.

The priority potential research-applications include:

— Using GSAA parcels stability over time to update the LPIS;

— Refining Reference parcel information on LC and LU;

— Identifying LC / LU zoning/typologies (based on multi-annual patterns).

Within the scope of this exercise, a data exploration and visualization platform was developed. The platform has potential to support several other use cases, such as decision support for monitoring, land administration and zoning, 'early' production of crop statistics, reporting on Output and Results Indicators, comparison between annual and multi-annual Sentinel information and testing with other layers (e.g. LUCAS survey, N2000, NVZ, etc.).

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Executive summary

The CAP Support Group D5 JRC carries out research work as part of its institutional activities and budget to bring innovative solutions and anticipate possible policy implementation needs by Member State administrations.

The results presented here investigate the potential benefits of the use/reuse of data from two key elements of the EU Member States Integrated Administration and Control System (IACS) that explicitly record and track land use (LU) and land cover (LC) of agricultural areas: the Land Parcel Identification Systems (LPIS) and GeoSpatial Aid Application (GSAA).

LPIS is a GIS repository of plots stable over time, the so-called reference parcels. Each plot contains information on the main land cover, geometric area and maximum eligible area eligible for payments under each different EU support scheme in Pillars 1 and 2 of the CAP in the Member States.

GSAA is an aid application form for farmers, provided through a geographic information based computer interface, used to process spatial and alphanumeric data on annually declared areas and main land uses.

Since at least 2018, both of these layers are available in digital form (scale of 1:5,000), enabling, as of now, yearly and multi-annual GIS studies.

The authors created an ad hoc platform to extract information about agricultural land from publicly accessible LPIS and GSAA data. Some preliminary data harmonisation and consolidation works were necessary prior to allow any data exploration and visualization.

A first test-case consisted in evaluating the stability over time of the parcels recorded in the GSAA and/or LPIS. Stability criteria include the persistence, over a period of time from 3 to 5 years, of parcel boundaries, landscape cover and/or land use content. Additional analyses were done to check the ability to retrieve information on crop rotation, land cover and land use patterns.

Then, using the previously generated information, several potential applications are tested or discussed such as the support to LPIS updating, decision support information for land parcel monitoring and/or checking or even the knowledge gain and zoning input to support decision systems as for instance in the frame of CAP National Strategic plans.

A glimpse was also given to the potential for more elaborated applications such as in the domain of land related modelling (e.g. soil carbon sequestration estimation).

Whereas the work was progressing, a diverse and almost endless list of exploratory topics has appeared such as the support to the CAP Output and Result Indicators reporting, or even the analyses of land connectivity and networking. A further step would be to combine these layers with other datasets (e.g. N2000, Nitrate Vulnerable zones, river networks …) and/or also with Sentinel multiyear temporal evolution to improve decision support system on land practices and to gain knowledge on LU/LC.

The authors are definitely looking forward to investigate some of these opportunities in the near future.

Last but not least, the authors are now convinced that, the more the Member States will experience added-values from using/reusing their IACS data first for their own interest, the more reactive they will be towards the mandatory IACS data sharing legislation.

1 Introduction

The European Union's common agricultural policy (CAP) is a long-standing policy that aims at supporting farmers to improve agricultural productivity, to ensure a stable supply of affordable food, maintain landscapes, and to keep the rural economy alive.

Income support for farmers comes from the European agricultural guarantee fund. European Union Member States (MSs) are responsible for the administration and control of payments to farmers in their country. The main building block of the management of payments system is the Integrated Administration and Control System (IACS).

IACS consists of a number of digital, interconnected databases, two of which are of particular interest for the scope of the present study:

- The system for the identification of agricultural parcels (including all land eligible for payment), better known as the Land Parcel Identification System (LPIS) [ref. i, ii];
- The geographical interface allowing farmers to yearly declare and claim financial aid and named GeoSpatial Aid Application (GSAA) [ref. i];

NB: with the entry into force of a new CAP in 2023, a new delivery model is put in place. Nevertheless, an LPIS and a GeoSpatial Application (GSA) will remain part of the integrated system and thus still hold the same potential for studies and applications as illustrated in this report.

The LPIS is a GIS repository of land parcels stable in time, the so-called Reference Parcels (RP). Each parcel contains information on the main land cover, the geometric area and the maximum eligible area eligible for payments under each different EU aid scheme in Pillars 1 and 2 of the CAP in the MS. It serves MSs' administrations to manage and control the farmers' aid applications and farmers to make their aid claim.

The GSAA is an aid application form (and corresponding graphic material) for farmers, provided through a computerised geographical information-based interface, which is used for processing spatial and alphanumerical data on annually declared areas and main land uses.

LPIS is mandatory for Member States in digital format since 2004 at scale 1:10,000 and was updated in 2015 to scale 1:5,000.

GSAA is mandatorily digital since 2018, but some Member States have digital GSAA databases predating 2018.

The LPIS and GSAA are EU Legal mandatory datasets but their development, updating, upgrading are Member States' responsibility together with their ownership. For years access to these data was only possible through direct request to the Member States. Recently, with views of building a European data economy as part of the Digital Single Market strategy, the European Commission calls to publicly share the spatial information residing in the IACS and this, according to the INSPIRE directive. This has been enforced through the art. 67 of Reg. (EU) 2021/2116 [ref. iv];

Based on its experience gained over years, the JRC D5 CAP support group is conducting research works as part of its institutional activities and budget with a view to bring innovative solutions to anticipate possible policy implementation needs and support Member States administrations to set policy implementation methods.

In the current case, the combined use of LPIS and GSAA datasets on land cover and land use over multiple years appeared promising to open opportunities for potential applications inside and beyond IACS, including:

- LPIS support and update;
- GSAA support;
- Decision support for land monitoring;
- Output and Result Indicators reporting (as laid down by the new CAP legislation as part of a new performance, monitoring and evaluation framework [See annex I of Ref. iii];
- Knowledge gain and zoning to support land management (e.g. national strategic plans).

This report gathered results and insights from a preliminary attempt to establish methods for the aforementioned applications. Also, to support this work, a data exploration and visualization platform was developed and deployed internally on the JRC infrastructure.

2 Methodology

The first step in our study was to identify one or multiple viable case studies. By this it was meant to use publicly available LPIS and GSAA datasets for at least three consecutive years and containing a minimum set of workable Land Cover (LC) and Land Use (LU) information. By workable it is intended that datasets consist of at least containing the parcel polygons, the main LC and the main declared LU for each year.

Once has to note that despite the INSPIRE initiative and its plea for data interoperability and harmonisation, the current situation is not yet that far. In some cases, only general information on the declared LU is available, like ‘cereals’. In other data, more detailed information is provided, like ‘barley’, ‘winter wheat’, ‘rye’… So, some data pre-processing are necessary prior to any possible use.

Once suitable datasets have been identified, data have been downloaded, (pre-processed), stored and organised in a PostgreSQL database with PostGIS extension.

The bulk of the work presented in this report was produced using a LPIS/GSAA dataset publicly available on the Austrian INSPIRE geoportal.

Less wide-ranging work has also been carried out for the ‘Bourgogne – Franche Comté’ and ‘Provence Alpes Côte d’Azur) French Regions (but only the equivalent of GSAA is available in the French ‘Géoportail’) and for Slovenia.

Four main sets of analytics have been performed:

- LPIS analytics;
- GSAA analytics;
- LPIS/GSAA relationships;
- Land pattern analytics (including crop rotation, LU/LC zoning).

To note that this initial work gave rise to a proof of concept exercise consisting in combining GSAA data and analytics with ancillary information to estimate soil carbon sequestration attributable to cover crops.

2.1 LPIS analytics

The LPIS case study was sourced from publicly available data, as compiled and distributed by the Member State. It was imported into a PostgreSQL database as three tables recording geometric information of the Reference Parcels (RP) for the years 2019, 2020, and 2021.

For Austria, the tables were enriched with additional information, such as the pertaining province.

The available Austrian public dataset did not include a standard registration of land cover for each RP, therefore this key information was derived from the GSAA layer. In particular, for each LPIS parcel, the area of all intersecting GSAA parcels was calculated and aggregated according to the main types of land cover usually registered in LPIS (i.e. Arable Land (AL), Permanent Grassland (PG), Permanent Crops (PC)). The prevalent land cover, defined as land cover from GSAA with the greatest extent, was then assigned to the corresponding LPIS parcel.

By overlaying LPIS and GSAA, statistics on the number of GSAA parcels per LPIS parcel were calculated for each year.

The detailed information present in the GSAA also allowed to produce statistics on the number of crops present in each LPIS parcel.

These general statistics have been used to further characterise the LC through the spatial distribution and quantification of the main LC types.

2.2 GSAA analytics

As for the LPIS, the publicly available GSAA information was imported into a PostgreSQL database. This time it consisted in five tables, each recording geometric information and land use (derived from farmers’ declaration) for one year. The time interval ranged from 2017 to 2021.

Data pre-processing was performed to supplement the tables with information, such as the land use translation in English, the land cover derived from the declared land use, a crop code converted according to Eurostat nomenclature [ref. vi], a crop category indicated according to Eurostat nomenclature, prevalent crop species, arable land crop group, pertaining province, area and perimeter of the GSAA parcel.

The classification of all crop products according to the Eurostat annual crop statistics handbook (which, in most cases, follows the classification used in the Farm Structure Survey) was added to the GSAA table in an effort to enhance data standardisation and interoperability. An intermediate table was created to automatically assign to each crop (translated to English) the corresponding Eurostat nomenclature (to the highest level of detail possible). Each class is given two attributes, one populated with a standard crop code and the other with its description. As additional information, and when possible, the prevalent crop species were extracted and recorded in an additional field.

General statistics have been produced to characterise this time the LU types, their quantification and spatial distribution.

