European Commission

JRC TECHNICAL REPORT

IACS data sharing project

Final report

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Abstract

The objectives of the 'IACS65 data sharing project' performed by the JRC (coordinated by D3 unit – Land resources, with the participation of JRC D5 and JRC B6, and the support of DG ENV) were to make:

- more visible and accessible IACS spatial data (especially LPIS and GSAA) in the EU geoportal (INSPIRE geoportal) by the production and publication of discovery metadata for datasets and services (view, download) – WP1
- improve interoperability with other relevant data sets for the interest of public administration (LULUCF, crop classification, landscape features) – WP2
- ensure effective re-use through use cases, with a specific focus on soil conditions – WP3
- explore IACS data when it is integrated with third data bases (with specific focus on soil data bases and satellite images) – WP4
- collaboration with the Member States (Paying agencies) – WP 5

The IACS 65 activities aimed also to support the Member States in their obligations with regards to INSPIRE directive provisions that foresee data sharing of spatial data. This obligation is now laid down in (EU) Regulation 2021/2116 (Art. 67) [1] on IACS data keeping and sharing. Besides the strict implementation of INSPIRE, this article also foresees the setup of national geoportals for the general public (Art 67(3)) and the production of EU statistics (Art 67(4)).

Substantial progress has been made in the 30 months for the project thanks to AGRI/JRC efforts to facilitate IACS data sharing with Member States, even though data are not yet available for all Member States. Good results have been obtained and the positive trend along time was possible thanks to the following EC support and actions:

- publication of technical guidelines for the data discovery metadata and datasets metadata
- adaptation of INSPIRE geoportal for better visibility of LPIS and GSA(A) (In line with the implementation action on High Value data sets),
- trainings for the paying agencies,
- exchange during workshops, conference, and missions,
- AGRI/JRC/MS participation to use cases: soil health use-cases namely on modelling of soil erosion, soil organic carbon, soil contamination by pesticides, land degradation index, and interoperability based on Land-use, Land-use change and forestry (LULUCF), crop classification and Landscape features,
- creation of a specific pillar in the agri-food data portal to access most national (or regional) geoportals to view or download spatial IACS like data
- follow-up of important EU funded projects, notably NIVA[1] project

Nevertheless, the efforts should continue, notably the Commission support to the Member States in the format of exchange at workshops, publication of technical guidelines, organisation of trainings and joint participation (MS/EC) to use cases that represent direct advantage for the Member States in their policy evaluation, reporting and design.

The IACS65 project led to a development of an extended and larger endeavour: the construct a prototype of a **Spatial Agricultural Information System** through a new Administrative Agreement between DG AGRI and JRC, to be launched in April 2023. This system will meet some of ECA recommendations to DG AGRI (for accessing the data at parcel level and the need to build analysis capacity for big data).

[1] "New IACS Vision in Action" (NIVA) – Niva4cap

Acknowledgements

The project activities have been organised with the support of DG AGRI through the Administrative Agreement "IACS65 data sharing", engaging JRC D3 (Land Resources) and D5 (Food Security), and the collaboration of JRC T1 (Digital Economy) and DG ENV 01 (Strategy, digitalisation, better regulation, economic analysis).

The JRC wishes to acknowledge the support from and the positive collaboration with DG AGRI A4 (Data Governance) Colleagues for their patience, feedback, expertise and continuous encouragement, namely Mohamed EL AYDAM, Stavroula KANAKAKI, Miguel FERNANDEZ FERNANDEZ, and finally Pierluigi LONDERO.

This work would not have been feasible without a substantial administrative and organisational support provided by the JRC Colleagues.

Finally, the JRC would like to thank all the project participants and the Member States administrations for their active engagement.

Authors

Wojda, P., Escriu Paradell, J., Minghini, M., Kotsev, A., Toth, K., Schillaci, C., Simoes Vieira, D., Matthews, F., De Rosa, D., Martin Jimenez, J., De Medici, D., Scarpa, S. and Jones, A.

1. Introduction

Policy context and background

With the higher environmental and climate goals of the Common Agricultural Policy (CAP), and related legislation (Farm to Fork, Biodiversity, Climate and Soil strategies of the European Green Deal), more than ever DG AGRI needs data which allow to measure the performance of the policy towards its objectives, especially those related to the impact of agriculture on the environment and the climate. Additionally, JRC scientific services needs additional data to further support the development of indicators and to provide, at the same time, scientific evidence for the policy making.

These processes often require a high level of granularity to identify which activities and which agricultural practices are carried out and to distinguish or differentiate their impact (often with the CAP support). The performance should be assessed in the framework of the CAP and other EU policies. The Integrated Administration and Control Systems (IACS)[2], with its subsystems such as Land Parcel Identification System (LPIS) and Geospatial Application (GSA)[3] are playing central elements, together with other elements in the realm of the CAP.

The EU legal framework regarding the data sharing, and more precisely agricultural geographic data sharing, is quite large. Due its current dynamic evolution, a coherence and some guidance in its implementation must still be provided in the coming months. Nevertheless, in this context, the following main legal pieces taken into consideration have been identified: the INSPIRE Directive[4], the new CAP legislation, the High-Value Datasets under the Open Data Directive and finally the future Common Data space for Agriculture.

Rich and valuable information exists in the systems setup by the Member States for CAP management, namely the Integrated Administrative and Control System (IACS) and it is of a very good quality – as it undergoes 100% administrative checks and on-the-spot checks on a 5% sample. IACS data is collected with the sole purpose of carrying out controls on aid claims before paying. It is not accessible to the Commission – except to AGRI auditors, on request – and often even other public administrations in the same Member State do not have access to it (e.g., national statistical institutes). The situation will persist in the new CAP presenting a stronger focus on performance rather than on compliance – IACS data will remain in the remits of Member States.

IACS data sharing could potentially (development ongoing) contribute to the EU common data space for agriculture with essential public agricultural data that will support policy development and the agri-food industry alike. Moreover, the availability of this data will be essential for monitoring and reaching environmental (Green Deal) objectives set out in biodiversity, food security, farm to fork, upcoming soil health law, and even zero pollution strategies.

The effective sharing of IACS data is a long-term objective, which is part of the regular support provided to the Member States (MS) by the EC. According to the distributed nature of IACS, the spatial data in these systems is "owned" by the MS (generally handled by the Paying Agency in charge of the CAP payments). Taken into consideration this 'ownership' of data by the MS, as well as the proven methodology of INSPIRE, DG AGRI opted for a collaborative approach with the MS to ensure a common understand of the legal framework concerning data sharing, a good feasibility demonstration and a widespread take up.

In 2017, **DG AGRI setup a process** (in collaboration with DG ENV, DG CLIMA, JRC and EEA) aiming at:

[2] IACS: 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 (OJ L 435, 6.12.2021, p. 187); Commission Delegated Regulation (EU) 2022/1172 of 4 May 2022 supplementing Regulation (EU) 2021/2116 of the European Parliament and of the Council with regard to the integrated administration and control system in the common agricultural policy and the application and calculation of administrative penalties for conditionality and Commission Implementing Regulation (EU) 2022/1173 of 31 May 2022 laying down rules for the application of Regulation (EU) 2021/2116 of the European Parliament and of the Council with regard to the integrated administration and control system in the common agricultural policy

[3] It should be noted that the name of Geospatial Aid Application (GSAA) has changed to Geospatial Application (GSA) as stipulated by Article 65(4)(a) and Article 66(1)(b) of Regulation 2021/2116

[4] 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) was published in the official Journal on the 25th April 2007. The INSPIRE Directive entered into force on the 15th May 2007

- an efficient access to (spatial and non-personal) IACS data channelled through the INSPIRE infrastructure as a single-entry point and
- effective re-use of these data.

This process is of interest of the EU bodies and also MS public administrations, allowing potentially for an easier reporting, monitoring and evaluation purposes in different domains, in a coherent policy environment.

Several concrete actions have already been performed. In 2018 and 2019, actions were launched with the MS as well as with EC services (to ensure policy coherence and technical support) to:

- clarify the practical actions to be achieved by the MS for IACS data sharing in the context of INSPIRE (DS/CDP/2019/03)
- provide guidelines for the MS to allow the publication of INSPIRE compliant metadata in the EU geoportal (DS/CDP/2019/04). The guidelines were realised in the context of a pilot study with five MS (conducted by JRC D5).
- launch the discussion on the interoperability of IACS data sets.

Other actions are planned for the future to connect and to provide support to different EC DGs and to the Member States administrations. In this process the collaboration of the Member States is key, in particular the Paying agencies who manage the IACS systems. As an outcome, the fruitful collaboration with the MS must also be underlined. The collaboration with the MS, thanks to different meetings with experts, surveys, consultations, workshops, conferences and bilateral meetings with the paying agencies was reinforced and more than 13 MS were actively participating in the process. The collaboration with other EC DGs also improved, in particular with ENV, CLIMA, ESTAT, CNECT, GROW and the EEA. The 5th EC DGs meeting took place on 13 December 2022.

IACS65 Administrative Agreement

In 2020, a more ambitious set of actions was planned in the framework of an Administrative Agreement between DG AGRI and JRC called "IACS65 data sharing project". These actions aimed at improving data discovery, data accessibility, data interoperability, data efficient use in particular soil health use-case, finally checking feasibility of a creation of a more integrated system for data management. Consequently, the use cases proposed in this AA allow to prototype, test and illustrate the importance of data sharing in the domains of agriculture, environment and climate as well as the benefits for the administration in their evaluation, monitoring and reporting duties. These actions were accomplished within a collaborative spirit between the European Commission services and the Member States. The project has been finalized end of March 2023.

The IACS 65 activities aimed also to support the Member States in their obligations with regards to INSPIRE directive[5] provisions that foresee data sharing of spatial data. This obligation is now laid down in the CAP (EU) Regulation 2021/2116 (Art. 67) on IACS data keeping and sharing. Besides the strict implementation of INSPIRE, this article also foresees the setup of national geoportals for the general public (Art 67(3)) and the production of EU statistics (Art 67(4)).

Substantial progress has been made in the 30 months for the project thanks to AGRI/JRC efforts to facilitate IACS data sharing with Member States, even though data are not yet available for all Member States. Good results have been obtained and the positive trend along time was possible thanks to the following EC support and actions:

- publication of technical guidelines for the data discovery metadata and datasets metadata
- adaptation of INSPIRE geoportal for better visibility of LPIS and GSA (In line with the coming implementation action on High Value data sets),
- trainings for the paying agencies,
- exchange during workshops, conference, and missions,
- collaboration with the MS, thanks to different meetings with experts, surveys, consultations, workshops, conferences and bilateral meetings with the paying agencies was reinforced and more than 13 MS were actively participating in the process as of November 2019. The collaboration with other EC services also improved, in particular with ENV, CLIMA, ESTAT, CNECT, GROW and the EEA.

[5] Directive 2007/2/EC; https://inspire.ec.europa.eu/inspire-directive/2

- AGRI/JRC/MS participation to use cases (soil health use-cases namely on modelling of soil erosion, soil organic carbon, soil contamination by pesticides, land degradation index, and interoperability based on Land-use, Land-use change and forestry (LULUCF), crop classification and Landscape features),
- creation of a specific pillar in the agri-food data portal to access most national (or regional) geoportals to view or download spatial IACS like data
- follow-up of projects of interest: NIVA, Sen4STAT, Sen4CAP, OpenIACS, BestMAP

Nevertheless, the efforts should continue, notably the Commission support to the Member States in the format of exchange at workshops, publication of technical guidelines, organisation of trainings and joint participation (MS/EC) to use cases that represent direct advantage for the Member States in their policy evaluation, reporting and design. The IACS65 project led to a development of an extended and larger endeavour: the construct a prototype of a Spatial Agricultural Information System through a new Administrative Agreement between DG AGRI and JRC, to be launched in April 2023.

2. Objectives of the IACS65 Administrative Arrangement

The objective of this Administrative Arrangement (AA) was to provide AGRI D3, in collaboration with ENV E4, with the technical support in different domains in order to ensure IACS data sharing across the EU. The implementation of data sharing was done in the respect of the relevant EU legislation (for data protection as well as for the establishment of specific infrastructures) and taking into account the EU proposals of the evolution EU data ecosystems (evolution of INSPIRE and EU common data space).

The overall objective of the 'IACS data sharing process' is to ensure a discoverability, an efficient access (single entry point) and effective re-use of spatial IACS data (interoperability and use cases) in a coherent policy environment. Consequently, the use cases proposed in this AA allowed to prototype, test and illustrate the importance of data sharing in the domains of agriculture, environment and climate as well as the benefits for the administration in their evaluation, monitoring and reporting duties.

The use cases addressed data sharing between public administrations first. The capacity to involve other stakeholders from different agro-environmental-climatic sectors was analysed in the framework of the EU Common Data Spaces.

To meet these objectives, the following work packages were executed within 30 months (10/2020 until 03/2023), and were conducted or coordinated by experts in the JRC:

- WP 1 – from INSPIRE towards EU common data space (JRC T1)
- WP 2 – Interoperability of IACS spatial data sets (JRC D5)
- WP 3 – Soil health use cases (JRC D3)
- WP 4 – Exploratory analysis for an optimal use of IACS data (JRC D3)
- WP 5 – Collaboration with the MS (all participants)

The collaboration with the MS was crucial. Different physical events were organised to take on-board the most CAP Paying Agencies possible and to improve the cooperation with the ones already involved in the AGRI process, but this was hampered by the COVID crisis Instead, some on-line events were proposed: Committee meetings, Group of experts meetings, experts meetings.

The overall coordination of this AA was ensured by JRC D3:

- WP 6 – Coordination (JRC D3)

3. Work package 1: data discoverability and accessibility

The objective of this work package was to analyse and support the inclusion of IACS data into the foreseen Common Agricultural Data Space defined under the European Strategy for Data[6]. IACS data, if made available in an easy-to-use manner through the adoption of the right standards, can be used for a broad spectrum of different use cases and actors (academia, private sector, public sector, European Commission, etc.).

The work under this work package summarised technological lessons and provided guidelines on optimising the reuse of agricultural data (concerning IACS data primarily, but also possibly extensible to other data sources in the agricultural domain). To this end, novel technologies and emerging standards from INSPIRE (notably for exposure of data through Application Programming Interfaces (APIs)) have been shown, tested and evaluated in an agile and inclusive manner, necessarily in close collaboration with volunteering Member State stakeholders and authorities, while taking into consideration initiatives in the domain of data sharing.

In addition, considering the cross-cutting nature of agricultural data, links to the environmental agenda and reuse of the lessons learned and data made available within the context of the GreenData4all initiative have been pursued. Relevant information collected by DG AGRI about the IACS data shared practices in the Member States have been used as input.

a. Objectives

The following main three objectives have been identified in the context of Work Package 1 on Discoverability and Accessibility of IACS data:

— Let stakeholders easily find, access and re-use IACS data through INSPIRE services.

— Demonstrate the added value of the integration of IACS data within an EU Common Agricultural Data Space.

— Support sharing of IACS data from Paying agencies through standard-based APIs endorsed by INSPIRE.

All these objectives have been channelled through the reuse of the INSPIRE infrastructure, as detailed in the next section explained the methodology use in the project for the mentioned work package.

b. Methodology

The work package has been implemented reusing components already existing in INSPIRE, set up under the legal basis of the European INSPIRE Directive.

Discovery of IACS data has been eased by producing interoperable metadata describing the IACS data resources available in the Member States. The metadata has been prepared at national level following the corresponding requirements and recommendations established by the Directive (implementing rules and related technical guidelines) for producing metadata. This set of rules have been complemented with those particularly established for IACS data metadata in the 'Technical Guidelines on IACS Spatial Data Sharing, Part 1 – Data discovery', developed in the context of the IACS65 project. Between the main provisions established in this technical guidelines, the mandatory and optional keywords for classifying IACS data metadata resources should be highlighted. These IACS keywords have been included in a common 'IACS Data metadata code list' available in the INSPIRE registry.

Several IACS data metadata validation tests have been additionally prepared in order to check the adherence of these metadata records to the generic rules established by INSPIRE metadata implementing rules and the specific IACS requirements set out in the 'Technical Guidelines on IACS Spatial Data Sharing, Part 1 – Data discovery[7]'. Such tests are at the disposal of European data providers in the INSPIRE Reference Validator, the tool available in the infrastructure to check the compliance of different resources (metadata, data and services) to the requirements emanating from the INSPIRE Directive.