2.3 Land stability analytics

The land stability analysis resulted in simple logistic workflows to evaluate the temporal stability of the parcels recorded in the LPIS and GSAA. Stability criteria included persistence in time over periods ranging from 3 to 5 years of parcel boundaries, and/or the land cover, and land use recorded information.

Even if the intrinsic condition of LPIS parcels is that they have to be stable in time, they are not necessarily immutable since they have to be updated to reflect LC changes that occurred on the ground. Analysis were performed by overlaying LPIS parcels over three different time windows (2019-2020, 2020-2021, and 2019-2020-2021) and detecting changes that occurred.

The first analysis was done focusing only on parcel physical boundaries. In was then completed with an analysis regarding the evolution of land cover over three years.

An analogous process was performed on GSAA layers. Parcels were overlaid over three different time windows (2019-2020, 2020-2021, 2019-2020-2021) to detect changes in geometries. Information on GSAA boundary changes was then followed by an analysis regarding this time the change in declared crop (Land Use) over three years.

Further in-depth analysis was performed on arable land parcels, with the aim to generate information about crop rotations or successions. For such purpose, the most relevant arable land crops were grouped into main crop classes: i.e. cereals, leguminous, root crops, and industrial crops. Crop rotations or successions, using the aforementioned crop classes, were then generated over a five-year period ranging from 2017 to 2021. Parcels having the same rotational sequence but shifted in time have been gathered in the same Crop rotation group.

Also, out of the 5 years, more in-depth transition analyses can be performed by intersecting GSAA layers from 2 different years (consecutive or not) focusing on:

- Land cover, observing area and location of land cover that remained stable or changed;
- Crop classes, observing area and location of each arable land crop group that remained stable or changed to a different crop category;
- Crops, observing area and location of each crop that remained stable or changed to a different crop.

One of the key applications of such data processes would be the support to LPIS refinement and/or update. The basis assumption is that GSAA parcels identified as highly stable in time could be used to refine or upgrade the LPIS layer and to enrich LPIS attribute tables with additional LC information.

This highly stable GSAA parcels has been defined as "*candidates*" hereafter in the text.

In assessing the match between LPIS and GSAA parcels, three different *identity criteria* were tested:

- A GSAA parcel is exactly identical to a LPIS parcel thus not accounting any technical tolerance (as per ST_Equals PostGIS predicate);

- A GSAA parcel intersects with a LPIS parcel, and respective areas differ by less than perimeter*0.5 (with a ceiling of 1,000 m^2), to account for minimum LPIS dataset margin of error (technical tolerance);
- A GSAA parcel intersects with a LPIS parcel, and respective areas differ by less than perimeter*1.25 (with a ceiling of 1,000 m^2), to account for a maximum LPIS technical tolerance [ref. vii];

The use of a technical tolerance is to account for the intrinsic precision of the digital parcel layers used. 0.5m is a 'rule of the thumb' value estimating the maximum accuracy one can obtain on the ground to locate a field border. 1.25m is the maximum value accepted for the management of geo-referenced data at cartographic scale of 1/5,000.

To identify potential candidates for LPIS update, the following *stability criteria* were examined:

- GSAA parcel boundary is not identical to the corresponding LPIS parcel and has not changed boundary for 3 years;
- GSAA parcel boundary is not identical to the corresponding LPIS parcel, has maintained its boundary unchanged for the last 3 years, and had unchanged land cover for the last 3 years;
- GSAA parcel boundary is not identical to the corresponding LPIS parcel, has maintained its boundary unchanged for the last 3 years, and had unchanged land use for the last 3 years;

The combination of different identity criteria and stability criteria allows defining candidates according to different standards (as might be required depending on several factors, such as data quality, geographical context, farming practices, etc.).

2.4 Data exploration and visualization platform

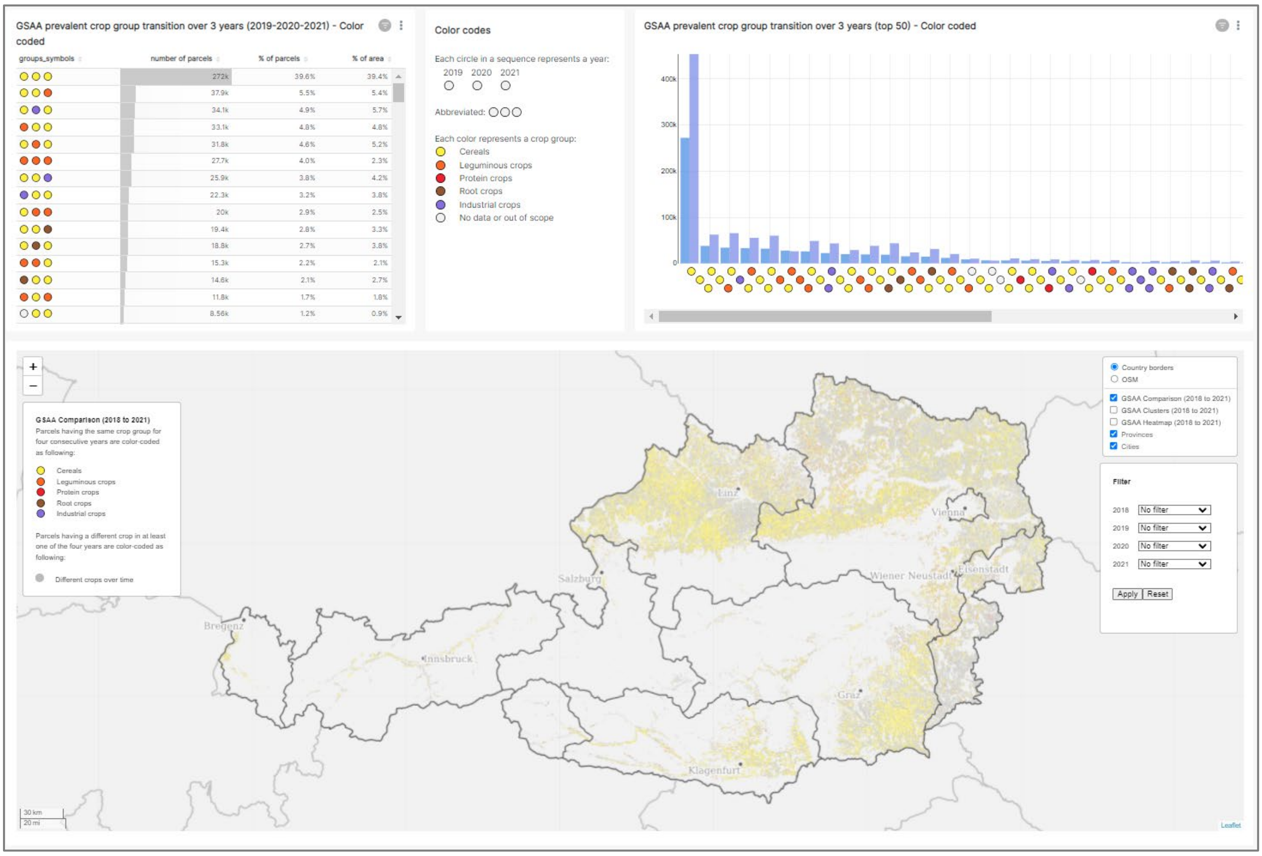
To facilitate the analyses described above, a data exploration and visualization platform was developed and deployed on the JRC infrastructure (Figure 1). The user interface was designed as a dashboard with a clear layout, easy to interact with, and initially divided in six thematic sections.

The dashboard queries in PostgreSQL database, can allow one to present a large set of statistics and analytics through interactive tables, graphs, and custom maps without requiring technical knowledge from users.

The platform comprises the following technical components:

- PostgreSQL database containing all the relevant data;
- Apache Superset software for data exploration and visualization;
- Geoserver software for publishing geospatial data stored on the PostgreSQL/PostGIS database;
- Custom JavaScript code using Leaflet for map visualization;
- Redis for caching data;
- Nginx as reverse proxy.

Figure 1. Screenshot illustrating some possible outputs from the data exploration and visualisation platform



Source: Data exploration and visualisation platform, JRC D5.

3 Results

The results reported hereafter concern five main use cases:

- LPIS analytics;
- GSAA analytics;
- Candidates for LPIS update using GSAA data;
- Crop rotation and zoning;
- Cover crops estimates and soil carbon sequestration.

Each are presented here as results sub-sections.

3.1 LPIS analytics

Most of the LPIS case study work was performed out of the Austrian LPIS dataset made publically available under the INSPIRE directive [ref. v]. It comprised three tables including geometric information (shape files and areas) of the reference parcels (RPs) for the years 2019, 2020, and 2021. The number of RPs, as retrieved from the datasets publicly provided by the MS, were 1,260,787 in 2019, 1,283,369 in 2020, and 1,299,745 in 2021.

3.1.1 Setting of LPIS Land Cover information

Unfortunately, no information of land cover was available in the LPIS RP layers. Thus, for each RP, the LC information was extracted and computed from the land use information available for its part in the GSAA layers. For each RP, the LC type (Permanent Crop, Permanent Grassland, and Arable Land) was attributed according to the dominant LC in term of areas determined for the declared crops in the corresponding GSAA parcel(s).

Once this pre-processing step performed, general statistics on LC have been produced. Thus, over the three years, the number of parcels prevalently covered by permanent grasslands in Austria accounts for some 64%. Arable land parcels account for about 33%, while permanent crops account for some 3.4%. See annual values in Table 1.

Table 1. LPIS prevalent land cover (percentage based on number of parcels).

Year	Arable Land	Permanent Crops	Permanent Grassland
2019	32.71%	3.07%	64.22%
2020	32.77%	3.41%	63.82%
2021	32.85%	3.41%	63.74%

Source: JRC D5 platform.