After having checked the compliance of the IACS metadata, these descriptive records are periodically harvested from national geospatial catalogues, through their corresponding INSPIRE discovery services, becoming

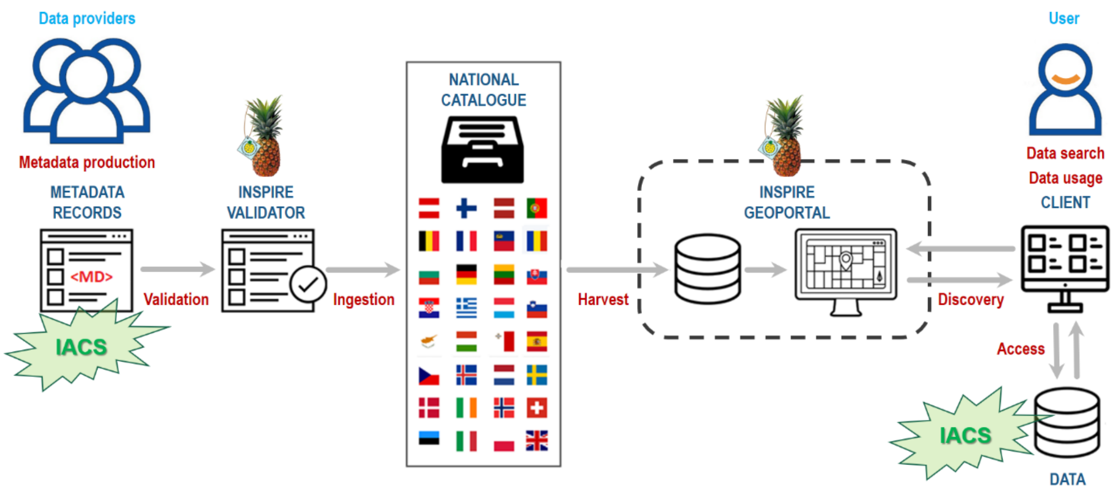
[6] https://digital-strategy.ec.europa.eu/en/policies/strategy-data
[7] https://publications.jrc.ec.europa.eu/repository/handle/JRC121450

available for users through the INSPIRE Geoportal, which is the central access point for geospatial information in Europe. Users may use the geoportal to search for data of their interest. The results of the searching (discovery) process are obtained by comparing the user's search entries with the information encoded in the mentioned metadata records. Once a result set of metadata records is identified by the user, they might access the different INSPIRE view and download services serving such IACS resources.

As part of the INSPIRE Geoportal, a new frontend has been prepared to let users browse Agriculture Data, including LPIS and GSA(A) IACS data, based on the High Value Datasets categories set out by the Implementing Regulation on High-value datasets (Commission Implementing Regulation (EU) 2023/138 of 21 December 2022 laying down a list of specific high-value datasets and the arrangements for their publication and re-use[8]) recently adopted by the Commission and published in the Official Journal of the European Union on 20th January 2023. Three of these categories, the 'Geospatial', 'Earth observation and environment' and 'Mobility', overlap with the data themes in the scope of the INSPIRE Directive. Agricultural IACS data are included as part of the 'Geospatial' category mentioned above.

The graphic provided below (***Figure 1***) shows the workflow for the discovery and access of national IACS data assets through the INSPIRE infrastructure.

Figure 1. Workflow for the discovery and access of national IACS data assets through the INSPIRE infrastructure



Finally, to complement this methodology, several activities have been running in the scope of the IACS65 project to demonstrate the benefits of implementing the emerging OGC APIs endorsed by INSPIRE, for interacting with IACS data resources.

As illustration, during the Expert Group on Direct Payments Meeting held on 27 September 2021, a presentation from North-Rhein Westphalia (NRW, Germany) on their experience implementing and exposing IACS data through OGC APIs was offered to the audience (***Figure 2***), as example best practice to be followed. Additionally, in the second part of Working Group 1 of the 3rd Workshop on IACS data sharing held on 1 March 2023, a presentation and a practical demonstration on OGC API Features from the GeoE3 Project was delivered (***Figure 3***). This demonstration showed an API implementation serving an IACS datasets in GeoPackage/GeoJSON formats.

[8] https://eur-lex.europa.eu/eli/reg_impl/2023/138/oj

Figure 2. Implementing and exposing IACS data through OGC APIs, NRW illustration.

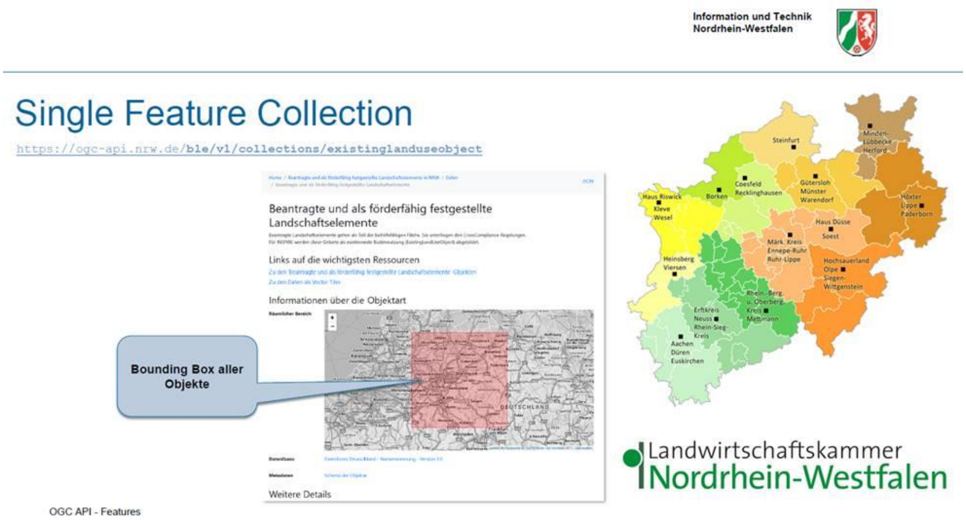
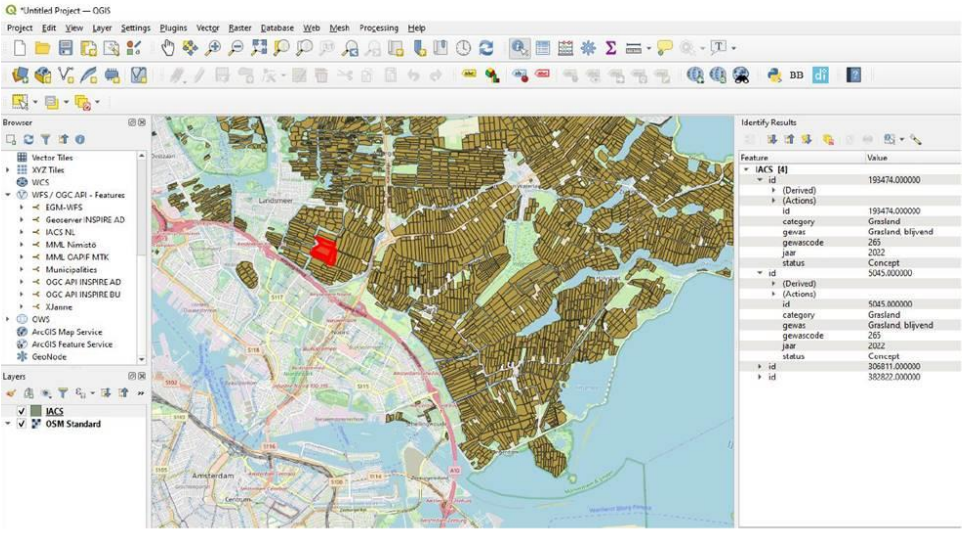


Figure 3. Demonstration showing an API implementation serving an IACS datasets in GeoPackage/GeoJSON formats.



Such APIs will constitute one of the key building blocks of the new European Common Data Spaces, being currently shaped and developed under the European Strategy for Data. Data Spaces are aimed at becoming the future data sharing paradigm in the short/mid-term.

In implementing the work package, DG AGRI has been supported in clarifying technical aspects related to IACS data (high-value data sets and the corresponding INSPIRE themes). Additionally, a link with DG CNECT has been established, to ensure a common definition and understanding of the EU Data Space implementation, including the agricultural data in the scope of the 'Geospatial' High-value Dataset category, as an asset for the implementation of the sectorial EU Common Agricultural Data Space.

The following groups of closely related activities are foreseen for the implementation of the work package:

— Improve the discoverability of IACS data through the INSPIRE infrastructure.

— Analyse and support for the inclusion of IACS data within the foreseen agricultural data space.

c. Tasks and deliverables

The following tasks were planned and have been executed:

— Task 1.1 Harvesting existing metadata catalogues and identification of metadata describing IACS datasets.

— Task 1.2 Establishment of a discovery interface for IACS data.

— Task 1.3 Feasibility for establishment of an IACS/agricultural data space code list register.

— Task 1.4 Analysis of typical use cases requiring IACS data.

— Task 1.5 Prototypes/sandboxing through the use of different technologies and standards.

— Task 1.6 Proposal for an approach for inclusion of IACS data in the agricultural data space

— Task 1.7 Events – including:

- Workshop on the establishment of an agricultural data space.
- Training on APIs, standards and data management in INSPIRE.
- Presentations to CAP GREX and Committees

The following deliverables were planned and have been delivered:

- D1.1 Technical report summarizing the developments related to improving the discoverability of IACS data through the INSPIRE infrastructure (providing overview of the results from the implementation of tasks 1, 2 and 3 of WP1).

  Analysis of the existing IACS datasets in the INSPIRE geoportal was conducted, and the results communicated to MS Paying agencies. Delivered:

  - 1st draft on 'INSPIRE Geoportal IACS Statistics' report. January 2021.
  - Presentation to the MS Committee with Paying Agencies. January 2021.
  - Periodic updates of the statistic during the whole duration of the project (GREX meeting, periodic consultation minutes, several meeting organised by DG AGRI).

- D1.2 Discovery front-end interface for IACS data as output from the implementation of task 2 of WP1.

  Delivered:

  - IACS Metadata code list implemented in the INSPIRE Registry, following the established governance process. March 2021.
  - Tests on IACS metadata available in the staging instance of the INSPIRE Reference Validator, including a guiding description document on how to use them. December 2021.
  - Tests on IACS metadata available in the production instance of the INSPIRE Reference Validator. Related news item[9]. March 2022.
  - Discovery frontend interface mock-up and URL access (protected). June 2021.
  - Revamped discovery frontend (JRC.T1 servers). September 2022.

- D1.3 Technical report summarizing the support for the inclusion of IACS data within the foreseen agricultural data space (providing overview of the results from the implementation of tasks 4, 5, 6, 7 of WP1).

  This deliverable was agreed to be delayed by July 2022, following discussions between DG AGRI and JRC to define possible synergies with the on-going activities for the establishment and set-up of the Common European Agricultural Dataspace and the link with the Green Deal Dataspace.

- D1.4 Events.

  The following event and training activities have been delivered:

  - Workshop: INSPIRE Discoverability Clinic (including workshop, report and overview document), attended by 100+ representatives of Paying agencies. 8 June 2021.
  - Presentation at the Expert Group on Direct Payments Meeting (including a presentation OGC API – Features), including an update on the status of IACS Data discoverability and accessibility and providing an implementation best practice on OGC API – Features from North Rhine-Westphalia region. 27 September 2021.
  - Meeting on INSPIRE and IACS Data Sharing to support the German Paying Agencies, including national and lander representatives, AGRI and the JRC. 9 February 2022.
  - JRC 'Food4Thought' seminar on IACS data sharing. Dissemination activity. 9 March 2022.
  - INSPIRE training for AGRI and other staff involved IACS65 project at the JRC Ispra site. 10-11 October 2022.
  - IACS65 presentation at the 5th EC DGs Annual meeting about IACS data sharing. 13 December 2022.

[9] https://github.com/INSPIRE-MIF/helpdesk-validator/issues/727

- 3rd Workshop on IACS data sharing. Shortly described below in this document. 28 February - 1 March 2023.

d. Results

This section enumerates the different results obtained in the scope of Working Package 1 during the duration of the IACS65 project.

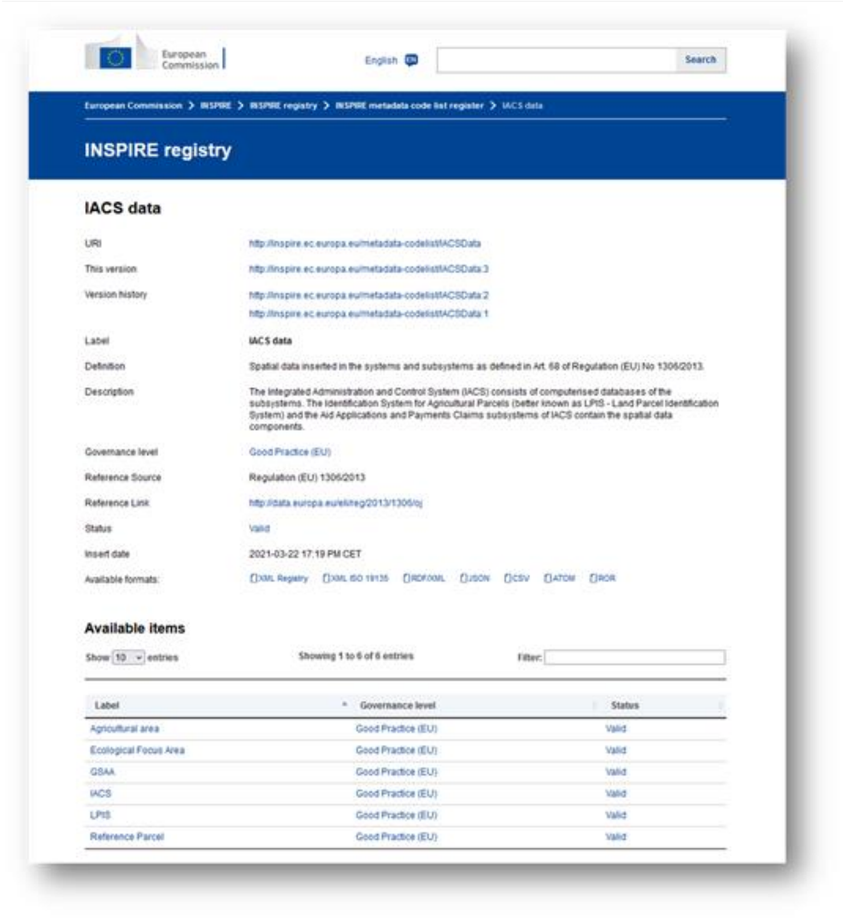
— Technical Guidelines on IACS Spatial Data Sharing, Part 1 – Data discovery (***Figure 4***).

Figure 4. Technical Guidelines on IACS Spatial Data Sharing, Part 1 - Data discovery

- Technical Guidelines on IACS Spatial Data Sharing, Part 1 – Data discovery:
- https://op.europa.eu/en/publication-detail/-/publication/f09b0355-f7c5-11ea-991b-01aa75ed71a1/language-en

IACS data metadata code list available in the INSPIRE Registry (***Figure 5***).

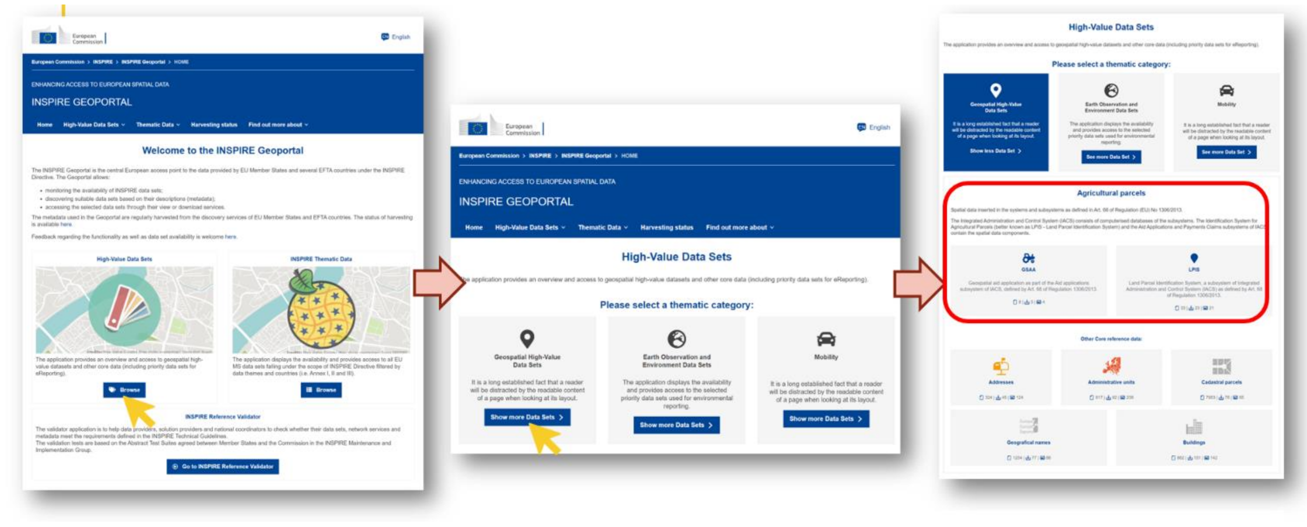
Figure 5. IACS data metadata code list available in the INSPIRE Registry.



- IACS data metadata code list: https://inspire.ec.europa.eu/metadata-codelist/IACSData

— High-value Datasets (HVDs) filtering in the revamped INSPIRE Geoportal for directly accessing IACS data resources (***Figure 6***).

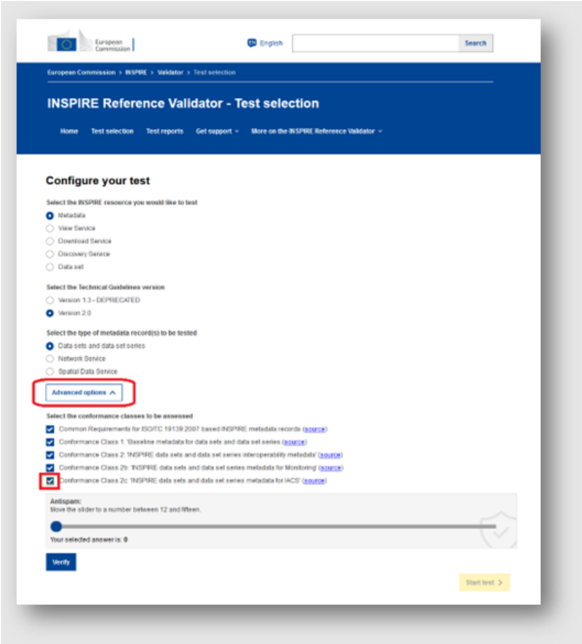
Figure 6. High-value Datasets (HVDs) filtering in the revamped INSPIRE Geoportal for directly accessing IACS data resources.



HVDs filtering in the revamped INSPIRE Geoportal: [*https://inspire-geoportal.ec.europa.eu*](https://inspire-geoportal.ec.europa.eu)

— IACS data metadata tests in the INSPIRE Reference Validator (***Figure 7***).

Figure 7. IACS data metadata tests in the INSPIRE Reference Validator.



IACS data metadata tests: https://inspire.ec.europa.eu/validator/test-selection/index.html

The IACS data metadata tests are based on the specific IACS metadata requirements stated in the Technical guidelines on IACS spatial data sharing. Part 1 - Data discovery, allowing Member States and EFTA countries to check the conformance of their IACS metadata records.

— INSPIRE Discoverability Clinic workshop celebrated on 8th June 2021.

It helped in increasing the indicators on availability, but more efforts are need to achieve Pan-European coverage.

— 3rd Workshop on IACS Data Sharing, which took place in the EC JRC-Ispra site on 28 February and 1 March 2023.

JRC.T1 actively participated in the event by organising Working Group 1 on Data Discoverability and Accessibility, while reporting to the workshop plenary session on the current status of IACS data sharing through the INSPIRE infrastructure and the outcomes from the working group.

The agenda for Working Group 1 was set up with the view of achieving the following objectives:

- Make participants understand how IACS data sharing works in the INSPIRE infrastructure.
- Arise awareness about the use of current tools and resources available on IACS data sharing and promote their use.
- Explain to non-experts the basic concepts shaping EU Data Spaces, and the Agricultural Data Space, aimed at paving the future of data sharing infrastructures.
- Discuss on how to better support IACS data sharing in INSPIRE, and how to contribute to the EU Agricultural Data Space, in the future.

The working group was structured in two parts:

- A first one, more theoretical and descriptive, dedicated to explain the basics of IACS data sharing through the INSPIRE infrastructure and to provide a simple but exemplified description of each of the tools currently available.

- A second one, providing a vision about the future, explaining through practical demonstrations the concepts and ingredients for the upcoming EU Data Spaces, and the use of the emerging OGC APIs as a powerful and modern way of exposing data in such data spaces.
- At the end of the second part, a guided discussion was organised with the active participation of the attendees, based on five open questions. All the outcomes were shared in the plenary session held before closing the workshop.

The exchange with the community during Working Group 1 of the 3rd Workshop on IACS data sharing, together with the outcomes during the whole duration of the IACS65 project, helped in finding the conclusions and further steps stated in the following section.

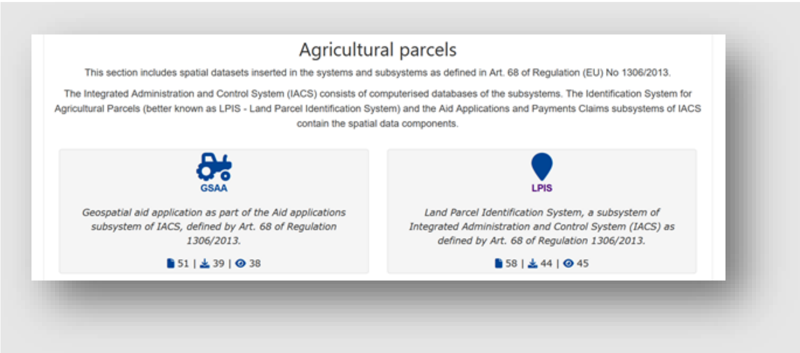
— Current status of IACS data sharing through the INSPIRE Geoportal (February 2023).

The graphics included below (***Figure 8***) show the availability of IACS data through the INSPIRE Geoportal on 21st February 2023. A slow but sustained increase, with positive trend, has been maintained since 2021.

Lack of metadata according to the 'Technical Guidelines on IACS Spatial Data Sharing, Part 1 – Data discovery' still affects 16 countries, which does neither have interoperable LPIS nor GSAA data – This is equivalent to the 51% of the EUR27 (plus Switzerland, Iceland, Liechtenstein and Norway).

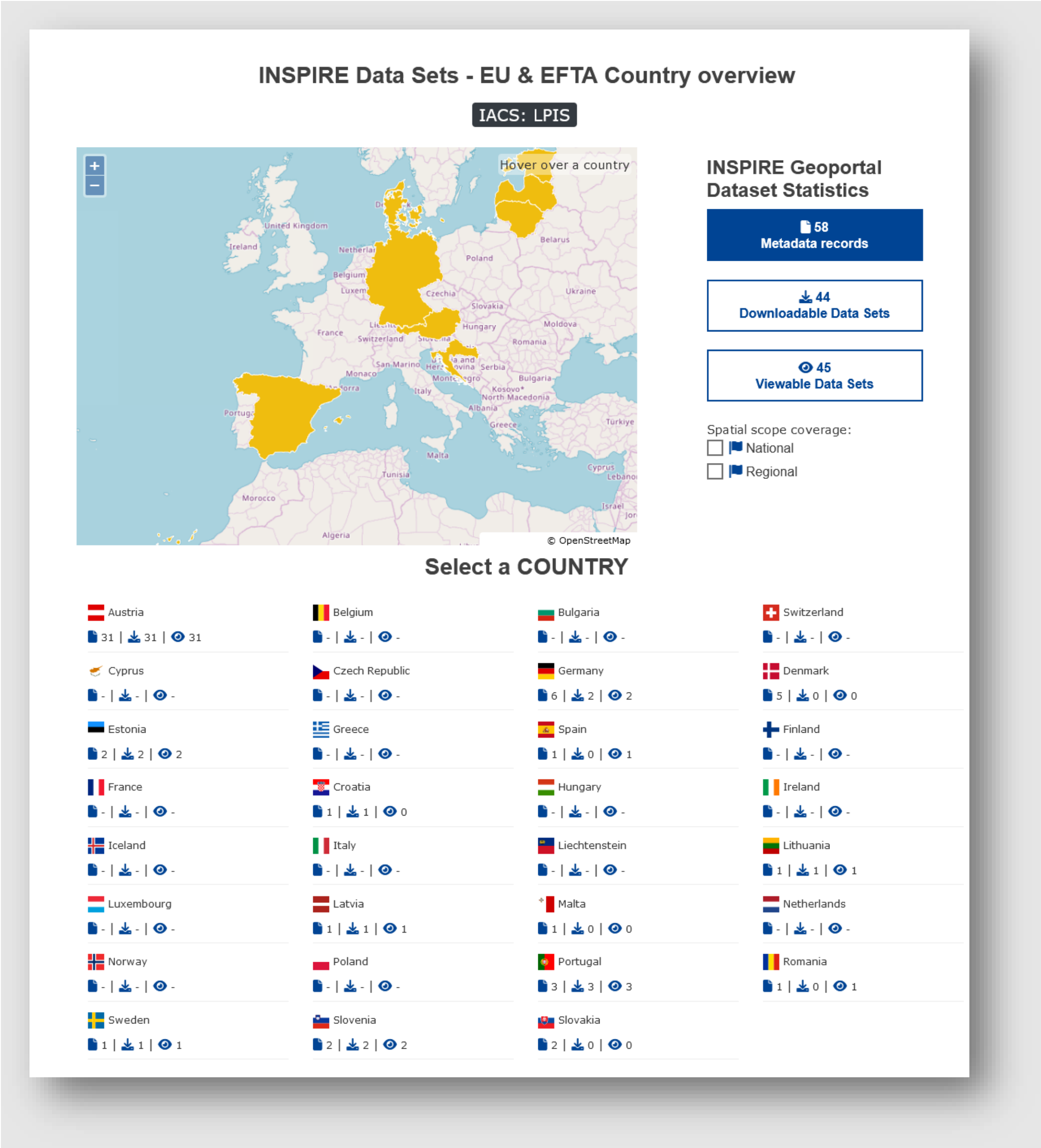
- Global statistics for Agricultural Parcels.

Figure 8. Global statistics for Agricultural Parcels (INSPIRE Geoportal – February 2023).



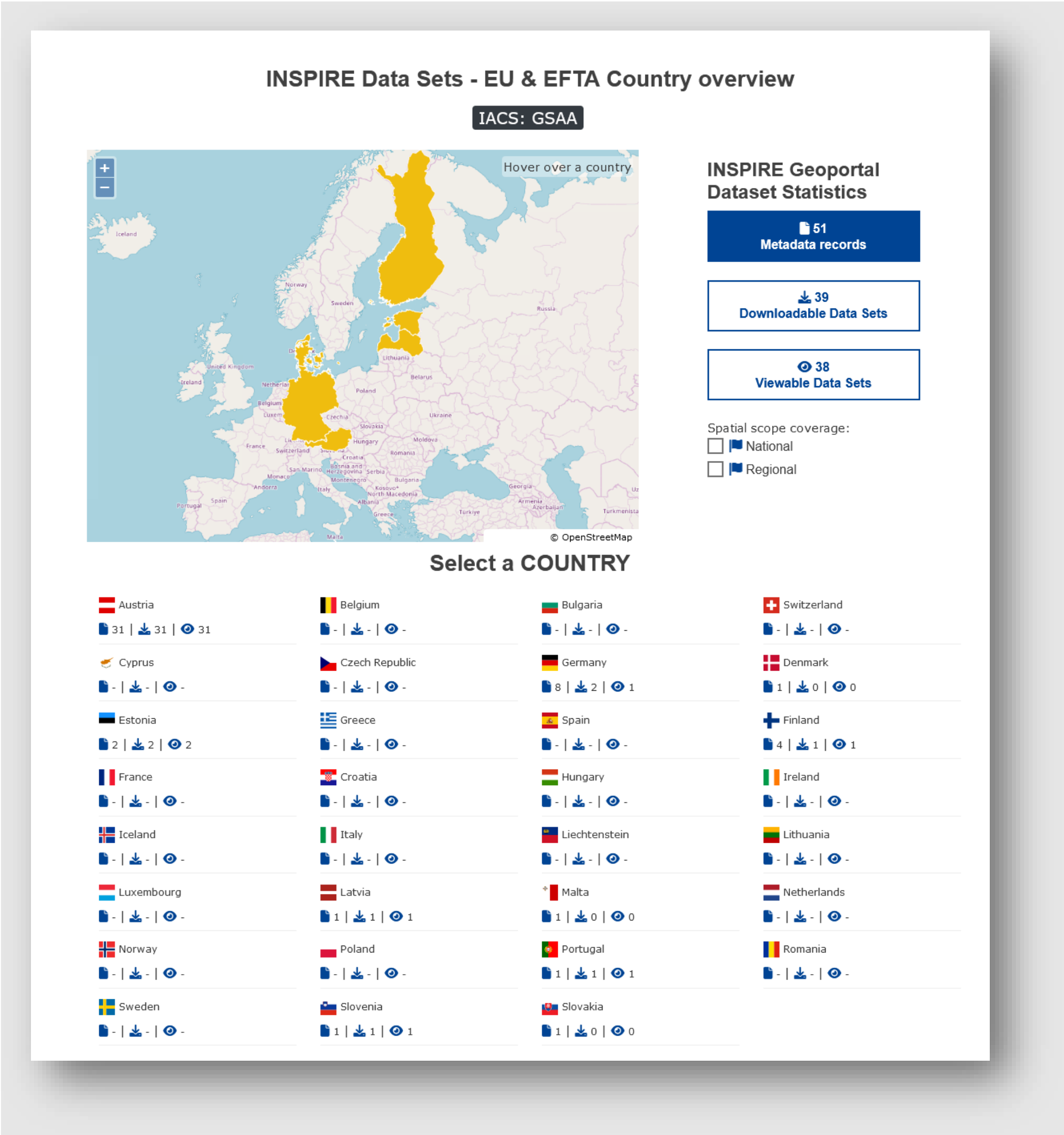
Statistics for LPIS IACS data type (***Figure 9***).

Figure 9. Statistics for LPIS data (INSPIRE Geoportal – February 2023)



- Statistics specific for GSAA IACS data type (***Figure 10***).

Figure 10. Statistics for GSAA data (INSPIRE Geoportal – February 2023)



e. Conclusions and further steps

This section summarises the general conclusions regarding IACS data discoverability and accessibility at the end of the IACS65 project.

— INSPIRE has proven to be an appropriate infrastructure to effectively discover and share interoperable IACS Data.

— The Technical Guideline is usable: 49% of the whole Europe (EUR27, plus Switzerland, Iceland, Liechtenstein and Norway) is using it. However, European coverage has to be improved.

— Appropriate actions need to be taken to improve the situation, including actions to continue promoting engagement of Member States (INSPIRE experts, DG-AGRI, National Contact Points and Paying Agencies).

— There is a need to organise ad-hoc training activities in potential future projects as a continuation of IACS65, while to follow-up the development and evolution of the pillars for the new Agricultural Data Space, and promote the implementation of APIs (OGC SensorThings-API and OGC API-Features).

After holding the 3rd Workshop on IACS data sharing on 28 February and 1 March 2023 with Paying Agencies and INSPIRE representatives from Member States, the following outcomes were highlighted:

— The current tools available for discoverability and accessibility of IACS data through the INSPIRE infrastructure are useful. However, the majority of participants were not aware of their existence.

— Correctly interpreting and describing the metadata elements of IACS datasets according the technical guidelines on data discoverability represent some difficulties.

— Tutorials and training sessions would be needed, especially for non-experts. Support from INSPIRE experts is necessary to use the current IACS data tools and understand how to publish spatial datasets according to the INSPIRE rules.

— Standard APIs are very important as a modern mechanism for accessing the data. There is a need to:

  - Raise awareness and understanding why APIs have to be implemented.
  - Devote financial resources to such implementation.
  - Create knowledge resources and building competencies and skills.

— Proper mechanisms to transfer all this knowledge are crucial to achieve the expected goals. Early engagement of Member States would be desirable in future IACS data sharing activities, to establish in advance appropriate organisational structures.

As a general recommendation for future IACS data sharing activities, the current tools available in the INSPIRE infrastructure should be evaluated and possibly improved and/or evolved in the light of the new requirements, technologies and organisational set ups adopted for data sharing in the upcoming EU Data Spaces. IACS65 project achieved a first step in the exchange and interoperability of IACS data across Europe.

4. Work package 2: data interoperability

a. Objectives

Data sharing is a process consisting of two main pillars: enabling data discovery, by means of metadata published in data catalogues, and enabling data interoperability by means of common data models, semantics and publication protocols for data harmonisation. In context of IACS-INSPIRE data sharing, the first pillar was addressed in the "Technical Guidelines on IACS Spatial Data Sharing – Part 1 – Data discovery[10]", published in 2020, providing a full technical guidance in the subject. The subject of work in frame of this AA was to develop interoperability target specifications for the spatial datasets (Land Parcel Identification System – LPIS and Geospatial aid application – GSA) to present them according to the rules of the INSPIRE Directive[11].