When considering the area covered instead of the number of parcels, permanent grasslands steadily amount to about 55.5%, arable land to about 42.7% and permanent crops to 1.8%. Annual values are presented in Table 2.

Table 2. LPIS prevalent land cover (percentage based on area).

Year	Arable Land	Permanent Crops	Permanent Grassland
2019	42.76%	1.76%	55.48%
2020	42.65%	1.81%	55.54%
2021	42.72%	1.80%	55.48%

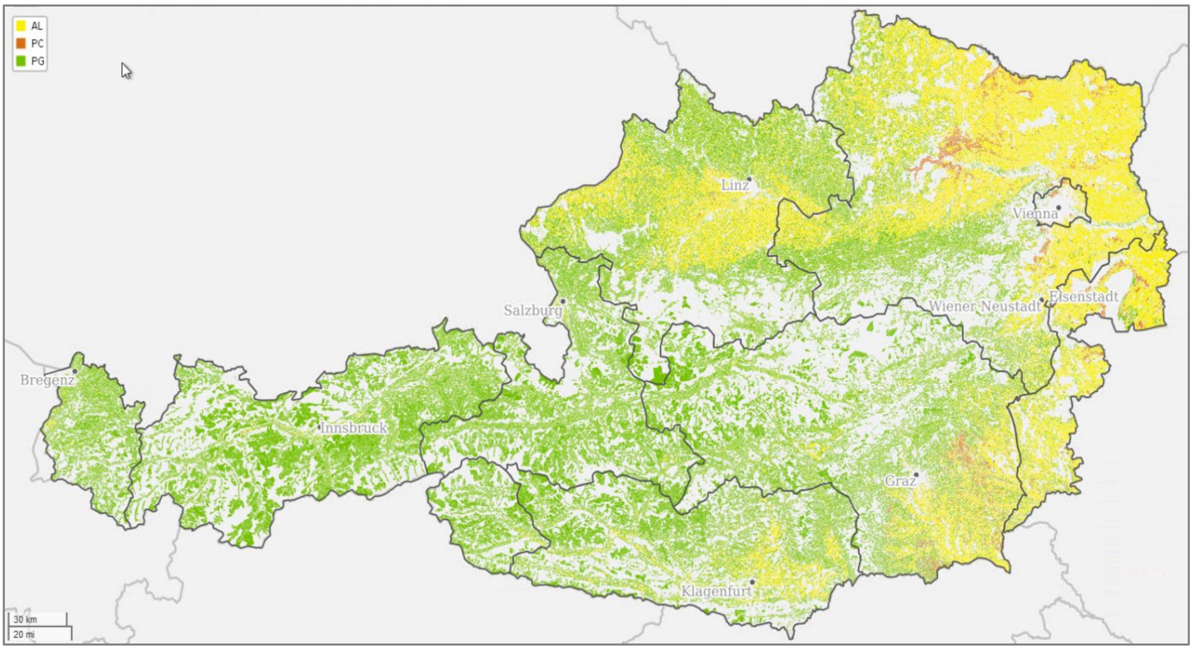
Source: JRC D5 platform.

Possible applications:

Once displayed as a map, one can easily observe that the share of main LCs is, unsurprisingly, not uniformly distributed over the country. Some areas are predominantly covered by permanent grasslands while others are predominantly arable land areas. Others present diverse mixed structure situations. This distribution depends, more or less directly on economical, pedo-agro-environmental and climatic conditions.

Even if very simplistic, this type of mapping can represent a good basic information in view of land management planning and decision support (see Figure 2).

Figure 2. Map of LPIS prevalent land cover distribution in Austria in 2021.



Source: Data exploration and visualisation platform, JRC D5.

3.1.2 LPIS stability analysis

Over time, the reference parcels in the LPIS can be subject to updates or modifications to reflect actual changes occurring on the ground. It may also be subject to upgrade when eligibility rules for payment change. We overlaid LPIS parcels over three different time windows (2019-2020, 2020-2021, 2019-2020-2021) to identify and quantify the changes in geometries that occurred. For the LPIS parcels, no tolerance on RP perimeters was applied. Results are presented in Table 3.

Table 3. LPIS parcel stability (percentage based on total number of parcels).

	2019-2020	**2020-2021**	**2019-2020-2021**
No change in geometry	82.88%	84.93%	69.95%

Source: JRC D5.

Possible application or learning:

Getting information on the Land Parcel system management. At a first glance, when observing changes from a year to another one, it seems that there is a high stability of LPIS parcels at national level (some 15% changes only).

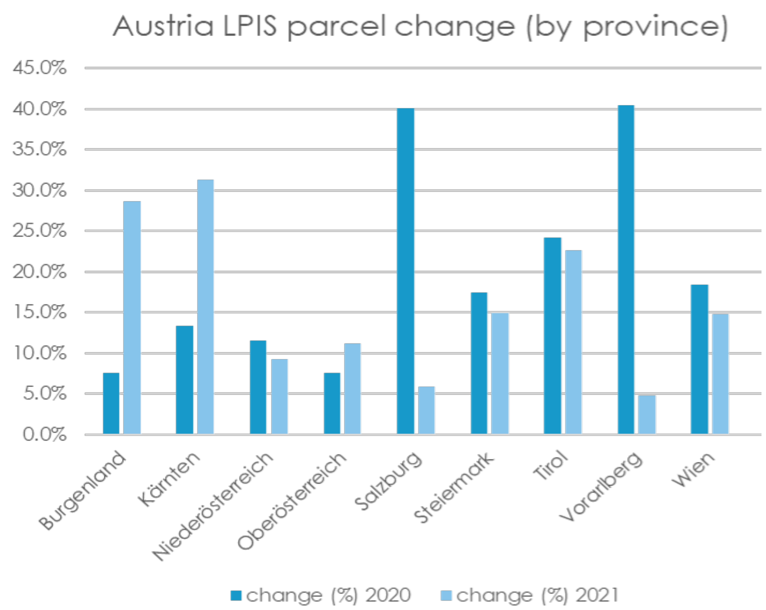
Nevertheless, when results are presented more in details (e.g. by Provinces), figures vary substantially as reported in Figure 3 and Figure 4.

While in some Provinces (Niederösterreich, Oberösterreich), few changes seem to occur (around 10% of total parcels) some others, like Tyrol, show values of twice that level. This would deserve some further investigations since, intuitively, one would expect a lower level of change in areas predominantly covered by permanent grasslands (Tyrol) than in areas covered by arable land (e.g. Oberösterreich).

For other Provinces, a phenomenon of LPIS updating (if not upgrading) is clearly visible, which certainly corresponds to the availability of new ortho imagery as photo interpretation background (e.g. 2020 in Salzburg and Vorarlberg; 2021 in Burgenland and Kärnten).

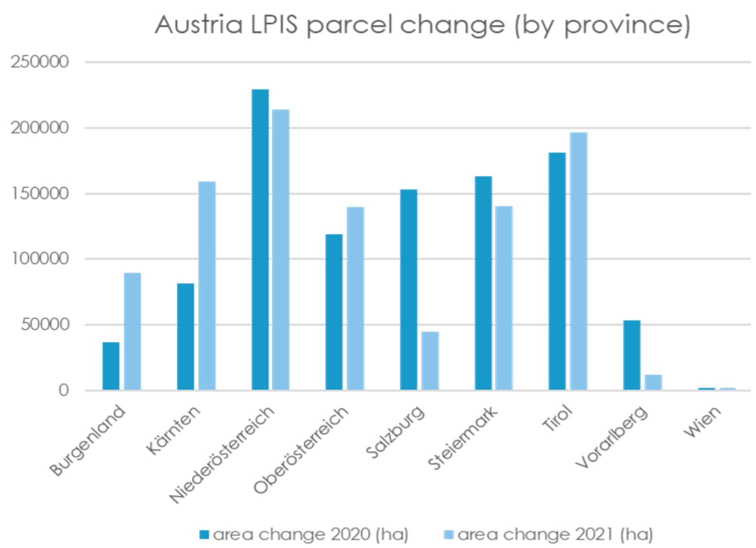
Lastly, in the Wien Province, a rate of 15% change is observed in a large number of parcels but it is very low in term of equivalent surfaces. It may be explained by the extension of urbanisation around the city capital.

Figure 3. Percentage of LPIS parcels changed in geometry, by Province, comparing 2020 to 2021.



Source: Data exploration and visualisation platform, JRC D5.

Figure 4. Surface (in ha) of LPIS parcels changed in geometry, by Province, comparing 2020 to 2021.



Source: Data exploration and visualisation platform, JRC D5.

An analysis was performed to check the stability of the main LC over the LPIS parcels between 2019, 2020 and 2021. The results are presented in Figure 5. As could be expected for a reference parcel system, the great majority of parcels present a stability in their LC. Nevertheless, we can observe that some 4,400 ha of grasslands have been converted to arable land over that period.

To note, that some 20,500 ha (LPIS) remained undeclared during the period and represent areas with high risk of abandonment or possibly also some risk of avoidance of cross-compliance rules. The type of LC has been derived from the LU declared in GSAA since the actual LC information was not available in the source LPIS layer which, undoubtedly, introduces some bias and uncertainty in the estimated numbers. In the table below PC and PG parcels certainly remained unchanged as type of LC but this cannot be confirmed because there is no information declared for one or 2 years.

Figure 5. LPIS prevalent land cover transition (2019-2020-2021).

Source: Data exploration and visualisation platform, JRC D5.

Last, if not already used by the entity managing the LPIS, this type of LC evolution analysis can be of help to identify areas in a Region/country where the LC is very much stable over time and areas where the LC evolve rapidly. Such information can then be used to prioritise zones of VHR aerial acquisitions when full yearly coverages are not possible. Even, if an annual VHR aerial is available, such information can be used to prioritise the work of image orthorectification and then of LPIS update through photo interpretation.