The objective of this work package was to provide harmonised and interoperable LPIS and GSA data specification that would facilitate the application of standardised procedures (e.g. to generate statistics, perform data analytics and modelling future scenarios for supporting decision makers), so that these datasets can be reused without repeating the same transformation every time. Interoperability serves in first place the (re)users. Reusing spatial data of IACS is very important in the context of the European Green Deal. A number of policies, such as LULUCF (Land Use, Land Use Change and Forestry), Biodiversity strategy, Nature Restoration Law, Zero pollution, etc. are likely to benefit from increased interoperability.

Interoperability offers great advantages to the data providers too. The monitoring and evaluation of the new performance based CAP explicitly requires higher level of data integration with various thematic datasets (e.g. soil, biodiversity, topography, etc.). Rather than collecting the data on their own, PAs can benefit from the commonly applied standards in reusing third party data.

b. Methodology

The work package has been implemented following the INSPIRE methodology for data specification development. This methodology is user driven, which means that the appropriate degree of data harmonisation is defined by representative use-cases. This is a very important principle, as insufficient harmonisation does not ease the practices of the potential users, while too much harmonisation puts an increased burden on the data providers (INSPIRE Data Specification Drafting Team, 2008). The right degree of data harmonisation can be achieved by analysing the implementation of representative use cases – to clarify the requirements and measure the associated burden.

In the course of the project the following use case were performed:

— Reusing IACS spatial data for LULUCF reporting

— Using IACS spatial data for training crop classification algorithms

— Using third party information for detecting and quantifying landscape features.

While the beneficiaries of the first two use case are the spatial data communities in large sense (who are reusing LPIS and GSA data), the third case was to analyse, how the IACS community can profit from greater interoperability with others.

A cornerstone of implementation of these use cases was a semantic mapping between the source and the target data. This fundamental step clarified how the spatial object types and the terminology of the source and target domains are related, if they are communalities to build on in course of our work.

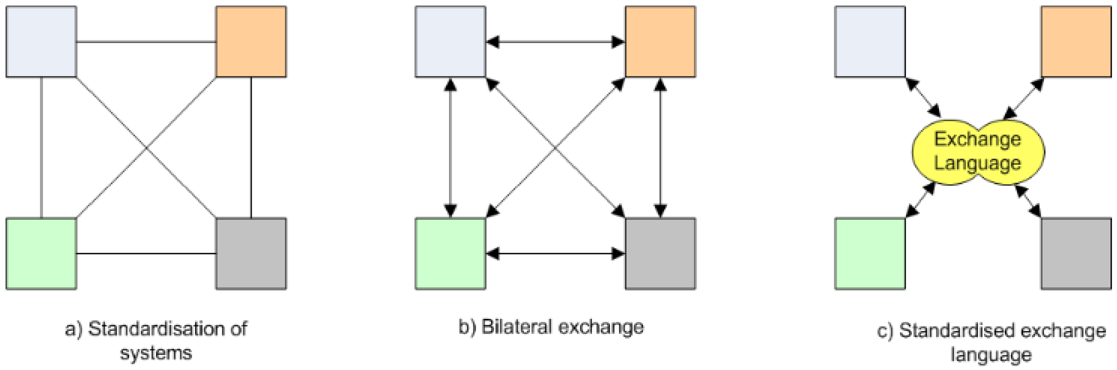
The use cases were implemented based on spatial data from various MS, notably the Czech Republic, Austria, Bulgaria, Germany, Lithuania, Spain and Romania. On one hand, this diversity of data allowed to define the commonalities to be reflected in the interoperability target. On the other hand, it also served to define what the users need for effective reusing of data. In addition to the use cases, another important input was the stakeholders' reflection on the Interoperability discussion paper (Toth K., 2020), which helped to understand the preferences of the main data providers – the Paying agencies and the LPIS custodians.

[10] https://publications.jrc.ec.europa.eu/repository/handle/JRC121450

[11] 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 (https://eur-lex.europa.eu/eli/dir/2007/2/2019-06-26)

Interoperability can be achieved by adoption of a commonly agreed "language" between different data providers, as shown in ***Figure 11***.

Figure 11. Basic architectures for interoperability (adopted from Lasshuyt and van Hekken 2001)



This common "language" should be described in technical terms, including an interoperability target model and other data specification elements. In INSPIRE, the interoperability target is documented according to a specific template that is based on ISO 19131 (Geographic information – Data product specification). The central part of this specification is the data mode (application schema), documented in the Unified Modelling Language (UML).

The original idea presented in the discussion paper was to split the LPIS dataset based on its feature types and harmonise every feature type according to the concepts of that INSPIRE data theme, which was found to be the most similar in the content. The three related INSPIRE data themes were:

- Land Cover (LC) (INSPIRE Thematic Working Group on Land Cover 2013),
- Land Use (LU) (INSPIRE Thematic Working Group on Land Use 2013) and
- Area management / restriction / regulation zones & reporting units (AM)[12].

According to this approach, interoperability could have reached by extending the appropriate spatial data types in these INSPIRE themes. After careful considerations, this approach has been dropped, because of the following reasons:

- The LPIS and the GSA are among the best harmonised datasets at the EU level (they respond to the same functional requirements stipulated by EU law), which use a well-stablished vocabulary, also known by the stakeholders. When searching agricultural data, the users look for agricultural or reference parcels, rather than for land cover or land use units. Consequently, changing the naming convention, which is required in harmonisation with INSPIRE would not add value, rather would introduce ambiguity.
- The spatial object types of LPIS should have been mapped to different data themes (LC and/or LU) of INSPIRE, leading to splitting this dataset, which would not facilitate its reuse.
- The HVD implementing regulation[13] refers to the LPIS and GSA datasets using its original semantics. As these datasets are not included in the Annexes of INSPIRE, but are explicitly part of the HVDs, it makes sense to achieve interoperability in the frame of this latter.

Consequently, instead of extending several INSPIRE data themes, the approach of providing a specific and unique harmonised model both for the LPIS and GSA datasets was selected. From these models, if necessary, the mapping to the INSPIRE data themes is straightforward and easy, as it was demonstrated in course of testing (see Conclusions of this section).

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[12] https://inspire.ec.europa.eu/Themes/139/2892

[13] Commission Implementing Regulation (EU) 2023/138 of 21 December 2022 laying down a list of specific high-value datasets and the arrangements for their publication and re-use

However, the modelling work did not need to be started from scratch. The starting point was the IACS domain model (Tóth and Kučas 2016), which was simplified, retaining only the spatial object (feature) types and leaving out all business information, such as beneficiaries, payments, controls, etc.

It should be noted that the work on IACS-INSPIRE interoperability started in the period when IACS was governed by Regulations 1305/2013, 1306/2013 and 1307/2013, to be continued under the new CAP Regulations; notably when 2021/2115 and 2021/2116 entered in force. In terms of spatial information the only change is related to the phasing out the concept of the ecological focus area. On the other hand, in the context of Performance Monitoring and Evaluation Framework (PMEF), the environmental and climate aspects gain more importance. This may require extending the spatial information content of IACS, keeping in mind the principle of no double counting. Inserting or extending landscape features (LF) in existing spatial datasets is one of the direction that MS might take in the future. Therefore, LF have been included in this Technical Guideline (TG) as an anticipatory measure.

It should be also noted that the name of Geospatial Aid Application (GSAA) has changed to Geospatial Application (GSA) as stipulated by Article 65(4)(a) and Article 66(1)(b) of Regulation 2021/2116. Since GSAA is a relatively newer term (introduced in 2013), which, unlike to LPIS, is less known in the user communities, it is reasonable to change the terminology now, before it gets a wider spread.

The interoperability specification development process followed an iterative way. The first draft of the specifications was reviewed by the experts who participated in the interoperability pilots. Their proposals and comments were also discussed at the Data sharing workshop on 28 February – 1 March. The agreed changes have been implemented in a new version, which is delivered in frame of this AA. Before finalising, another review – with a wider audience of stakeholders (Paying Agencies and INSPIRE community) is also recommended.

It should be noted that interoperability requires certain operational components, such as registries of application schemas, glossary or code lists. The interoperability target models are also based on harmonised code lists, which should be shared in a publicly accessible way. On the top of the Technical Guidelines on interoperability, a proposal for the content of the code list registers have been also prepared.

c. Tasks and deliverables

i. Technical Guidelines on IACS Spatial Data Sharing. Part 2 – Interoperability

These Technical guidelines are build on the INSPIRE Generic Conceptual Model (INSPIRE Data Specification Drafting Team, 2014) and follow the INSPIRE data specification template with the following sections:

- Introduction
- Overview
- Data content and structure
- Application schema LPIS
- Application schema GSA
- Reference systems, units of measurements and grids
- Data quality
- Dataset level metadata
- Delivery
- Data capture
- Portrayal
- Conclusions

The harmonised data models described in this report represent a concrete proposal to solve the lack of harmonisation of LPIS and the GSA datasets across Europe. In addition to the common data models for LPIS and GSA this report provides a full data specification according to INSPIRE. Despite preserving the IACS semantics, the proposed solution facilitates the creation of INSPIRE conformant datasets from the LPIS and GSAA implementations of the Member States.

ii. Input to the IACS code list register

The IACS-INSPIRE Interoperability Technical Guideline (TG) includes an interoperability target model, which contains a number of code lists. The purpose of a code list is to present an agreed set of codes with multilingual names, together with their definitions and descriptions. These can be used as values of properties (attributes) Code lists serve as controlled vocabularies for the values of object properties, to be reused by a wider audience.

The data model provided in the TG defined the following code lists:

— Agricultural area type,

— Non-agricultural eligible area type,

— Ecological focus area type and

— Landscape feature type.

d. Results

As previously mentioned, the central parts of the TG are the interoperability target models defined for the LPIS and the GSA data.

i. LPIS application schema

The LPIS application data includes the following feature types:

— Agricultural area

— Reference parcel

— Landscape feature

— Non-agricultural eligible area

— Ecological focus area

The TG describes the following relationships among these five main feature types:

— Each Agricultural Area and Non-Agricultural Eligible Area has to be mandatorily aggregated to one Reference Parcel, whilst each Reference Parcel is mandatorily associated to one or many Agricultural Area(s), or Non-Agricultural Eligible Area(s). A Reference Parcel cannot be associated at the same time to Agricultural Area(s) and Non-Agricultural Eligible Area(s).

— Each Agricultural Area can be associated to one or many Ecological Focus Area(s), whilst each Ecological Focus Area, if existing, has to be mandatorily aggregated to one or many Agricultural Area(s).

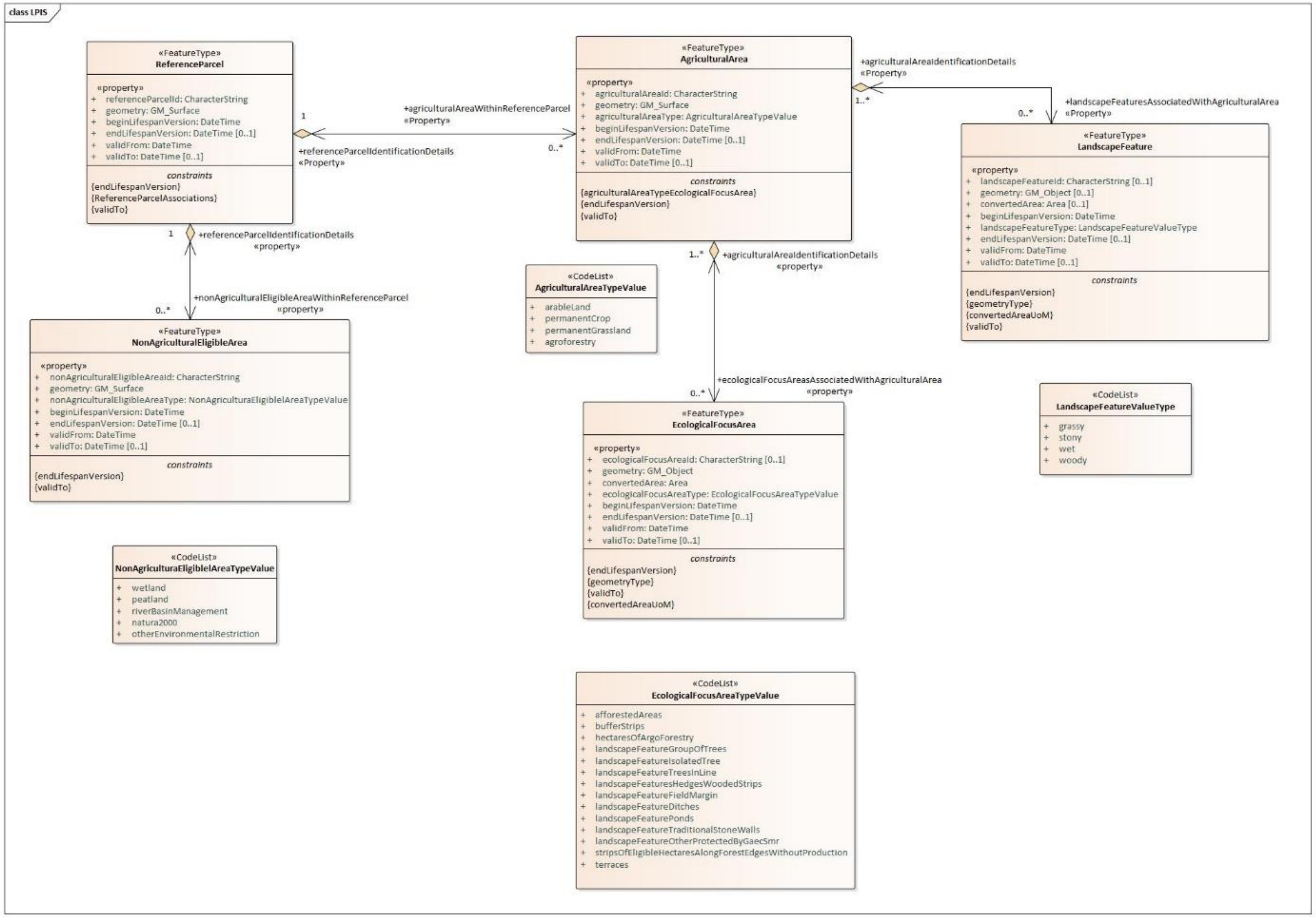
— Each Agricultural Area can be associated to one or many Landscape Feature(s), whilst each Landscape Feature, can be aggregated or spatially linked to one or many Agricultural Area(s).

— Each Ecological Focus Area, if existing, can be composed by one Landscape Feature and each Landscape Feature, if existing, can be associated to one Ecological Focus Area.

The overview of this model is presented in ***Figure 12***.

All feature types together with their definition, attributes, associations and constraints are describe in the feature catalogue provided in the TG.

Figure 12. LPIS UML model – overview



ii. GSA application schema

GSA application schema consists of one spatial object:

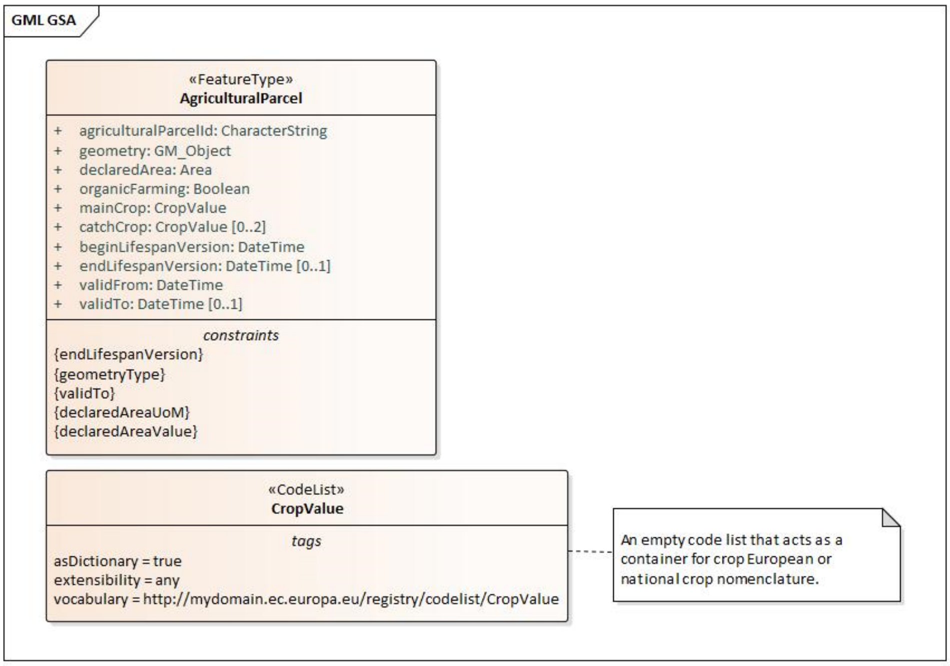
— AgriculturalParcel

This spatial object is made of a series of object-specific attributes (of different types) and constraints. The usual spatial representation geometry of this feature type is surface. However, for sake of protecting the economic interest of the farmers or fulfilling national data protection regulations, simplified geometries, such as points of multipoints are also allowed[14].

To preserve the semantic harmonisation and interoperability of GSA datasets, the type of those attributes providing information about different classification systems is a code list.

An overview of the GSA UML model is provided in ***Figure 13***.

Figure 13. GSA UML model



It should be noted that due to the diversity of crop code lists used in the MS, but also at European level (Crop Production (CROPPROD) , Integrated Farm Survey (IFS), Land Use/Cover Area frame Survey (LUCAS) of Eurostat), it was not possible to mandate a unique nomenclature. Instead, a requirement for publishing the code list in a publicly accessible registry was mandated, as it is shown in ***Figure 13***.

iii. Proposal for the content of the IACS code list registers

For sake of interoperability, some attributes of certain feature type can take only pre-defined values (code-lists). These values have to be shared in publicly accessible registries. In course of data specification development, the following code lists and values were defined and proposed for implementation in a registry:

— Agricultural area (arable land, permanent crop, permanent grassland, agroforestry),

— Non-agricultural eligible area (wetland, peatland, river basin management, Natura 2000, other environmental restriction)

[14] Result of the crop classification pilot project.

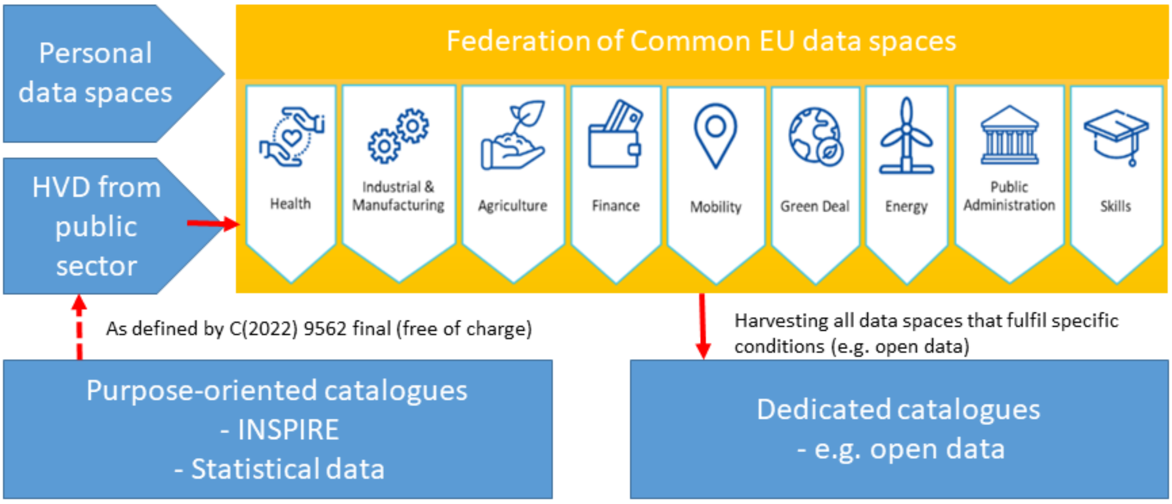
— Ecological focus area (afforested area, buffer strip, hectares of agro-forestry, LF types, such as ditches, field margin, group of trees, isolated trees, ponds, hedges, trees in lines, strips of eligible hectares without production, terraces, other LF protected by GAEC or SMR),

— Landscape features (wet, woody, grassy, stony).

iv. Input to the data flows for the Agricultural Data Space

In parallel to establishing the Common EU data spaces, the EU proposed other data-related initiatives: notably the High-Value Datasets (HVDs) Implementing Regulation under the Open Data Directive. Open data and High Value Datasets should be published in the EU Open Data Portal. ***Figure 14*** presents an overview of these initiatives.

Figure 14. Collaboration between various elements of the EU data services



In future, an EU Common Data Space Catalogue hosting information about the data available in the Common EU Data Spaces will be defined and established by the Data Spaces Support Centre .This EU Common Data Space Catalogue will likely take the form of a federation of catalogues, where metadata from different sectoral data space catalogues is harvested into this EU Common Data Space catalogue :

- Directly from catalogues defined for the sectoral/domain-specific data spaces (Mobility, Green Deal, Agricultural, etc.).
- Indirectly, from cross-purpose and cross-boundary catalogues:
  - INSPIRE Geoportal (for geospatial data).
  - EU Open Data Catalogue (for open data).

The sectoral/domain-specific catalogues will be harvesting these cross-purpose and cross-boundary catalogues, providing indirectly the harvested content into the EU Common Dataspace Catalogue.

Since the EU Common Data Space Catalogue will be a federation of more specific portals, the Commission should be active in promoting, coordinating and using this federation. This might be the natural bridge, providing an overview on data availability. Special care should be taken on who is the authoritative owner of data and how to prevent harvesting twice the same information to avoid duplicates. This will include private and public data providers.

As a result, several actions were pointed out for the future:

- More connections should be established between the EU INSPIRE Geoportal, the EU Open Data Portal and the Agricultural Data Space in order to increase collaboration and avoid different data sharing workflows and duplicated efforts for reporting data in the MS.
- Alignment and interoperability of the different metadata profiles used by each specific community should be established and ensured. DG DIGIT should take care about the semantic interoperability between them.

- Particularly, the alignment between GeoDCAT-AP (including its implementation for HVDs) and the INSPIRE metadata rules, profiles and existing good practices15 is foreseen as a key activity in the near term.

[15] GeoDCAT-AP INSPIRE good practice, endorsed in the past, needs a revision to keep alignment and consistency to current GeoDCAT-AP updates).

e. Conclusions and further steps

The specifications of the TG were tested on the example of the Lithuanian LPIS and proved to be fully feasible as illustrated in ***Figure 15*** and ***Figure 16***.

Figure 15. Thematisation of AgriculturalArea features according to agriculturalAreaType values

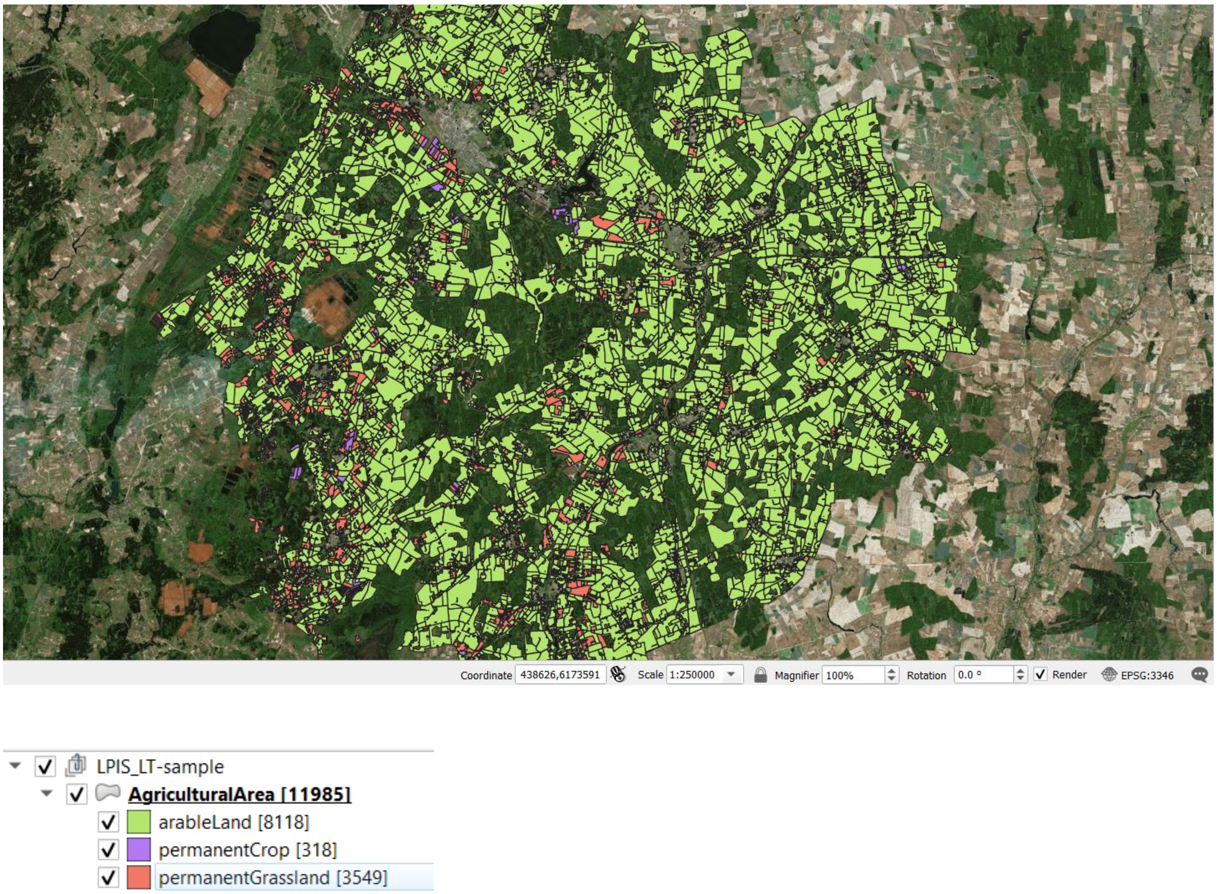
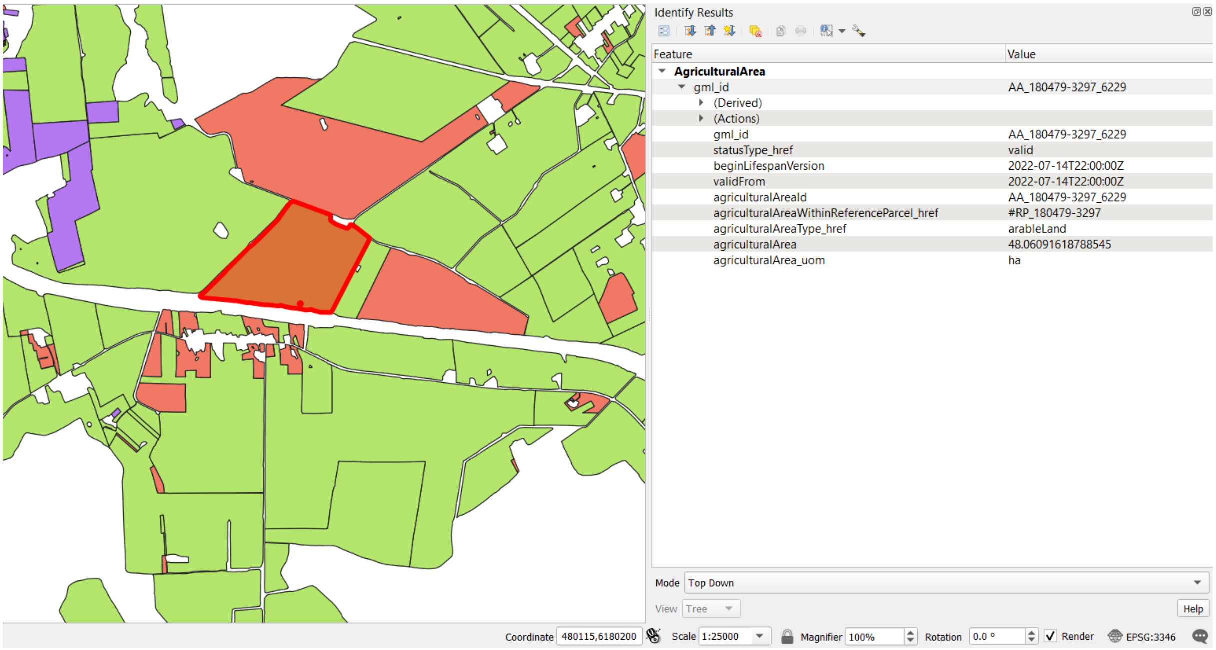


Figure 16. Attributes of a selected AgriculturalArea feature



In course of testing, the mapping from the data models of the TG to the INSPIRE land cover and Land use themes was also performed. If there is a need to further harmonise with INSPIRE, the common European LPIS and GSA models facilitate the task in a large extent.

The TG and the proposal for the content of the IACS code list register help to solve the lack of harmonisation of LPIS and GSA datasets across Europe, which is currently a big obstacle to IACS data sharing and interoperability. The common data models for the LPIS and the GSA datasets, together with a full data specification in INSPIRE compliant form and the related gml application schemas have a key role in this process.

Regarding the roadmap to endorse the LPIS and GSA data specifications, the TG will be shared with DG AGRI, the Paying Agencies (PA) and the custodians of the LPIS and GSA data, as well as with the INSPIRE community. We suggest organising a review and voluntary testing with these stakeholders. The feedback collected will lead to a revision of the TG and the publication of the final version. In parallel, the endorsement procedure will be discussed and agreed with JRC, DG AGRI and the INSPIRE MIG (Maintenance and Implementation Group).

5. Work package 3: soil health use-cases

The objective of this work package was to identify which IACS data are relevant for investigations, correlations and modelling of agricultural practices related to parameters of soil health, such as soil erosion, soil carbon storage or presence of pesticides/antibiotics and land degradation index. Some IACS input data, preferably accessed through the INSPIRE infrastructure will be feed in different models that the JRC D3 Soil Team has developed and will be integrating into the future European Soil Observatory under development. The data will help to calibrate these models and to use them for other research topics and for policy support. The following domains will be considered: the new Common Agricultural Policy, climate and environment.

The work package identified the relevant IACS data in these processes ("data offer": what IACS or IACS-related data are available in a particular Member State's implementation). It also indicated what other data are necessary for modelling purposes in different above-mentioned domains ("data demand": what data must be injected into models). This will identify not only IACS-related data but it may go beyond, identifying other land-use or land-cover data. Finally, it will propose how to close the gaps between available and requested data.

The following soil health related micro-use-cases were developed further:

- soil erosion modelling,
- soil carbon modelling,
- soil contamination by pesticides – geo-statistical analysis,
- land degradation index.

The following tasks were performed for each use-case:

- Task 1. Access to the input data: IACS (LPIS and GSAA) and all possible associated data on farm management and soil conservation (tillage, cover crop application, plant residues application, contouring, etc.). The most critical parameter is the crop type at parcel level (GSAA). Topographic and climatic parameters can be, also, derived from regional and pan-EU datasets already available (ESDAC, Cordex, Copernicus, LPIS QA).
- Task 3.2.2 Data-model integration and model calibration/validation with local or regional information on agriculture and soil biological, physical and chemical properties.
- Task 3.2.3 Model uncertainty and scenario analysis

a. Objectives

Soil erosion modelling

The work presented in this this section was developed under an overarching goal of producing a new generation of soil erosion modelling tools to support decision making in the EU. Through its augmentation with multitemporal data from Copernicus (Sentinel-2) and the Rainfall Erosivity Database at European Scale (REDES), IACS data is shown to provide the basis informative analysis into the time periods of highest soil erosion risk for different crop cultivations in Europe.

Based on the findings of this soil erosion modelling use-case, IACS data is demonstrated as a valuable spatial and informatic backbone that can be enriched with further available data resources in Europe. New multitemporal risk indices can inform land managers and policy makers of the time periods when soil protection against erosion is most necessary. Through the production of field parcel-specific and regional intercomparisons, the multi-scale benefits of IACS data are highlighted which allow new data-driven evaluations at the spatial scale of interest.

Soil contamination by pesticides

The objectives of this Use Case was to set-up a modelling framework that integrates land management histories for LUCAS points in order to try to understand the impact of pesticides residues on soil. This could be done at parcel level as registered in IACS (LPIS and GSAA) and scaled-up as required. The focus should be on crop or crop-types, applied crop rotations, fertilizer regimes (chemical or organic), pesticide applications, tillage and any GAEC measures applied through years. The eventual modelling framework based on the IACS data will be complemented by pan-European geospatial and earth-observation datasets (such as CORINE Land Cover, LUCAS, Copernicus).

Soil carbon modelling

The objective of this use case was to develop a data-driven approach for enhancing the spatial prediction of soil organic carbon (SOC) dynamics by integrating accurate spatial-temporal information on land use and management practices at the parcel level, obtained from Geospatial Aid applications (GSAA) datasets. The methodology combines high-resolution, parcel-level GSAA data with environmental and edaphic variables, such as climate and soil properties, to model SOC changes in European agricultural landscapes.