3.2 GSAA analytics

The GSAA case study comprised of five tables including geometric information on farmers' declarations from 2017 to 2021. General statistics were calculated for the years 2019, 2020, and 2021, while crop rotation analysis was extended to the five years (2017-2021). The number of parcels, as recorded in the datasets publicly provided by the MS, were 2529896 in 2019, 2614636 in 2020, and 2610510 in 2021.

3.2.1 GSAA statistics

LC percentages obtained from declared land uses are presented in Table 4 and Table 5. Permanent grassland accounts for over 50%, both in number of parcels and area, and arable land accounts for more than 40%.

Table 4. GSAA land cover (percentage based on number of parcels).

Year	Arable Land	Permanent Crops	Permanent Grassland
2019	43.87%	4.15%	51.98%
2020	42.21%	6.94%	50.85%
2021	42.11%	6.99%	50.9%

Source: JRC D5.

Table 5. GSAA land cover (percentage based on number of area).

Year	Arable Land	Permanent Crops	Permanent Grassland
2019	41.55%	1.84%	56.61%
2020	41.48%	1.95%	56.57%
2021	41.55%	1.95%	56.5%

Source: JRC D5.

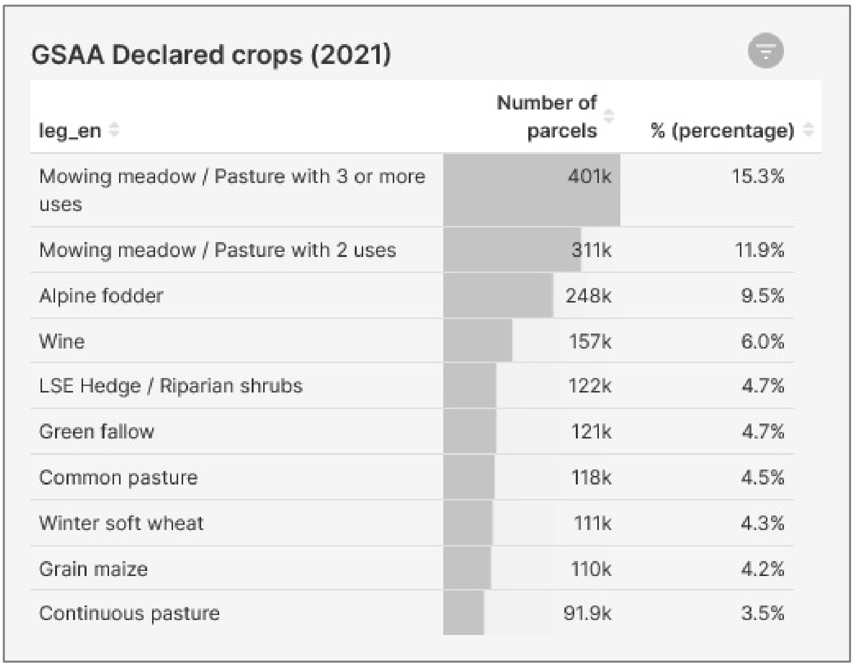
These values are obviously very similar to the one of the LPIS since, by lack of LC data in the LPIS layer, GSAA data were used to derive them. Nevertheless, some slight differences appear because for LPIS parcels, the main LC was retained to do calculation while for the GSAA parcels the actual LC of each parcel was used.

Obviously, considering the LU information provided in the GSAA allows for a deepest characterisation of the main LC. As example, the most declared crops in 2021 are presented in Figure 6 and Figure 7, respectively by number of parcels and area. Thus, one can conclude that most of the permanent grasslands are used as pasture or grassland with two to three mowing events per year or under sporadic grazing. A large share of PG located in Alpine areas is used for fodder production. One also notes that most of the permanent crop areas consist of vineyards.

Possible application:

The above described information is of great importance for instance to improve land monitoring efficacy when using remote sensed data such as the Sentinel stacks. If the only information one gets on a considered parcel is that it is Permanent Grassland, one can only expect to retrieve for instance a ‘green grassy NDVI profile’ all along the year. If it is known that the parcel is used for fodder production and mowed twice a year, one can expect to observe, in the general green grassy profile, a decrease of the NDVI followed by an increase reflecting the two mowing events. This type of scenario reasoning is the basis for and has been widely used in the frame of the Checks-by-Monitoring for the Common Agriculture Policy (CAP).

Figure 6. GSAA declared crops (2021): number of parcels.



GSAA Declared crops (2021)

leg_en	Number of parcels	% (percentage)
Mowing meadow / Pasture with 3 or more uses	401k	15.3%
Mowing meadow / Pasture with 2 uses	311k	11.9%
Alpine fodder	248k	9.5%
Wine	157k	6.0%
LSE Hedge / Riparian shrubs	122k	4.7%
Green fallow	121k	4.7%
Common pasture	118k	4.5%
Winter soft wheat	111k	4.3%
Grain maize	110k	4.2%
Continuous pasture	91.9k	3.5%

Source: Data exploration and visualisation platform, JRC D5.

Figure 7. GSAA declared crops (2021): area.

GSAA Declared crops area (2021)

leg_en	Area (ha)	% (percentage)
Alpine fodder	915k	28.7%
Mowing meadow / Pasture with 3 or more uses	494k	15.5%
Winter soft wheat	233k	7.3%
Mowing meadow / Pasture with 2 uses	210k	6.6%
Grain maize	194k	6.1%
Winter barley	90.7k	2.8%
Silage maize	84.3k	2.6%
Continuous pasture	78.5k	2.5%
Soybean	75.8k	2.4%
Common pasture	61.5k	1.9%

Source: Data exploration and visualisation platform, JRC D5.

The platform dashboard allows to produce a wide range of statistics and spatial distribution analyses of land use. It also allows to operate some automatic groupings to produce, for instance, main crop groups (see Figure 8) to serve as basis for crop rotation analyses.

Figure 8. GSAA arable land crop groups (2021).

GSAA arable land crop groups (2021)

groups	Number of parcels	Area (ha)	% of parcels	% of area
cereals	483k	833k	43.9%	62.9%
	411k	173k	37.4%	13.1%
leguminous	123k	175k	11.2%	13.2%
industrial crops	45.9k	81.9k	4.2%	6.2%
root crops	36.2k	60.7k	3.3%	4.6%

Source: Data exploration and visualisation platform, JRC D5.

<u>Possible application:</u>

Deriving statistics on the declared land use can be of help for deciding on which type of crops it would be cost-effective to invest efforts in developing automatic methods to detect or monitor them.

In the Figure 9 below, one can identify the crops that are significantly represented in term of total coverage in the country. For these crops one can expect to have sufficient data to possibly train models. Considering their importance, it is of interest to investigate on how to characterise them in automatic manner.

Figure 9. Land use types classifies as major are extent in 2021

LC/LU type	% of total area
Mowing meadow / Pasture with 3 or more cuts	15.3
Mowing meadow / Pasture with 2 cuts	11.9
Alpine fodder	9.5
Vineyards	6
EFA Hedge / Riparian shrubs	4.7
Green fallow	4.7
Common pasture	4.5
Winter soft wheat	4.3
Grain maize	4.2
Pasture	3.5
Meadow	2.1
Silage maize	2.1
Exchange meadow (field/grassland/arable pastur	2.1
Winter barley	1.9
Clover grassland	1.7
EFA Embankment / Dry stone wall	1.6
EFA Field shrubs / Tree / Bord Group	1.5
Soybean	1.4
Winter tritical	1.3
Winter rye	0.9
Oil pumpkin	0.9
Grassland fallow	0.9
Summer barley	0.9
Summer oats	0.8
Miscellaneous fields for food production	0.8
Other grassland areas	0.6
Clover	0.6
Potatoes	0.5
	91.2

Source: Data exploration and visualisation platform, JRC D5.

Oppositely to Figure 9, in Figure 10 below, one can identify the crops that have a very minor presence in the country. For these crops, in case someone would decide to check their presence or monitor them, developing automatic methods may not worth the effort and time. It will be more productive to use an alternative observation method (e.g. getting a geotagged image of these fields) or even to perform a field visit/check.

Figure 10. Land use types with minor presence in 2021

LU/LC	number of delclared parcels
Hemp	1319
Pear	1220
Seed potatoes	1207
Strawberries	1120
Summer tritical	1073
Mustard	1067
Elderberry	1013
Lentils	896
Linseed	821
Chickling vetch	817
Marian thistle	794
Plums	756
Chia	51
Millet	32
Nectarine	30
Winter turnip	29
Aromatic plants	29
Quinoa	27
Afforestation	24
Strawberries	23
Cuminum	20
Beans	15
Bitter lupines	14

Source: Data exploration and visualisation platform, JRC D5.

Also, and obviously, these sets of GSAA declarations hold a great potential for crop modelling. Many studies and applications relying on crop information are based on crop area estimates through sampling methods which intrinsically hold a level of inaccuracy if not bias. GSAA provides a spatial exhaustive description on LU in a considered year and at parcel level. Having access to GSAA information as early as possible in a crop season is promising for a better accuracy of models like for instance crop yield/production forecasting.

3.3 GSAA stability analysis (candidates for LPIS parcels)

For this part, methods were established to evaluate the stability over time of the parcels recorded in the GSAA. The geometric stability of GSAA parcels was evaluated over three time windows (2019-2020, 2020-2021, 2019-2020-2021). To determine the stability of GSAA geometry, a tolerance of 1.25m around the parcel perimeter was applied to account for small differences which can be attributed to the GSAA system technical accuracy and not to an actual change of shape form one year to another one. Results are presented in Table 6.