Land degradation index

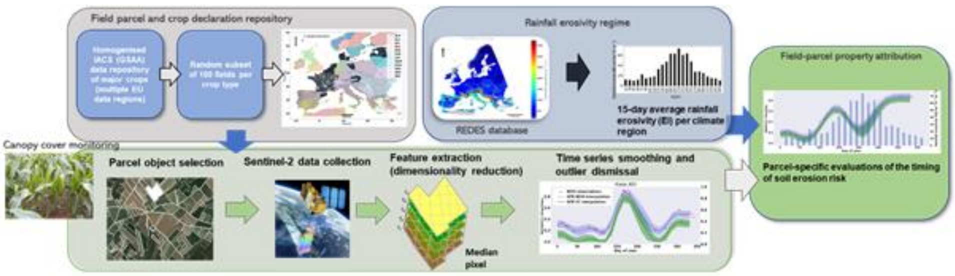
In the framework of the Administrative Arrangement IACS65 the main objective is to enhance the IACS spatial data sharing under INSPIRE, re-use of data towards EU common data space JRC provides DG AGRI with the technical support in assessing and ensuring IACS data sharing across the European Union (EU) for soil modelling. The objective of the 'IACS65 land degradation index' was to enhance discoverability and effective re-use of spatial IACS data (interoperability and use cases) in a coherent policy environment. Specifically after having ascertained that the most efficient system at the moment is the UNCCD SDG15.3.1 indicator, the specific objective was to understand the impact of IACS land use parcel data. The UN Sustainable Development Goal 15.3.1 indicator is implemented in a QGIS plugin that can be customized to perform the Land Degradation (LD) assessments based on global dataset and local capacities when data are available. The Land Parcel Information System (**LPIS**) and the Geospatial Aid Application (**GSAA**) – notably - compose IACS data, their sharing will enable to better monitoring land and soil degradation in relation to farming strategies.

b. Methodology

Soil erosion modelling

This use-case was addressed using a multi-step method consisting of: 1) the collection and harmonisation/homogenisation of a singular GSAA repository from multiple EU member states, 2) acquiring all available Sentinel-2 images during a year to describe the growth cycle of both cash and cover crops in each field parcel, 3) using crop-specific relationships between the Normalised Difference Vegetation Index (NDVI), an abundantly used proxy to assess vegetation cover, and the percentage canopy cover of each crop, and 4) the processing of average 15-day rainfall erosivity values per climate region to describe the pattern of heavy rainstorms throughout the year. Each component of the data processing pipeline was built on the spatial and informatic descriptions already available in the GSAA data repository. For example, the geographic field boundary and crop cultivation declarations allowed both the application of crop-specific models and the association of spatially-specific properties (e.g. rainfall and crop canopy development) to each individual field parcel in a standardised manor across all available data regions in the EU.

Figure 17. Overview of the workflow of the outlined user-case



An overview of the workflow of this outlined user-case is showed in ***Figure 17***. Starting with a standardised repository of IACS data, several dynamic properties were sequentially attributed to each parcel using a combination of methods based on Sentinel-1 and REDES data. The output was a parcel object with a number of new attributed properties relevant for the assessment of soil erosion in a timely manner.

Pesticides

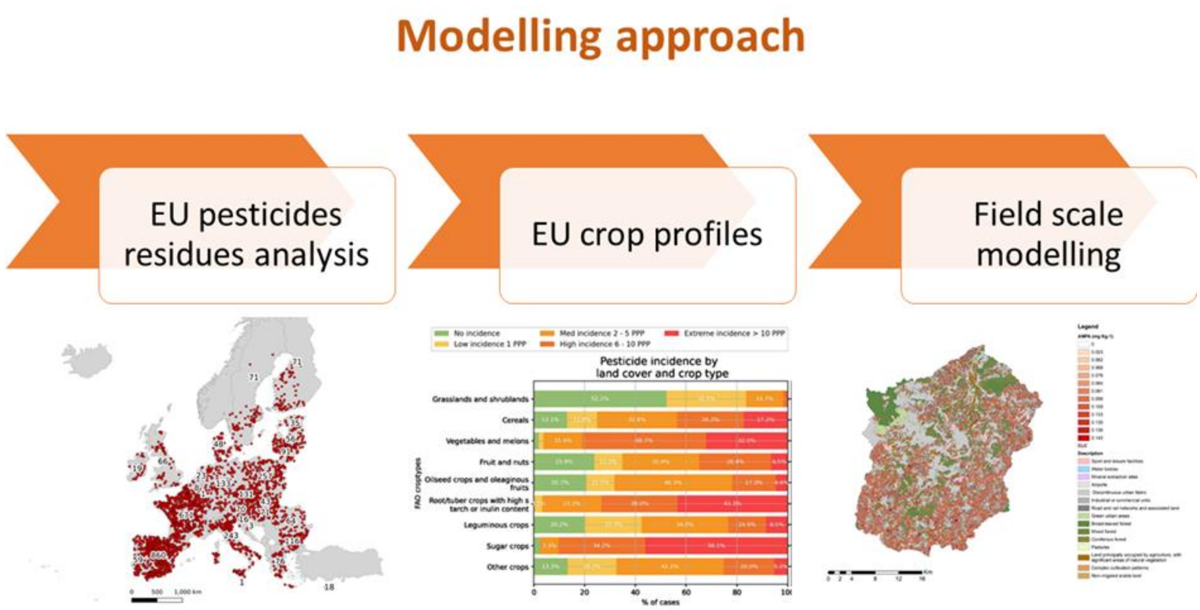
Four tasks were foreseen in relation to the development of a geospatial modelling framework for analysis related to pesticide-related issues.

- Task 0: Identification of suitable geospatial modelling framework and identification of input data.
- Task 1: Access to the input data via LPIS, GSAA and integration with all possible associated data on farm management (applications, tillage, irrigation etc.). Site-specific environmental parameters can be also derived from regional and pan-EU datasets already available (ESDAC, Cordex, Copernicus). Identification and access to Pan-European earth-observation data from available sources.
- Task 2: Data integration and model calibration/validation with local or regional information on crops, agricultural practices and LUCAS points.
- Task 3: Model uncertainty and scenario analysis.

In what concerns the present work it was possible to define a modelling approach with the SWAT model, combine several different datasets with IACS data (LPIS for generic land cover classification, GSAA for crop-related data allowing to construct crop profiles), such as Copernicus (Corine Land Cover (CLC), Copernicus Climate Change Service) but also with LUCAS dataset survey. This allowed to integrate and create input dataset for the modelling exercise.

As a general approach, the entire universe of LUCAS data used for the assessment of pesticides residues in EU soils were used, defining crop profiles at EU level whenever the number of sampling point presented statistical relevance, followed up by a local application of these profiles in a local scale (watershed) with high resolution parcel definition (***Figure 18***).

Figure 18. *General modelling approach*



Soil organic carbon

Changes in SOC stocks in France from 2009 to 2018 were analyzed using a Generalized Additive Model (GAM) with data from LUCAS and IACS datasets. The trained model predicted spatial changes at a 500m resolution. GAMs are semi-parametric regression models that capture nonlinear relationships between variables. The response variable, ΔSOC, was the arithmetic difference between SOC levels in 2018 and 2009, calculated from LUCAS surveys. Explanatory variables included:

- SOC levels and soil clay content from LUCAS dataset;

- Annual mean temperature, precipitation, and their seasonality from WorldClim dataset;
- Latitude and longitude from LUCAS dataset;
- Average cover management factor (Av.C-factor) from the time-series of crop-specific C-factor.

The rop-specific C-factor was calculated for each GSAA parcell for every year between 2010 to 2018.

To evaluate the importance of accurate time-series crop rotation information from GSAA datasets, two models were fitted by changing the average C-factor:

- Complete time series: Av.C-factor from the entire GSAA time series (2009-2018);
- Non-Complete time series: Av.C-factor from GSAA data for LUCAS survey years (2009, 2015, and 2018).

Model performance was assessed using mean absolute error (MAE), accuracy coefficient (Xa), and coefficient of determination (R2). The effect of covariates was examined through partial dependent plots (PDPs).

Land degradation index

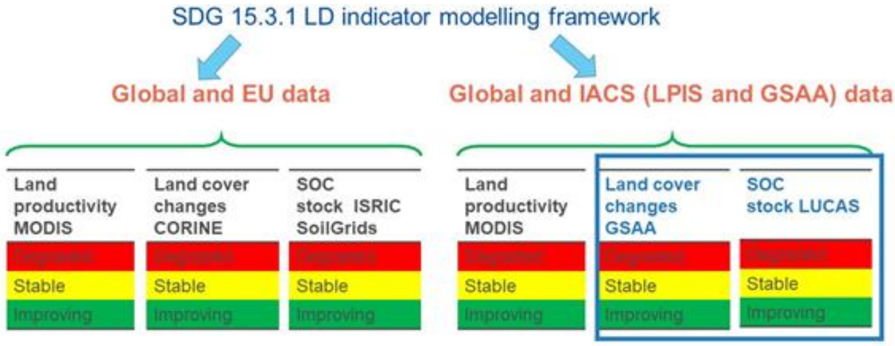
Land Degradation is an umbrella term considering soil threats as a reduction of their ability to deliver ecosystem services, and negatively influence soil health. It is defined as the persistent reduction in the capacity of the land to support human and other life on Earth (IBPES, 2018).

To identify the time series length of IACS data which can best fit with the calculation of SDG 15.3.1 LD indicator, several tests were carried out using the GSAA data and their sharing defined by Art. 68 of Regulation 1306/2013, delineation of agricultural parcels with cultivated crop or crop groups as submitted by the farmer. We found a suitable test at NUT3 level located in southern France (Heraùlt), which provided useful data for the years 2009 to 2018.

The overall goal was to include GSAA land cover time series into the SDG 15.3.1 indicator geospatial framework to detect signs of degradation due to agricultural change in land cover and of course due to land productivity dynamics and SOC stock changes. The hypothesis was that LPIS and GSAA data could be used to tailor the calculation of the SDG 15.3.1 LD indicator, which can add precious information on the parcels geometries and the land cover changes by providing scenarios to develop policy support options. Additionally, methodologies on how to bridge the gaps between available data and requested data for the SDG 15.3.1 indicator implementation are discussed. The most common case was to report the effect of parcel land cover changes (either positive or negative changes) when the global set of sub-indicators reported a stable condition. By replacing the global sub-indicator land cover with the IACS (LPIS and GSAA) parcel land cover to assess the SDG 15.3.1 indicator was easier to find new LD hotspots.

The United Nations Convention to Combat Desertification (UNCCD), custodian agency for the SDG 15.3.1 indicator of LD, has developed a geospatial framework using a set of globally available remote sensing data referring to a defined baseline (year 2000) and a reporting period (2015 and every five years onwards). The SDG 15.3.1 indicator (***Figure 19***) has been implemented in a QGIS plugin called 'Trends.Earth' by the Conservation International institute (Gonzalez-Roglich et al., 2018) https://www.conservation.org/about/trends-earth. This would generate a baseline for the evaluation of the progress toward LDN, and better define solutions such as restoration measurement to tackle LD processes.

Figure 19. Data involved into the SDG 15.3.1 indicator calculation using the global and EU available dataset, and the IACS (LPIS and GSAA) data.



c. Tasks and deliverables

- **Task 0**: Identification of suitable geospatial modelling framework and adapt it to the IACS input data.
- **Task 1** Data acquisition: IACS (LPIS and GSAA) data on parcels geometries and planted crops and land uses allowed for the implementation of a land cover time series at parcel level for the period 2010 to 2018, converted in a spatially harmonised raster at 20m spatial resolution that can be used in the calculation of the SDG 15.3.1 land degradation indicator.
- **Task 2** Modelling: Using the Trends.Earth plugin in QGIS environment, we calculated the UNCCD SDG 15.3.1 indicator using the "one out all out" methodology consider the three sub-indicators combined, i) Land productivity dynamics, ii) Land cover changes (IACS), iii) SOC stock based on LUCAS 500m map.

d. Results

Soil erosion modelling

The feasibility of IACS data for developing new methods to assess soil erosion has been outlined through this user-case study. These developments also represent a key step in the improvement of soil erosion models by using new data-driven methods to generate model input parameters that come from the abundant collections of modern geospatial information. Moreover, the complimentary interactions between the primary information stored in IACS data repositories and external data resources can open new method-based opportunities in soil health research. Thereafter, by 'applying the method to the parcel', these interactions allow the utilities of IACS data to be extended to a range of other research topics that require additional information beyond the primary information stored within IACS data.

An example of the opportunities provided when dynamic properties are associated with individual IACS field parcels was outlined at 2 different spatial scales of reference in section (3). Copernicus Earth observation data (e.g. Sentinel-2, and potentially Sentinel-1) can enrich the core spatial and administrative information contained within the IACS database. Continued progress in Earth observation and remote sensing (e.g. tillage assessment and timing, irrigation, cropping density…) can further enhance these informatic properties to address numerous frontiers in soil health research. Given that these dynamic components of land cover are critical across numerous aspects of soil health (soil organic carbon content, soil nutrient content, soil biodiversity, soil water retention…), their association with IACS field parcels opens a plethora of opportunities to understand contemporary trends in a broad range of factors beyond soil erosion.

A critical primary factor in determining the susceptibility of field parcels to soil erosion is the length and timing of the period that the soil is left without vegetation cover. It is shown here, on a parcel-specific basis, the possibility to infer the timing and length of harvest periods and secondary/cover crop implementations using Sentinel-2 time series information. This information can allow both basic assessments of green cover dynamics in field parcels, but also secondary intercomparisons with other variables (e.g. rainfall erosivity), as undertaken in this report. It is proposed that, with the addition of more static (topography, soil mineral properties) and dynamic (rainfall, soil moisture, crop residue cover) properties with each field parcel from complimentary data resources, that further opportunities will capitalise on the IACS database to model relevant trends in soil health characteristics.

Pesticides

In terms of **scientific** advances, we verified it is possible to calibrate a process-based model for individual contaminants based on the concentration of pesticides residues on soil, following the first EU pesticide assessment. This enables the possibility to estimate pesticide exports associated to sediments, its dissolved fraction on water, but also additional potential off-site effects caused by the resuspension of sediments in water courses. Moreover, it also allows to predict how the pesticide application on soil can affect water quality, and to make use of such predictions for further ecotoxicological assessment.

On a **land management** perspective, the increase in spatial resolution and the combining effect of IACS with supplementary datasets (e.g. CLC, Climate, remote sensing) results in more precise modelling outcomes, and therefore allows increased precision and efficiency in any land management action that follows.

Such modelling exercise can be also fundamental for the determination of reduction rates for pesticides application, thus serve as base for **future policy** developments. Moreover, it can also be used to assess the efficiency of **current policies** in the reduction of environmental impacts of the use of pesticides (e.g. reduction on 50% use of pesticides).

Despite the clear potential evidenced by this work, a **follow-up** is suggested in order to tackle several data limitations as observed during this modelling exercise. The expansion of the pesticides data collection from 3,300 points as a result from this pilot study, to 41,000 considering all the 2022 LUCAS survey points, could provide more robust crop profiles to be used as model inputs, considering additional climate, environmental and socioeconomic conditions. The complementary of the existing dataset with important information such as pesticide application date, additional land management operations, or if organic farming is taking place, could definitely help assessing the impact of these substances in a more precise spatiotemporal context.

Finally, the ultimate consideration would be that a series of scenarios (e.g. pesticide management, organic farming) should be tested in order to assess the efficiency of the current policy strategies (e.g. Soil strategy (EC, 2021)), but also to inform back to the land owners, about the environmental impact of the use of these substances to the environment, and how to tackle them the best way possible.

Soil organic carbon

Both complete and non-complete time series models demonstrated the ability to predict Soil Organic Carbon (SOC) changes between 2009 and 2018, with an average Mean Absolute Error (MAE) of 2.06 g kg-1. The model using comprehensive time series information showed marginally better performance, highlighting the importance of accurate time series data in data-driven modelling approaches. Gaps in time series data can impact model accuracy and lead to erroneous predictions, while complete time series allow for a better understanding of trends and patterns over time.

The combined effect of Av.C-factor and SOC2009 on SOC changes showed a similar covariate response between fitted models. Management practices that encourage soil loss were accountable for significant carbon losses at the European scale. Incorporating land use information and its direct temporal impact on soil mass balance within the SOC modelling framework is essential for creating effective and sustainable land management strategies.

Spatial predictions from the model trained with complete time series information showed higher variation in parts of France characterized by intensive agricultural systems. Intensive agricultural systems are generally characterized by the cultivation of subsequent different crops over the years or even within the same year. In these regions, accurate time-series information of crop cultivation at the parcel level (GSAA) drastically reduces the uncertainty in estimating SOC changes over time.

In contrast, for zones of France characterized by more static agricultural systems, such as pastures, only marginal differences were observed in predicted ΔSOC. Given the considerable burden of collecting and storing detailed time series data at specific parcels, providing accurate time series information in areas characterized by intensive crop rotations, while maintaining less precise data for locations with non-intensive practices such as pastures, could alleviate the data storage burden. This approach would require further analysis of the trade-offs between data collection and data usability across Europe.

*Land degradation index*https://www.conservation.org/about/trends-earth

The results showed in ***Table 1*** that the use of global sub-indicators to assess the UNCCD SDG 15.3.1 slightly underestimated the extent of LD in the case study in Southern France case study (NUT3 Hérault, FR813) compared with the use of IACS enhanced land cover spatial information. The use of LPIS and GSAA datasets represents a clear advancement in increasing the precision and reducing the uncertainty associated with the delineation of LD at parcel scale. Furthermore, IACS land parcels and crop types suggest a way to use all the information available and try to not degrade the detail land use in a set of land cover classes that might not represent well the EU and Member state (MSs) conditions.

Table 1. Land use reported by the LPIS and GSAA original metadata table, translation from the original language to English and conversion codes adopted to obtain the suitable land cover layer for the SDG 15.3.1 calculation.

Code from IACS	Original land use	Land Use Translation	Conversion table Land Use to Land Cover based on CLC guidelines
0	PAS D'INFORMATION	NO INFORMATION	no data
1	BLE TENDRE	TENDER WHEAT	Cropland
2	MAIS GRAIN ET ENSILAGE	CORN GRAIN AND SILAGE	Cropland
3	ORGE	BARLEY	Cropland
4	AUTRES CEREALES	OTHER CEREALS	Cropland
5	COLZA	COLZA	Cropland
6	TOURNESOL	SUNFLOWER	Cropland
7	AUTRES OLEAGINEUX	OTHER OILSEEDS	Cropland
8	PROTEAGINEUX	PROTEAGINOUS	Cropland
9	PLANTES A FIBRES	FIBER PLANTS	Cropland
10	SEMENCES	SEEDS	Cropland
11	GEL (SURFACES GELEES SANS PRODUCTION)	SET-ASIDE (SET-ASIDE AREAS WITHOUT PRODUCTION)	Other land
12	GEL INDUSTRIEL	INDUSTRIAL SURFACES	Artificial
13	AUTRES GELS	OTHER SURFACES	Artificial
14	RIZ	RICE	Wetland
15	LEGUMINEUSES A GRAINS	GRAIN LEGUMES	Cropland
16	FOURRAGE	FORAGE	Grassland
17	ESTIVES LANDES	ESTIVE LANDS	Grassland
18	PRAIRIES PERMANENTES	PERMANENT GRASSLANDS	Grassland

19	PRAIRIES TEMPORAIRES	TEMPORARY GRASSLANDS	Grassland
20	VERGERS	VINEYARDS	Tree Covered Surface
21	VIGNES	VINES	Tree Covered Surface
22	FRUITS A COQUE	NUT FRUITS	Tree Covered Surface
23	OLIVIERS	OLIVE TREES	Tree Covered Surface
24	AUTRES CULTURES INDUSTRIELLES	OTHER INDUSTRIAL CROPS	Cropland
25	LEGUMES-FLEURS	FLOWERING-VEGETABLES	Cropland
26	CANNE A SUCRE	SUGAR CANE	Cropland
27	ARBORICULTURE	ARBORICULTURE	Tree Covered Surface
28	DIVERS	MISCELLANEOUS	Other land

e. Conclusions and further steps

Soil erosion modelling

Outside the scope of enriching IACS with external datasets and methods, the potential to improve soil erosion modelling efforts by increasing the primary information content is heavily emphasised as an outcome of this pilot study. On-the-ground declarations of management practices are critical to understand if the risks to soil health from agricultural practices are to be properly evaluated. For example, during periods without green crop cover, the tillage method and intensity is key to understand the level of soil disturbance and the consequential soil loss. Remote sensing are advancing but have limitations in this perspective (Bégué et al., 2018), since small scale features caused by the tillage of fields are difficult to detect using Sentinel data. Furthermore, crop residues left after the harvesting process are typically hard to distinguish from the background soil, allowing only moderate accuracies using remote sensing-based methods (e.g. Azzari et al., 2019). These important components are difficult to derive and attribute to field parcels without their inclusion in the primary IACS data repositories from Member States.

Based on the outlined user-case, several limitations can be overcome with the integration of declared management practices. For example, using this approach, the total level of soil protection during periods without green vegetation cover may be overestimated or underestimated due to the absence of information on the tillage intensity and level of soil disturbance (e.g. if conservation or no-tillage was implemented). Given that tillage is a key trigger of both soil and tillage erosion, knowledge on when certain tillage techniques are used in each field parcel is highly important for proper assessments of soil degradation through erosion. Declarations on primary and secondary tillage operations within the IACS data system can fill these information voids and allow major steps forward.

Secondarily, declarations on secondary and cover crops can aid the intercomparison between field parcels and give better indications of the impact of different crop rotations on soil erosion. Having this information as IACS attributes in addition to the main crop declaration would allow their direct intercomparison to infer optimal crop rotation/succession regimes. At present, the Sentinel-2 data time series data captures these dynamics of green plant cover, however their direct inclusion would allow the comparison of the effectiveness of different crop rotation systems in preventing erosion in a regionally-specific way.

Pesticides

This study uses the LUCAS survey data for the assessment of contamination from the use of pesticides in the EU soils. Despite the delayed availability of data, in an early stage of this work was already possible to identify the impressive potential from using IACS data combined with other datasets such as land cover, climate, and the LUCAS survey.

The assessment of pollution in a given ecosystem need to be approached in a multidisciplinary way, in order to accurately consider the various forms of transport, change and fate of polluting substances. Therefore, this modelling exercise has shown that integrating several sources of data could benefit the understanding about the contamination of pesticides in the EU. Notwithstanding, also evidences the several obstacles accessing more detailed information, which could later benefit all EU citizens.

Despite the significant scientific advances that are suggested from the modelling exercise, several land management and policies could benefit from this work, namely:

- Potential to execute detailed land management in given areas, whereas the efficiency will be maximised;
- Determination of local thresholds and indicators, in order to execute a more balanced pest management without productivity losses;
- Assess the efficiency of current policies in the reduction of environmental impacts.

The follow-up of this work with additional IACS data but also increase in scale by integrating pesticide residues from the 2022 LUCAS survey would definitely provide more robust and concise outputs under this project.

Soil organic carbon

The integration of comprehensive IACS time series data in the modelling framework significantly reduces uncertainty in estimating spatial SOC stocks. However, the model's accuracy may be limited as it is developed using data only from France, potentially constraining its application in other EU Member States. Including complete time series data from additional Member States will likely enhance model performance and decrease uncertainty across the European Union.

The statistical model (GAM) used generic parameters such as climatic conditions, soil properties, and average C-factor as a land-use proxy. The C-factor indirectly accounts for challenging-to-estimate variables like agrotechnology implementation. This increases model prediction uncertainty. Future research could obtain parcel-level agrotechnology data from field records, incorporating valuable information like tillage intensity and fertilization strategies into models. This would reduce uncertainty, accurately assess economic and environmental trade-offs related to Common Agricultural Policy (CAP) objectives, and support measurement, reporting, and verification processes for carbon sequestration initiatives, ultimately enabling more informed decision-making in sustainable land management and soil conservation.

Land degradation index

As preliminary results of the prototype SDG 15.3.1 at parcel level, the implementation at MSs is still not possible, but for a number of NUTS 2 it will be adapted and validated using the methodological framework developed in IACS65 and the experience gained by performing the modelling exercise. What seems useful for a parcel scale is the early warning system that can be developed, and that can drive to tailored decision in terms of crop types, the establishment of specific rotations, or in the worst case the ban of tillage and the implementation of nature based solution such as Set Aside and buffer strips. The inclusion of additional landscape features (topography, vegetation indices and meteorological data) with the set information used so far in the DG AGRI IACS data sharing process implementation will drastically improve the delineation of degraded land and better capture early signs of degradation in agricultural land.

6. Work package 4: IACS data exploration

a. Objectives

The objective of this work package was to analyse the feasibility to further exploit the full potential of IACS data for the agricultural domain and beyond. In most cases, data found in IACS/LPIS relates only to land claimed or recently claimed for financial support. Similar information should be accessible through other database services for areas not subsidized or fully covered by the CAP, i.e forests, wetlands and unmanaged grasslands.

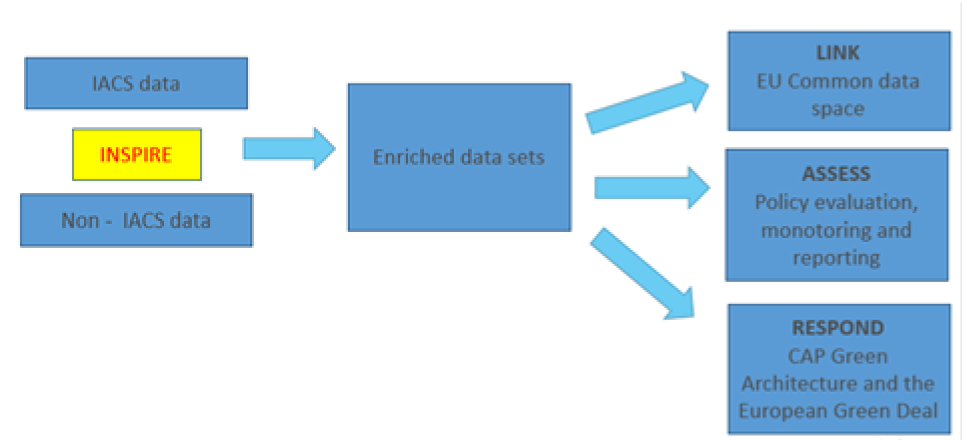
Furthermore, the extended information for IACS can also been linked to other (spatial or not) databases in order to simplify some administration tasks, policy evaluation monitoring; and reporting, as well as to support the development and application of models that are relevant for the environment and climate performance measurement/assessment.

Finally, these 'new' data will be assessed as to their suitability as candidates to feed and contribute to the future EU common data space for agriculture as well as respond to expectations under the CAP green architecture and the Green Deal (biodiversity, pollinators, pollution, circular economy, climate, ...).

Three interlinked goals are addressed (***Figure 20***).

- Link IACS to other data sources to simplify administrative tasks, policy monitoring, evaluation, reporting, environmental performance measurements and assessment.
- Assess how this new "linked dataset" can contribute to the EU Common Data Space on Agriculture and sustainable farm management.
- Respond to the new policy expectations under the CAP Green Architecture and the Green Deal.

Figure 20. Three interlinked goals addressed in the IACS data exploration exercise



This work package did not aim to extend IACS nor to duplicate data sets (which is the spirit of INSPIRE), however, the outcomes could contribute to a possible evolution of IACS in the future.

The outcome was to provide elements to establish a roadmap for actions in 2021, 2022 and 2023 that could be taken by the participating JRC units. The concrete realisation of this roadmap will need further discussion with DG AGRI and will be assessed against the human resources at the disposal of the different participating JRC units and is instantiated through the Spatial Agricultural Information System (SAIS) project to be kicked off in April 2023.The roadmap section is providing information (mainly based on literature review, pilot exercises and meetings with EC services and workshops with the selected Paying Agencies: PT, ES, EE) on the actions to plan to further develop the proposed vision of an integrated system for EU Land Resources.

b. Methodology

The methodology for the IACS65 work package 4 included: preparatory actions and planning, literature review, IACS data discovery, availability and efficient access, other data sources identification and integration, meeting with the selected CAP Paying Agencies to propose data IACS data exploration and the structured request for

IACS data, pioneer implementations based on real IACS data using specialised GIS software and BDAP cloud computing environment, development of demonstrators using available data, creation of a vision of an integrated EU Land Resources platform based on the current policy and research needs, proposal for a roadmap for its pioneer implementation.

The available data consider a wide variety of geospatial data sources, namely: ESDAC (Soil Database), LUCAS and LUCAS Soil modules data, JRC D3 products as developed in different research programmes (soil moisture, heavy metals distribution in EU), IACS databases (LPIS and GSAA) as made available by the collaborating Paying Agencies (PT, ES, EE and others in the future), Copernicus Services and Products, Copernicus Sentinel 1 and 2 data.

In order to ensure and enhance collaboration with the CAP Paying Agencies and other stakeholders, the results of data exploration were first presented to the collaborating Paying Agencies (e-mail communication on the 14th April 2021: Preliminary outcomes: Follow-up: kick-off meeting for IACS data exploration, 15 Feb, IACS65). The results were then communicated to all Paying Agencies at the occasion of the AGRI GREX meeting on the 28th of April 2021.

The roadmap elements for a possible development of an Integrated System for EU Land Resources as presented in the Second part of this deliverable were discussed at a wider forum at the upcoming GREX rescheduled as agreed between JRC and AGRI to end of September 2021 (***Table 2***).

Table 2. Proposed schedule of IACS data exploration as presented at the workshop on February 15th, 2021 with PT, ES, EE, with further adjustments and the real execution dates.

	Action	Deadline date	Actor
1.	Kick-off meeting	15 February 2021	PA (Paying Agencies) + EC
2.	Data prepared and available	28 February 2021	PA
3.	Analyses on data and data integration	31 March 2021	JRC D3
4.	Presentation of preliminary results and call for feedback	20 April 2021	JRC D3 + PA + AGRI D3
5.	Communication to all Paying Agencies, AGRI GREX meeting	28 April 2021	AGRI D3
6.	Possible item in the II JRC-AGRI workshop at the occasion of the GREX	27 September 2021	Member States + EC

The final literature review included JRC reports (technical guidelines…), peer reviewed articles and technical studies. As agreed between JRC and AGRI, targeted interviews (MS-PA, selected JRC units, EC services) will be conducted at a later stage, once the roadmap commented by the Member States. **The final reporting** was provided in the current deliverable in two parts. Part one describes the IACS65 project, its work package 4 focusing on IACS data exploration and integration, the methodology, data needs and scientific basis for the use of IACS data in soil-related matters. Part two provides a **roadmap** (actions, objectives, potential participants, proposed schedule) regarding the feasibility of the elements proposed in this study.

The report was delivered in June 2021 and it was approved by DG AGRI.

c. Tasks and deliverables

The following tasks were planned and have been executed:

Task 4.1 - Preparatory work/planning of actions

Task 4.2 - Literature review (land cover/land use classification)

Task 4.3 - Interviews with MS/JRC about use cases and the access to the data needed to their implementation

Task 4.5 – Structuration of the roadmap

Task 4.6 – Event (see WP 5) - is planned as GREX meeting on 27September 2021

Task 4.7 – Reporting

The following deliverables were planned and have been delivered:

D 4.1 Appropriate documentation and reporting along the execution of the AA leading to the final report and roadmap. (1st draft end of March 2021): delivered.

D 4.2 Final report and roadmap (end of June 2021): delivered.

D 4.3 Online workshop with Paying Agencies (April 2021): AGRI GREX took place on 27 September 2021

d. IACS data exploration: research draft outcomes

The first tasks had been executed: a preparatory work, planning of actions and literature review in the domains of land-cover, land-use classification. They led to the kick-off meeting between AGRI-JRC kick-off meeting that took place on 22nd January 2021.

Multiple levels of IACS data exploration and integration were proposed and they have been further explored until June 2021:

- Soil quality or soil erosion parameters at LPIS or GSAA parcel level, classified based on other available data (e.g. LUCAS) or models results (e.g. RUSLE[16] soil erosion model),
- Parcel level information to locally fine-tune coarser products such as e.g. Corine Land Cover,
- Integration of other data e.g. remote sensing, Copernicus services, ...
    - Land cover classification on crop level from satellite images using LPIS and GSAA data as training input.
    - Crop health classification based on vegetation indices derived from satellite images.
    - Soil quality/health classification based on crop health.

e. Vision of a product: Integrated system for EU Land Resources

After a preliminary analysis of the nature of IACS data contained in the LPIS and the GSAA systems as implemented and managed by the Member States and other geographical data available through existing channels such as INSPIRE, Agri-Food Data Portal, evolving APIs, a need for IACS data integration, further work on data integration, data and services compatibility and system interoperability becomes key.

To fully enable the IACS data potential, an integrated system of EU land resources is proposed by the JRC D3 to DG AGRI. The proposal for such a system, that could be built in different phases, composed of building blocks, provides:

- a possible vision for geographic data management platform (PostGIS database sitting in a JRC Big Data Analytics platform, using Warehouse technology for ad-hoc data retrieval, management and analyses within the current IACS distributed environment),
- a possible vision for geographic data integration with other INSPIRE-compliant available resources, enhanced by a direct access to the remotely sensed imagery, I.e., Copernicus Sentinel 1 and Sentinel 2,

[16] RUSLE see section below: RUSLE formula is an empirical calculation of soil loss based on different sources: the modelling process took several steps combining different remote sensing sources and filed survey collected information.