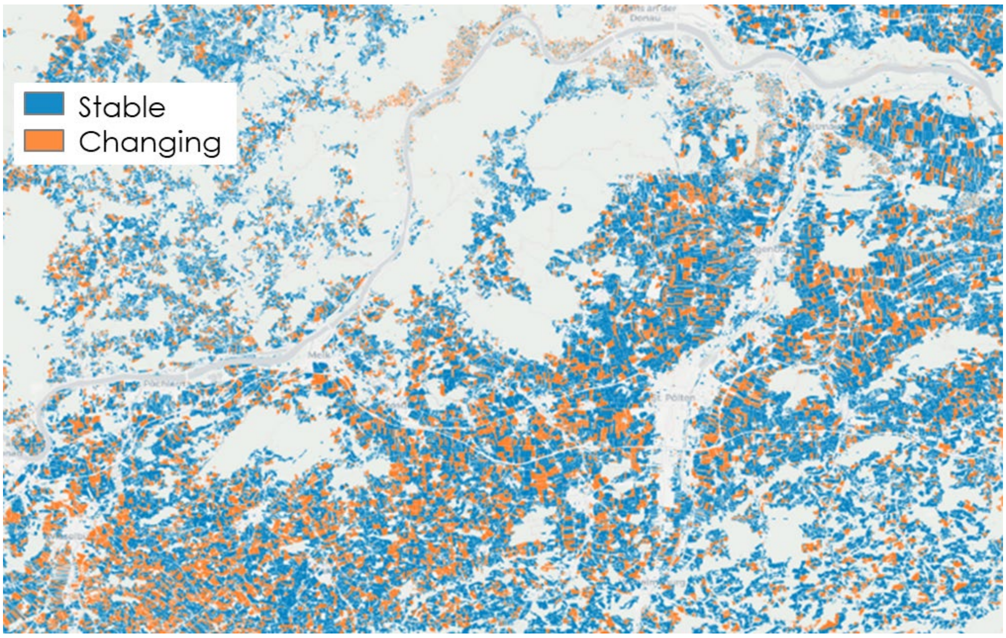
Table 6. GSAA geometric parcel stability: percentage of parcels with unchanged boundaries.

Years compared	Percentage of stable parcels
2019-2020	79.02%
2020-2021	83.07%
2019-2020-2021	67.69%

Source: JRC D5.

Thus over the 3 years period (2019-2021) some 68% of GSAA parcels remained physically stable whatever their land use. Such parcels are visible in blue on the map extract in Figure 11.

Figure 11. GSAA geometric parcel stability (2019-2021) map.



Source: Data exploration and visualisation platform, JRC D5.

As from hypothesis, GSAA parcels identified with geometry unchanged over at least 3 years may be considered as stable in time and proposed as candidates to constitute RPs for the LPIS.

So for the next step, statistics were produced by comparing information in the GSAA layer with the LPIS layer. When comparing only the geometry of parcels' physical boundaries, about 41% of LPIS parcels (with slight variations depending on the year) are corresponding to a single GSAA parcel. In other words; these agricultural parcels are stable in time and are already 'fixed' as reference parcels.

More than 50% of LPIS parcels contain two and up to more than 10 GSAA parcels.

As for examples, detailed data are presented for years 2019 and 2021 in Figure 12 and Figure 13.

Figure 12. Number of GSAA parcels per LPIS parcel, 2019.

Number of GSAA parcels per LPIS parcel (2019)

gsaa_count	Number of parcels	% (percentage)
1	510k	40.5%
2	278k	22.0%
3	139k	11.0%
0	103k	8.2%
4	69.2k	5.5%
5	39.1k	3.1%
6	25.2k	2.0%
7	17.5k	1.4%
8	13.3k	1.1%
9	9.94k	0.8%
10	8.04k	0.6%

Source: Data exploration and visualisation platform, JRC D5.

Figure 13. Number of GSAA parcels per LPIS parcel, 2021.

Number of GSAA parcels per LPIS parcel (2021)

gsaa_count	Number of parcels	% (percentage)
1	530k	40.8%
2	285k	21.9%
3	141k	10.8%
0	112k	8.6%
4	69.3k	5.3%
5	39k	3.0%
6	25k	1.9%
7	17.4k	1.3%
8	13.1k	1.0%
9	10.1k	0.8%
10	8.08k	0.6%

Source: Data exploration and visualisation platform, JRC D5.

One should note that 8.2% (2019, 2020) to 8.6% (2021) of LPIS parcels do not overlap with any GSAA parcel. As already mentioned, this means that, while these areas are potentially eligible for payment and registered in the LPIS, they have not been declared and claimed for payment in the last years. This information is of great interest since the absence of a claim can be correlated to a risk of land abandonment or not declared area possibly subject to cross compliance obligations. Such situations deserve specific attention.

Back to the 'candidates parcels', when overlaying the layer of 'stable GSAA parcels' with the corresponding LPIS layer, one can identify RPs that could be candidate for refinement and subdivision. Some examples are illustrated in Figure 14 *below.*

Figure 14. Geometrically stable GSAA parcels (yellow borders) superimposed on the LPIS parcel layer (black borders), with the proposed LPIS updates at the bottom of the figure.

Source: Data exploration and visualisation platform, JRC D5.

One can also consider creating a Reference Parcels layer directly out of the GSAA layers history as illustrated in Figure 15 *below. Three consecutive years on GSAA have been superimposed (2018 in Red, 2019 in green and 2020 in blue) as displayed on the left part of the figure. These are extracts from open data accessible from the French Web Géoportail. All GSAA remaining stable over the three years have been selected as candidate reference parcels and are displayed in the right part. Many parcels consist of individual GSAA parcels that remained stable in time. Others are composed with the stable envelop of some contiguous parcels from which inner borders varied from a year to another; the latter would often correspond to the so-called farmer blocks (see examples highlighted by an arrow).*

Figure 15. Identification of candidates for a Reference Parcel layer (right) out of the overlay of three consecutive years of GSAA (left) (2018 in Red, 2019 in green and 2020 in blue). Limits non-permanent over three years are dissolved to keep stable limits as candidate RP.

Source: Data exploration and visualisation platform, JRC D5.

Coming back to the Austrian case, further analyses were done to check the persistence over time, not only of the physical borders of parcels but also of their land use over 2019, 2020, and 2021. Results are presented in Figure 16.

While the total percentage of parcels with unchanged borders was 68.1%, the percentage of parcels with both borders and land use is of 48.9%. When observing values in Figure 16, this percentage is not really surprising since it corresponds to land uses attached to permanent grasslands and permanent crops which are highly represented in Austria. One can note that some 20% of parcels (mainly arable land ones) remain physically stable in time even if their LU changes regularly.

<u>Possible application:</u>

Getting information on Land Uses remaining stable in time can be of interest to further describe the main Land Cover information stored in the LPIS attribute table. As already discussed, knowing that a parcel is not only covered by a permanent grassland but always used as fodder grassland usually mowed twice a year is additional information that will allow to improve the monitoring scenarios or modelling parameters of studies exploiting these data. Similarly, having the additional information in the LPIS that a parcel is not only covered by a Permanent Crop but that this PC is actually a vineyard or an apple tree orchard can be very useful. For the purpose of current year land modelling (like for the Checks by Monitoring (CbM) or Area Monitoring System (AMS) for the CAP), it is important to have knowledge on parcel Land Use as early as possible in the cultivation season. However, information declared in the GSAA may take some time to be collected and made available. By contrast, the information stored in the LPIS will be available at any time.

Figure 16. GSAA: stability of parcels and declared crops over 2019-2020-2021 (truncated).

GSAA stability of declared crops (over 3 years) summary table

leg_en	Stable Parcels	Total Parcels (2021)	Stable Parcels (%)	Stable Area (ha)	Total Area (ha, 2021)	Stable Area (%)
Mowing meadow / Pasture with 3 or more uses	291210	400676	72.7%	314822	494377	63.7%
Mowing meadow / Pasture with 2 uses	227414	310711	73.2%	135186	209526	64.5%
Alpine fodder	141702	247736	57.2%	412745	915168	45.1%
LSE Hedge / Riparian shrubs	106307	121786	87.3%	3846	4476	85.9%
Green fallow	82861	121428	68.2%	33731	49659	67.9%
Common pasture	81190	117705	69.0%	39347	61457	64.0%
Continuous pasture	62028	91947	67.5%	49390	78461	62.9%
Wine	44469	157342	28.3%	15241	45017	33.9%
Meadow	40912	55047	74.3%	16713	23866	70.0%
LSE Edge / Embankment / Dry stone wall	36973	42144	87.7%	1204	1391	86.6%
LSE Field shrubs / Tree / Bord Group	33827	38364	88.2%	1246	1419	87.8%
Exchange meadow (field/grassland/arable pasture)	19239	53711	35.8%	16585	50596	32.8%
Grassland fallow	13545	22501	60.2%	3182	5824	54.6%
Miscellaneous fields for food production	11003	20631	53.3%	5282	11640	45.4%
Clover grassland	9908	45188	21.9%	9221	47914	19.2%
Stray meadow	8440	9812	86.0%	3296	3956	83.3%
Grain maize	6268	110175	5.7%	7219	194253	3.7%
Clover	5565	16024	34.7%	2970	13636	21.8%
Mountain mowing meadows	4856	6682	72.7%	3124	4621	67.6%
GAEC - pond	4062	4545	89.4%	153	171	89.5%
GAEC - ditch / water strip	3977	4785	83.1%	163	209	78.0%
Table apple	3938	5253	75.0%	4815	6583	73.1%
Silage maize	3522	54482	6.5%	3756	84295	4.5%
Other grassland areas	3089	16166	19.1%	162	1340	12.1%
Alfalfa	2650	11394	23.3%	2787	16091	17.3%
Forage grasses	2449	6752	36.3%	2085	7047	29.6%
Wood - Energy production (without Robinia)	1702	2128	80.0%	801	1013	79.1%

Source: Data exploration and visualisation platform, JRC D5.

3.4 Crop rotation analysis

The case study relies on open GSAA datasets available for Austria between 2017 and 2021 and for a region in France (Bourgogne Franche Comté) from 2016 to 2020. It aims to test the potential for crop rotation cycles identification and analysis.

The platform allows intersecting GSAA parcel geometries and tracking the transition of every land use over time. Queries can be done at land use level, aggregated in main crop group categories (i.e. cereals, protein crops, oleaginous …) or aggregated in main land cover types (AL, PG, PC).

The data exploration platform has a specific section with interactive transition matrices which can be filtered to answer specific questions or investigate particular cases.

Some basic use cases are illustrated hereafter.

3.4.1 Year to year land use analysis

The first basic analytic that can be produced through the platform is a transition matrix that compares land use declaration from one year to another. An illustration is provided in Figure 17 for the main (in term of % of total declared parcels) land use transitions between 2019 and 2020 for the Bourgogne Region in France.

Figure 17. Transition of land use, expressed in % of total parcels declared, from year 2019 to 2020 in Bourgogne Franche Comté Region (France). Only the main declared crops are displayed.

Transition (2019 - 2020)	common wheat	corn and grain silage	barley	other cereals	rapeseed	sunflower	other oilseeds	protein crops	fiber crops	frost	rice	pulses	fodder
common wheat	10.5%	20.3%	25.1%	4.1%	10.2%	7.1%	1.5%	2.9%	2.4%	0.5%	0.0%	0.4%	2.1%
corn and grain silage	36.3%	41.5%	4.8%	5.0%	0.1%	2.8%	1.8%	0.7%	0.1%	0.4%	0.0%	0.1%	1.3%
barley	5.7%	14.2%	13.7%	4.7%	28.2%	8.6%	1.3%	5.0%	1.2%	0.6%	0.0%	0.7%	4.8%
other cereals	11.6%	16.0%	8.6%	20.1%	4.2%	9.7%	1.8%	2.6%	0.2%	1.4%	0.2%	1.1%	7.3%
rapeseed	85.5%	3.5%	3.2%	3.7%	0.2%	1.2%	0.3%	0.4%	0.2%	0.2%	0.0%	0.0%	0.5%
sunflower	58.2%	8.1%	5.8%	15.8%	0.1%	3.3%	1.4%	1.1%	0.0%	1.6%	0.1%	0.4%	2.5%
other oilseeds	42.9%	15.9%	3.6%	7.7%	0.2%	5.7%	15.9%	2.0%	0.2%	0.9%	0.0%	1.1%	1.8%
protein crops	60.7%	5.0%	4.5%	8.7%	2.7%	3.4%	1.7%	4.1%	0.2%	0.8%	0.0%	0.7%	3.8%
fiber crops	79.3%	2.8%	2.3%	0.9%	0.3%	0.3%	0.2%	0.5%	4.1%	0.1%	0.0%	0.2%	0.4%
frost (no production)	1.8%	1.4%	1.1%	1.6%	0.1%	1.1%	0.2%	0.2%	0.0%	85.3%	0.0%	0.1%	1.4%
rice	2.0%	0.0%	3.6%	3.6%	0.6%	2.1%	0.0%	0.1%	0.0%	2.5%	72.3%	0.1%	5.7%
pulses	53.5%	2.2%	4.8%	18.8%	1.0%	5.4%	3.2%	1.8%	0.1%	1.0%	0.2%	1.9%	2.4%
fodder	10.8%	5.2%	2.2%	4.1%	0.2%	0.8%	0.3%	0.6%	0.1%	0.4%	0.1%	0.2%	65.7%

Source: Data exploration and visualisation platform, JRC D5.

Possible application:

Even if data provided in Figure 17 are for a limited set on a limited time lap, one can already extract rather useful information on the land use and crop succession (rotation) in that Region. One can observe that wheat is the predominant crop however only 10% of parcels were also planted with wheat in 2020. It means that wheat is predominantly part of a crop rotation system which include, without having details on the successions, crops like corn, rapeseed, sunflower, oilseeds, and pulses.

In a similar way, one can observe a different situation for parcels sown with corn. More than 40% of the parcels remained dedicated to corn production for the consecutive year. For the other parcels, corn is part of a rotation system that includes less variability than what is observed for wheat i.e. wheat, other cereals and oilseeds.

Last but not least, some parcels and crops are, not surprisingly, less subject to rotation either due to the specificity of the land (rice) or the specificity of the crop (perennial fodder crops).

While providing useful hints on possible land use and crop rotation systems, there is added value to gain from deeper analyses and from building more complex matrices over several years.

Analytics can be performed grouping the land use categories in main LC classes in order to study more consistent changes in land. An illustration is provided in Figure 18 through an extract of the Open database this time in the south of France (Region Provence). One can observe that some 4% of permanent grasslands parcels were converted to arable land. Oppositely, it seems that some 4% of arable land parcels were converted to new grasslands. Maps of these changes can be produced through the platform and allow for further analysis for what concerns their location and distribution (bottom of Figure 18).

Figure 18. Transition of land cover, expressed in % of total parcels declared, from year 2019 to 2020 in an extract of south of France.

Transition (2019 - 2020)	AL	PC	PG
AL	**95.8%**	0.1%	**3.9%**
PC	1.0%	**98.1%**	0.1%
PG	**4.0%**	0.0%	**95.9%**

Source: Data exploration and visualisation platform, JRC D5.

3.4.2 Arable land crop group rotation over 5 years

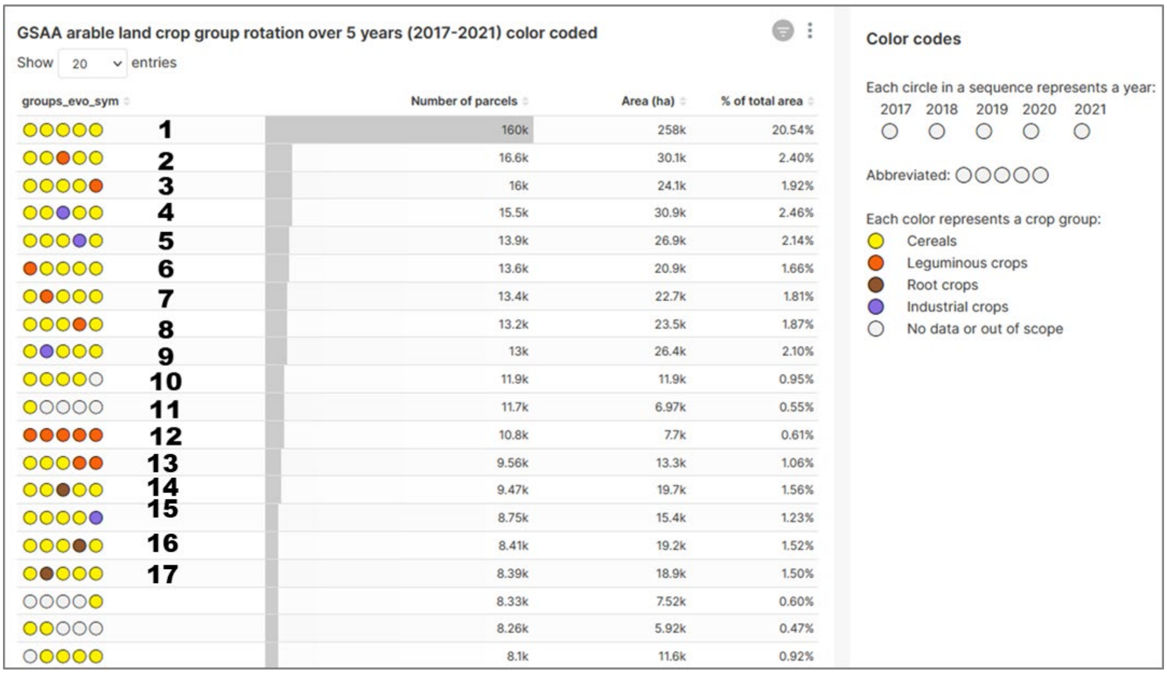
In the open access data available for Austria, land use declarations were available over 5 consecutive years (2017 to 2021). That gave the possibility to analyse crop rotation sequences over the whole country. In order to simplify the processing, declared land uses were aggregated in crop groups constituting the basis of well-designed crop rotations. To be beneficial for the soil and the environment, to interrupt pest and disease cycles, crops on a parcel should alternate between cereals, leguminous, root crops, industrial crops; an alternation within a single crop group, e.g. wheat and barley, will likely offer less benefits.

The chronological sequence of crop groups for each parcel can be tracked using a colour coded system to improve the readability of the results, as shown in Figure 19.

Possible application:

From these analytics one can already depict the main characteristics of crop rotation (or succession) practices in the considered area. In this case, one can observe that farming practices mainly consist of succession of cereals over the years. To a much lesser extent, one can also identify a 5 years rotation pattern with one year leguminous and 4 years cereals. (lines 2, 3, 6, 7 and 8 on Figure 19) and a system of 1 year industrial crop and 4 years cereals (lines 4, 5, 9, and 15 on Figure 19) and finally a system of 1 year root crop and 4 years cereals (lines 14, 16, and 17 on Figure 19). These findings suggest that rotation systems seem almost exclusively based on a 5 year cycle and not on a 3 to 4 year cycle as, elsewhere, is considered the norm.

Figure 19. Counting of arable Land parcels under the same main crop group rotation cycle over 5 years (2017-2021) in Austria



Source: Data exploration and visualisation platform, JRC D5.

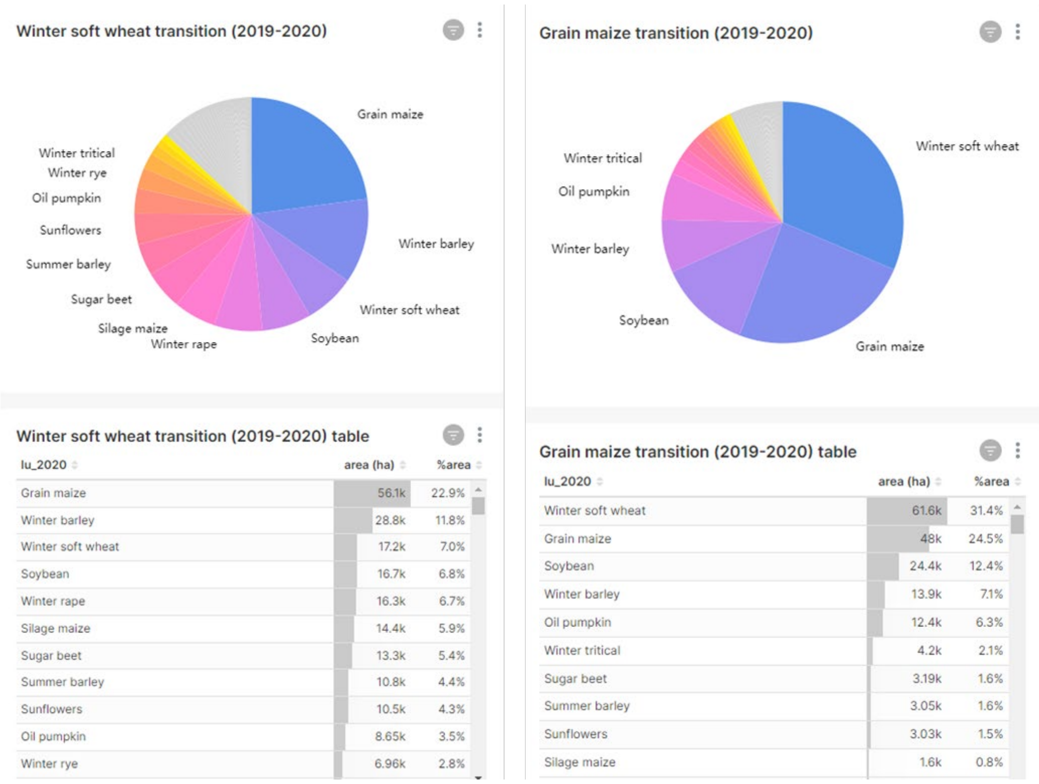
Some further detailed analysis was performed to understand whether the main practice consists only of mono-cropping e.g. wheat after wheat or if there is a rotation system among different cereals crops e.g. wheat-corn-barley. From Figure 20 below, one can conclude that it is mainly the second system that is in place. In fact, only 7% of areas sown with soft wheat in 2019, remained covered by soft wheat in 2020. Other areas were sown mainly with maize and barley. For grain maize, a third of areas remained sown with grain maize. On other areas maize was replaced mainly by soft wheat, soybean and winter barley.

These results are very succinct and deserve deeper analyses, but they allow to demonstrate the potential, for administrations for instance, to understand and possibly act on crop rotation systems and farming practices.

Taking advantage of this example, one can note that, in many datasets available, only the information on the main crop declared is provided. There is no information about a secondary crop (if cultivated). It is unfortunate, since the presence of secondary crop can be of great importance to inform on elements like protection of soil erosion, soil carbon, biodiversity among others. One can rely on Sentinel temporal data to check the presence and identify these secondary crops (e.g. cover crops, catch crops, green manure ...). See also paragraph 3.5.

Another potential application is to use these crop rotations/crop successions information to feed models to predict the implanting crop on a given parcel for the year to come well before having access to the corresponding farmers' declarations through the GSAA. This would allow to anticipate scenarios and define markers since the beginning of a parcel monitoring campaign using Sentinel data or equivalent. This could also be of great use to anticipate, on a given year, the statistics and distribution of crops used as input for crop yield and crop production models. Even today, statistics on crops and areas for the current year campaign are obtained through sampling methods and available, often partially, only from March/April and on.

Figure 20. Transition of areas planted with Soft wheat (left) and Grain maize (right) in 2019 to areas planted in 2020.



Source: Data exploration and visualisation platform, JRC D5.

3.4.3 Crop rotation system zoning

The platform also offers the possibility to perform on-the-fly density-based clustering analyses and generate heat maps. Queries and filters can be used to refine the data that will be used to generate and display the clusters.

Thus, information on crop rotation/succession (as discussed in the previous paragraph) were analysed. As examples, on Figure 21, a 'heat map' of parcels characterised by a cereal only succession system is presented; Figure 22 presents the 'heat map' of GSAA parcels conducted with a rotation system with one year of leguminous crop and 4 years of cereal crops.

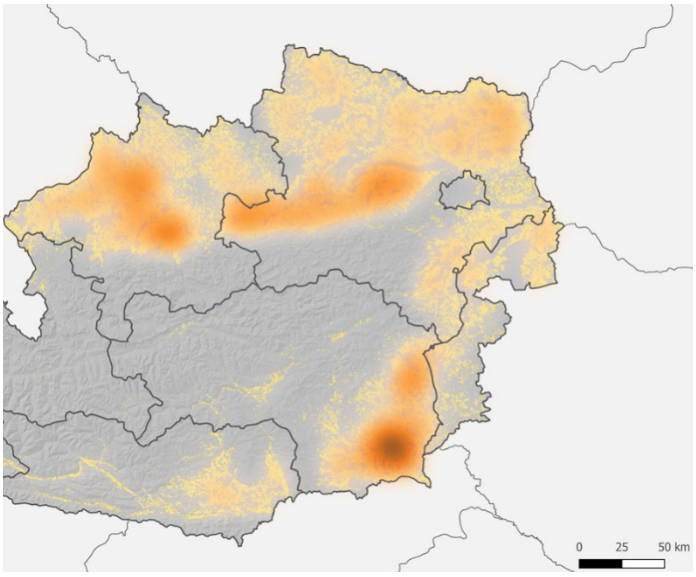
<u>Possible application:</u>

In addition to the point made in the previous paragraph, displaying the information as a density map can be very helpful for land management administrations. This type of information could be of useful in the frame of the CAP strategic plans, to identify areas in the Member State where to prioritise actions that target a change of farming practices, like incentivising diversified crop group rotations (e.g. on intensely coloured areas in Figure 21).

In parallel, as illustrated in Figure 22, one can identify areas where some crop rotation systems are in place and thus aligned with what is considered a good farming practice (e.g. intense areas in Figure 22 with high dominance of a rotation system based on one year of leguminous crops and 4 years of cereal crops).

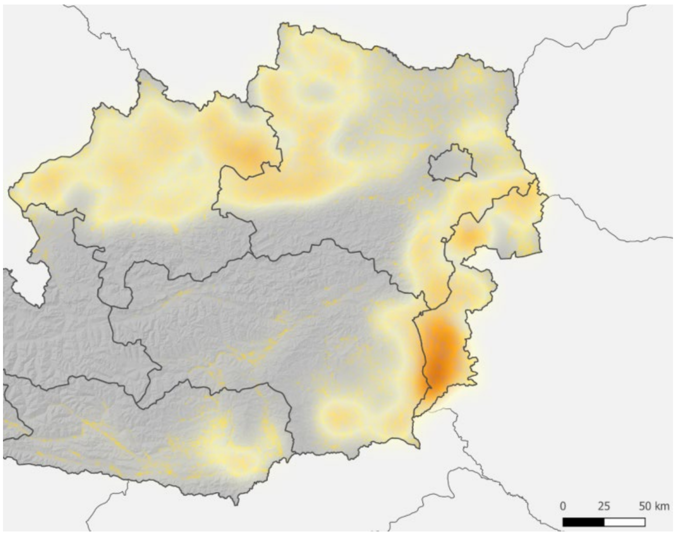
One possible observation relevant to Strategic Plans, is that, in order to identify agricultural zones, some Member States have made use of different data sources, such as climatic zones, soil maps, and even land cover maps. From the intersections of these maps, potential homogenous agriculture zones are derived. By exploiting the multi-annual information declared in GSAA and using clustering functions, one may expect to identify and delineate homogeneous types of farming systems, which do not represent a potential but rather the reality on the ground. This would then help to improve the accuracy and reliability of decisions to be taken for the strategic plans.

Figure 21. Heat map of only cereals succession on GSAA parcels over 5 years (2017-2021). The more intense the orange colour, the higher is the presence of parcels conducted with cereals succession.



Source: Data exploration and visualisation platform, JRC D5.

Figure 22. Heat map of GSAA parcels conducted with a rotation system of one year of leguminous crop and 4 years of cereal crops (2017-2021). The more intense the orange colour, the higher is the presence of parcels conducted with that rotation system.



3.5 Cover crops and soil carbon sequestration

The first results of this LPIS/GSAA analysis provided the opportunity for a proof of concept exercise aiming at estimating the current and potential contribution of cover crops in soil carbon sequestration.

Only a short summary of the method is given in this report since a specific paper will be issued by the author of the study and thus available for more details.

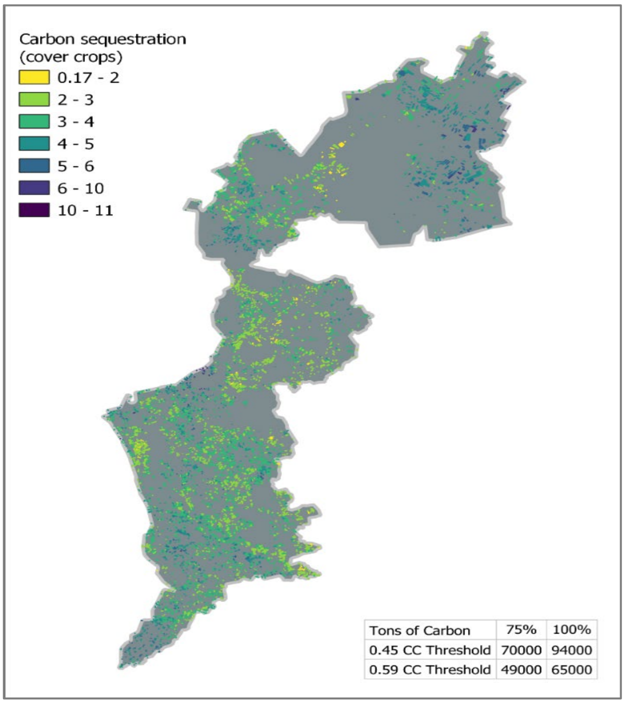
Cover crops detection was performed using the methods proposed by Nowac *et al.* [ref viii]. This preliminary study has focused on the year of cultivation 2020 for the Province of Burgenland, Austria. Since the use of cover crops is not declared by farmers within their GSAA, their occurrence has to be estimated. For this estimation, only parcels not declared with the cultivation of a winter crop are selected. The assumption is that, if the presence of a crop is detected on a parcel during the autumn-winter period, this signal is highly probably due to the presence of a cover crop since no winter crop has been sown. The detection of a crop occurring on these parcels has been done using Sentinel-2 multispectral images at 10 m spatial resolution over two months (December and January). The spatial average NDVI of each selected parcels was calculated for each non-cloudy or snowy satellite acquisition date that was available over the study period. $NDVI_{Max}$ was then defined as the maximum NDVI value among the average NDVI values calculated for each parcel for the December–January period. The parcel was considered covered if $NDVI_{Max}$ exceeded a given threshold. For a proof of concept, a simplified approach was used by applying the two different filtering threshold, 0.45 and 0.59, therefore obtaining two sets of cover crop parcels according to more stringent or less stringent criteria. Information from two raster maps, the Soil Organic Carbon (SOC) baseline raster (from the LUCAS high resolution SOC map) and the emission factor raster (interpolated from the continental EU process-based model), were combined to produce a 100m resolution raster of estimated sequestered soil carbon. Then, for each parcel, the weighted average of intersecting pixels from the SOC baseline raster and the estimated sequestered soil carbon raster were calculated and stored as attributes. As a last step, the difference between the two values was calculated, and then multiplied by parcel area to estimate the sequestered soil carbon benefit for each cover crop parcel in comparison to the baseline value.

Using the cover crops detection threshold of 0.45, the number of parcels with cover crops detected was 12,645 (17.9% of total parcels), with a total surface of 26,168 ha. Setting the threshold at 0.59, the number is reduced to 9,095 (12.9% of total parcels), with a total surface of 18,711 ha. Using the lower threshold, the current estimated SOC sequestration due to cover crops would be 94,000 tons (average 3.59 t/ha), while using the higher threshold it would be 65,000 tons (average 3.47 t/ha).

However, the aforementioned figures assume a 100% cover crop coverage of parcels. To establish NDVI thresholds it was assumed that soil cover had to exceed 50% for a plot to be considered as covered by vegetation. Therefore, actual cover crop coverage can range from 50% to 100%. Thus, by applying a discretionary average coverage value of 75%, with the lower threshold, the current estimated SOC sequestration provided by cover crops would be downsized to 70,000 tons (average 2.67 t/ha), and even 49,000 tons (average 2.62 t/ha) if using the more restrictive higher threshold.

Simulating the adoption of cover crops on all the viable parcels in the study area, carbon sequestration would be in the 240,000-320,000 tons range (75% to 100% coverage). Compared to the current status, the benefit in carbon sequestration would be in the 170,000-255,000 tons range (worst to best scenario). Figure 23 shows a summary of the first results.

Figure 23. Summary results and maps of the cover crops soil carbon sequestration estimation over one year (2020)



Source: JRC D5.

4 Conclusions

As part of the integrated management system that Member States had to put in place to manage CAP subsidies, two digital databases are of particular interest because they contain a certain amount of geospatial information on LC and LU over multiple years. LPIS, the LC database, exists in digital format since 2004 at a scale 1:10,000 and was upgraded in 2015 to a scale 1:5,000. GSAA, the LU database, exists in digital format since 2018.

The availability of this LC/LU information since 3 to 5 years, opens the potential for a variety of uses, both in relation to and beyond the IACS context. The aim of this study was to start investigating this potential using some open-access LPIS/GSAA databases and specifically those from Austria.

The work reported here was performed over a short prospective period of 7 months. This research work was conducted as part of the JRC D5 GTCAP institutional activities and budget with a view to identify innovative solutions and anticipate possible policy implementation needs from Member States administrations.

A preparatory phase consisted in developing and deploying an ad hoc data exploration, processing and visualization platform to allow on the work course adjustments. Despite the fact that data were openly shared under the INPSIRE directive initiative, an important and relatively time consuming work of crop name translation, data harmonisation and consolidation has been necessary.

Once the data and tools were in place, data analytics through queries, filtering and displaying techniques have rapidly allowed to confirm the potential held by these LPIS/GSAA digital datasets.

The derived detailed statistics and their spatial distribution allow to provide immediate information on the main LU/LC classes (but also on the least abundant classes), on LC/LU diversification, on LU succession or rotation, or even on land parcel stability or change.

From this information, several potential applications or use-cases could be tested such as:

— Support to LPIS updating and attribute table refining;

— Knowledge gain to support land parcel monitoring and/or checking;

— Knowledge gain and zoning input to support decision systems as for instance in the frame of CAP National Strategic plans.

It has also allowed to provide a glimpse on the potential for more elaborated applications such as in the domain of land related modelling (e.g. soil carbon sequestration estimation).

This study acted as an eye-opener: whereas the data exploration progressed, an endless and diverse list of exploratory topics appeared on the horizon. Some noteworthy cases are:

— Support to the CAP Output and Result Indicators reporting;

— Analyses of land connectivity and networking;

— Combined use with other datasets (e.g. N2000, Nitrate Vulnerable zones, river networks …) to improve decision support system for land practices;

— Combined use of GSAA multiyear content and Sentinel multiyear temporal evolution to gain knowledge on LU/LC;

— Comparison with land sampling surveys like LUCAS to estimate their possible complementary role in land area estimates.

The authors are definitely looking forward to investigate some of these opportunities in the near future.

Finally yet importantly, the authors are convinced that, the more the Member States will experience added values from using/reusing their IACS data (alone or in combination with other national, regional layers), the more reactive they will be towards the mandatory IACS data sharing legislation (i.e. Article 67 of EU Regulation 2021/2116). [ref. iv]

References

i. Regulation (EU) No 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the financing, management and monitoring of the common agricultural policy and repealing Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000, (EC) No 1290/2005 and (EC) No 485/2008 - (https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32013R1306)

ii. Commission Delegated Regulation (EU) No 640/2014 of 11 March 2014 supplementing Regulation (EU) No 1306/2013 of the European Parliament and of the Council with regard to the integrated administration and control system and conditions for refusal or withdrawal of payments and administrative penalties applicable to direct payments, rural development support and cross compliance – (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014R0640)

iii. Regulation (EU) 2021/2115 of the European parliament and of the Council of 2 December 2021 establishing rules on support for strategic plans to be drawn up by Member States under the common agricultural policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and repealing Regulations (EU) No 1305/2013 and (EU) No 1307/2013 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2021.435.01.0001.01.ENG)

iv. Regulation (EU) 2021/2116 of the European Parliament and of the Council of 2 December 2021 on the financing, management and monitoring of the common agricultural policy and repealing Regulation (EU) No 1306/2013 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R2116)

v. Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32007L0002)

vi. Handbook of Annual Crop Statistics 2020, Eurostat. Available online: https://ec.europa.eu/eurostat/cache/metadata/Annexes/apro_cp_esms_an1.pdf

vii. Commission Implementing Regulation (EU) No 809/2014 of 17 July 2014 laying down rules for the application of Regulation (EU) No 1306/2013 of the European Parliament and of the Council with regard to the integrated administration and control system, rural development measures and cross compliance – (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014R0809)

viii. Nowak, B., Marliac, G., Michaud, A., *Estimation of winter soil cover by vegetation before spring-sown crops for mainland France using multispectral satellite imagery,* Environmental Research Letters, 16 (2021) 064024, doi:10.1088/1748-9326/ac007c

List of abbreviations

AL	Arable Land
AMS	Area Monitoring System
CAP	Common Agricultural Policy
CbM	Checks by Monitoring
EC	European Commission
EU	European Union
GSAA	GeoSpatial Aid Application
JRC	Joint Research Centre of the EC
IACS	Integrated Administration and Control System
LC	Land Cover
LPIS	Land Parcel Identification System
LU	Land Use
LUChaP	Land Unit Characterisation for Policies (JRC D5 Unit project)
LUCAS	Land Use/Cover Area frame Survey (Eurostat)
MS	Member State
PC	Permanent Crop
PG	Permanent Grassland
RP	Reference Parcel (LPIS)
SOC	Soil Organic Carbon

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Annexes

Annex 1. Links to data, applications and documentation

Austria – INSPIRE Geoportal:

https://geometadatensuche.inspire.gv.at/metadatensuche/inspire/eng/catalog.search#/home

Database:

Host: s-jrciprap289p.jrc.it

DB: d5capanalysis

Superset Dashboard:

https://lpis-gsaa.jrc.cec.eu.int/superset/

GeoServer:

https://lpis-gsaa.jrc.cec.eu.int/geoserver/web/

Information and code to deploy the LPIS-GSAA Data exploration and visualization platform:

https://citnet.tech.ec.europa.eu/CITnet/stash/projects/mars/repos/lpis-gsaa/browse

Workflow documentation (commented queries):

Available on request: Gilbert-Madalin.VOICAN@ec.europa.eu

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