- a possible vision for geographic data visualisation, processing and analyses (a GIS software environment such as QGIS or ArcGIS): two levels, basic and advanced, described here after.

Basic visualisation, basic statistics and checking data availability (simplified view):

The basic access interface will have limited information in terms of datasets available for download and viewing. It will be more of a graphical repository that will show a summary of the information available in the IACS system with some previously calculated statistics (number of features, area covered, etc.). This repository will be updated as data are incorporated and upgraded in the system under development. In this way, in a friendly and simple way, it will be possible to establish search filters related to countries and regions that will provide us with the information available for each of them. These searches can also be performed through an interactive and dynamic map.

Once the information is geolocated and further details can be requested through a contact form from different user-profiles (area managers, policy makers, researchers, academics), making requests combining different European countries or regions. By filling in the access form (initially limited to EC staff), tickets will be opened and managed by the staff responsible for the data and requests will be provided in order of priority and complexity.

Advanced extraction and processing for analysts or scientists with internal support (requiring additional processing time)

Advanced scientific access to the data will be provided by the technical staff responsible for the database and the operations. These operations will be carried out in The JRC Big Data Analytics Platform (BDAP) through specific database tools, GIS and programs for processing large volumes of geographic data and satellite images. Access to platform is controlled for a limited number of users, although new users can be enabled with read only or editing permissions. Possible operations will be defined according to the policy priorities and needs.

The integrated system of EU land resources should contribute to:

Contribution to (from EU institution and integrated policies side):

- Improve DG AGRI analysis capacity (in the context of NDM CAP) – AFDP connection,
- Contribute to (agricultural) common data space – HVD/INSPIRE,
- Contribute to the Green deal data space,
- Contribute to the work of the policy-DGs such as: CLIMA, ENV, ESTAT, SANTE, and others.

Contribution to (from Member States side):

- Access to integrated data for multiple national institutions,
- Enriched information for final users/farmers/other stakeholders,
- Substantial help with the CAP Strategic Plans preparation, monitoring and assessment.

f. Conclusions

This work package focused on how to enrich IACS data with soil-related information coming from available sources, notably ESDAC and LUCAS Soil, how IACS data can fine-tune or contribute to other services and products such as LUCAS and Corine Land Cover, and how to use these integrated datasets for soil health investigations in the European land resources context.

It showed, for the time-being, potential benefits from such data integration to simplify a number of administration tasks, policy evaluation monitoring and reporting, as well as to substantially support the development and application of scientific models that are relevant for the environment and climate performance measurement and assessment.

A roadmap was presented for implementation of the vision of a pioneer scientific and operational tool for IACS geographical data integration with other land resources data called: **an integrated system for EU Land Resources**. The tool, as currently envisaged, will allow for data visualisation, analyses and more complex modelling. It will also ensure connection to other policy and research areas, notably in environmental, climatic and statistical domains.

The ‘new’ integrated datasets and the proposed system for EU Land Resources were assessed against their suitability as candidates for feeding and contributing to the future EU common data space for agriculture as well as their suitability for responding to the expectations under the CAP green architecture and the Green Deal (biodiversity, pollinators, pollution, circular economy, climate, …).

The explorative activities in the different areas of interest as they were detailed in the above sections and the roadmap itself, were further discussed between DG AGRI and JRC to envisage eventual implementation in future.

This vision has been implemented in a functional prototype. Two live demonstrations were performed by JRC on 31st of May 2021 and 24 June 2021, where DG AGRI D3 and JRC D3 team members were present. The comments and suggestions were be collected to further improve this report.

7. Work package 5: Collaboration with Member States

The objective of this work package was to organise the appropriate ways for communicating with the MS to ensure a common understanding between them and the EC services. This implies a common interpretation (in the implementation perspective) of the legislation about the protection of data and the setup of technical solution for sharing spatial data that is relevant for the environment in the broad sense (including agriculture and climate).

The methodology to ensure the above objective was based on the positive results over the two last years in the context of AGRI "process". To meet this objective events were organised as summarised in the tasks and table. **Some events were combined to increase efficiency.**

Given the particular situation due to COVID crisis, the missions (physical meetings) to Paying Agencies could not be guaranteed, even though the physical meetings are very helpful and generally boost the motivation of the MS. Therefore, in the first months of this WP selected PAs were contacted to present the project and invite them to participate in actions (in WP1, WP2 or WP3, as well as for WP4). A set of PAs expressed their interest for the Interoperability as indicated in the survey conducted by JRC D.5 in course of April 2020.The milestone events organised in the framework of the project

The events listed below, are pre-selected and reduced in numbers, at least for the physical meetings, due mainly to the sanitary COVID crises.

The project was kicked off on the 12th October 2020 with a meeting, with involved European Commission stakeholders and involved units on Webex. The meeting was divided into the opening plenary session, where a roundtable was organised annd the main project objectives explained. The policy-related contexts were presented by DG AGRI and DG ENV.
The second technical session focused on more in-depth technical objectives, presentation of work packages and discussions. As conclusions, a more interactive contacts should be established with the Member States to involve then in the project. Moreover, a special dedicated brainstorming and a kick-off of the work package 4 on data exploration and integration should be called.

2 presentations were performed at the **DP-RDC in September and October 2020**.

1 presentation was performed at the **NIVA** (WP3 – interoperability) IACS data sharing workshop on **24 November 2020**

Support of 2 presentations were provided at **MIG committees by AGRI in October and November 2020.**

Support to AGRI bilateral meetings with ES, EE, NL, IT, DE and PT in **October, November, December 2020.**

JRC supported provided to: IACS data sharing of the actions contributing to **the Environment Knowledge Community**, especially in the framework of the **Task Force on Green Data (kicked off December 2020).**

DG AGRI organised on 13th of April 2021 an EC Services IACS Data state-of-play meeting to inform about the initiatives and the work in progress.

A meeting was organised with 3 Member States (PT, ES, EE) on the 15th of February 2021 to define a framework on data exploration and integration and to ask these Member States to share the data. The IACS data have been received in further steps and the communication channels with the MS were open. The interim results have been presented at the AGRI GREX meeting and then the final results at AGRI GREX meeting on the 27th September 2021.

AGRI GREX Meeting on 28 April 2021

The IACS data sharing project was officially presented to all the Member States at the occasion of the AGRI GREX meeting. An entire session was dedicated to data sharing legal aspects, clarifications and practice. Some first practical results were presented when it comes to work package 4: data exploration and integration. The WP4 defined the main lines for research and trials, Soil erosion or soil quality elements at parcel level for a farmer/user, parcel level information to fine-tune larger products (CLC, Lucas, ...), how to integrate data or indicators (RS, DB, …), presented literature review, provided first analyses of the received and explored IACS data along the defined lines from the 3 participating Member States (PT, ES, EE).

AGRI GREX Meeting on 27 of September 2021

Progress was shown and discussed with the Member States. In order to show the progress on IACS data discoverability achieved during the last months through INSPIRE (from beginning of June to end of September 2021), the statistics on number of metadata resources, downloadable and view data sets were presented to the audience, where IACS data throw positive trends:

- 3 new countries provided IACS Data according the new TG for the first time (Austria, Lithuania and Portugal).
- 3 countries improved their IACS data resources available through the Geoportal (Germany, Denmark and Latvia), while no countries loosed them in the period.
- Lack of metadata according the new TG still exists for 19 countries, which corresponds to a 61% of the EUR27 countries, plus Switzerland, Iceland, Liechtenstein and Norway.

In the Interoperability WP two pilot projects - one in the LULUCF, the other in the crop classification domain – have been finalised. Based on the outcome of the pilots, some general conclusions on the technical measured needed for interoperability have been drawn. The most difficult part is semantic interoperability, which related to the differences in the definitions of spatial objects of various domains, as well as to the classification nomenclatures. Respecting the specificities of the fields, mandatory harmonisation of the concepts is less feasible. Instead, precise and publicly accessible documentation in registries will be promoted.

The other issue of reusing IACS spatial data is linked to the (missing) life cycle information of spatial objects. In this respect, the requirements and recommendations of INSPIRE will be followed. In addition, the Commission will further emphasize the importance of good and meaningful metadata, expressed in the quality of the Abstract and Lineage metadata element.

A new interoperability pilot, related to landscape features, will be launched very soon. This project may support the PAs in preparation and monitoring the implementation of their strategic plans. The question is whether the data of the existing EFA layer and/or other large-scale third-party datasets (e.g. topography) can be reused for identification and quantification of landscape features. MS are called to participate in and/or support this pilot.

The pilot projects will provide input to Part 2 (Interoperability) Technical guidelines (TG) on IACS-INSPIRE data sharing. Some outcomes of these pilots have a minor impact on Part 1 (Data discovery) of the TG. The Commission will update Part 1 at the end of the process.

A user case-study was presented by Francis Matthews, a PhD researcher undertaking dynamic modelling of soil erosion within the collaborative doctoral partnership of the JRC. This gave an example of how an end-user could utilise IACS data to perform relevant scientific research with policy significance. The presentation showed how IACS data can form the informatic backbone of a time-specific approach to the assessment of soil erosion using remotely sensed data for parcel-specific crop phenology timeseries alongside the JRC database on the EU-scale rainfall erosivity risk (REDES). An example was given of the benefits of a homogenised IACS database from multiple member states, allowing a query-based selection of a singular crop to show the seasonal variation in the associated erosion risk across multiple countries. Finally, an outline was given of the benefits of IACS parcel-vector information for characterising the connectivity of eroded soil and associated organic carbon, nutrients and pollutants to assess the off-site consequences of soil erosion.

Finally, JRC showed in a presentation different approaches undertaken to discover, access and explore IACS data, in particular the Land Parcel Identification System (LPIS) and Geospatial Aid Application (GSAA) datasets. Technical details showed the process of IACS data exploration and integration, which consisted in the following steps. A possible design of an IACS integrated database together with its GIS information system were presented. The process of IACS data ingesting into a database was presented, taking into consideration data sources and data structures. Some obstacles were identified.

Schema mapping between national implementations and a central repository was explained, and semantic aspects were discussed. Data from the INSPIRE geoportal were privileged, other MS platforms were considered, including other data of interest. A process designed and carried out to ingest data, utilised libraries, scripts and protocols were shown.

Then, an example of the big data and processing platform – BDAP (Big Data Analytics Platform) was provided together with different methodologies for data analyses using remote sensing techniques. Main characteristics of BDAP and some explanation about parallel processing followed up. NDVI script presentation with results examples (graphs and maps). Examples related with grasslands cover (LPIS), maize crops (GSAA) and LUCAS points in various parts of the EU, including the collaborating Member States (Estonia, Spain, Portugal) were shown and discussed.

Some examples of the interactive tools were proposed allowing for the interaction with IACS and integrated data. Possible basic and advanced user interfaces, with different contents and separate ways to interact with data were shown.

A focus was put on how to enrich IACS data with soil-related information coming from available sources, notably ESDAC and LUCAS Soil, how IACS data can fine-tune or contribute to other services and products such as LUCAS and Corine Land Cover, and how to use these integrated datasets for soil health investigations in the European land resources context.

Finally, a Roadmap for further actions and implementation was presented. A vision of a pioneer scientific and operational integrated system for EU Land Resources was described. The latter will allow for data visualisation, analyses and more complex modelling. It will also ensure a connection to other policy and research areas, notably in environmental, climatic and statistical domains. A proposed IT environment was analysed.

Interoperability pilots were explained and discussed during the **EEA EIONET NRC for agri-environment meeting on 27 May 2021**. LULUCF and Crop classification use cases were presented.

The **INSPIRE Discoverability Clinic Workshop** was organised online (webex) by JRC B6 Unit with support of JRC D5 Unit, on **8 June 2021**, 9:00-12:30, as a part of work on AA EDEN (IACS65). The WS was attended by 109 participants including MS (PAs and INSPIRE NCPs), DG JRC, DG AGRI and DG ENV. Main objectives of the workshop were:

- To support MS Paying Agencies (PAs) in creation and publishing the metadata related to IACS data sets in accordance with INSPIRE Metadata technical guidelines and Technical guidelines on IACS spatial data sharing. Part 1 - Data discovery.
- To improve networking between PAs and INSPIRE National Contact Points (NCPs).
- WS Report and materials have been shared with DG AGRI. The report was also presented on the INSPIRE MIG-T meeting on 09 July 2021

The INSPIRE Discoverability Clinic workshop increased the indicators on availability, but more efforts should be done to achieve Pan-European coverage.

The **interim meeting was called on the 15th of December 2021** on Teams. The main goal was to summarise the state of play of each work package of the project, collect potential concerns or requests and propose a way forward to achieve the subsequent deliverables on time. Progress was obtained. Member States and Paying Agencies are registering metadata in the INSPIRE Geoportal. This is visible through the new frontend or user interface of the geoportal, which is ready to be launched when the Implementing Act on High Value Datasets (HVDs) enters into force. The INSPIRE Discoverability Clinic workshop held on 8th June 2021 increased the indicators on availability, but more efforts should be done to achieve Pan-European coverage. For the data interoperability, the experts contracts were distributed and the work on interoperability Part 2 was continuing. The work in WP3 was started and some progress was obtained. Other parts of work were on track.

The **kick off meeting of the LF pilot project took place on 3 February 2022** with participation of LT, CZ, RO and NL. The participants presented the first steps of the implementation: the selection of test areas and semantic mapping between the broad categories of LF defined by the Commission and the local nomenclature used by the PA for the former EFA and GAEC7 elements. The semantic mapping has been performed from the selected third-party datasets too.

Promotion of the IACS65 Project work and activities in the scope of the **'Food4Thought' periodic seminar organised by JRC.D5 (9th March 2022).**

JRC supported the presentation of **DG AGRI at the MARS conference held on 12 September 2022** in Barcelona, Spain.

A work package 3 (soil health use-cases) dedicated meeting took place at DG AGRI premises in **Brussels on 20th October 2022**. The work has been presented on soil erosion, soil contamination by pesticides, soil organic carbon and land degradation index.

The 5th annual meeting was organised by DG AGRI in Brussels on **13th December 2022.**

Finally, a considerable final **3rd IACS data sharing workshop was held** at JRC Ispra premises 28 February – 1 March 2023. It succeeded in bringing together different communities of practice, from Common Agricultural Policy Paying Agencies, through Mapping Agencies, Agricultural Ministries, Statistics Agencies, INSPIRE-related contact points, farming industry, practitioners in these aspects and finally European Commission and EU Agencies.

8. Work package 6: Project coordination

a. Meetings

The overall project duration was 30 months. The project has been implemented in collaboration with the JRC participating units, the relevant DGs (AGRI and ENV), and with external experts.

The JRC organised a kick-off workshop on-line to present the project leading team and to discuss the firsts actions and the modalities for collaboration.

Physical meetings or video conferences between DG AGRI and DG JRC were foreseen and delivered at critical milestones of the project, more precisely in ***Table 3***:

Table 3. Meetings between DG AGRI and DG JRC

Meeting	Type of deliverable	Delivered[17]	Location	Time of delivery
Kick-off meeting	Meeting minutes	0.25	online	October 2020
Inception review	Meeting minutes	5	online	March 2021
WP4 review	Roadmap	6	online	May 2021
Interim review	Meeting minutes	14	JRC	December 2021
Draft final review	Meeting minutes	28	online	April 2023
Final report	Final report	30	AGRI	April 2023
Periodic consultations	Meeting minutes	Monthly	Online (mostly)	Monthly or 3-monthly

At the end of the project, the JRC produced the current concise draft of the final report describing the activities performed during the AA. The final report will be submitted no longer than 30 days after the end of this Agreement.

The JRC had identified a leader and a back-up per work package who was in contact on a regular basis with the work package leader in DG AGRI. JRC provided an overview of the team at the kick-off, and informed DG AGRI of any key changes during implementation.

[17] In months from signature of the AA.

9. **Conclusions**

a. IACS data harvesting

JRC D3 Soil Team has been working on harvesting and collecting IACS data from several sources which made available these data, in order to create a unique database of IACS data. This in fact will be the focus of the next SAIS Project.

More in details, data harvesting has been carried out from the following types of sources:

- Inspire Geoportal (High Value Datasets): https://inspire-geoportal.ec.europa.eu/ (on February 15th 2022, 2448 Datasets were available, 1362 downloadable and 1491 viewable);
- MS National geoportals;
- other national services;
- Agri-Food Data Portal.

The reason why not only Inspire Geoportal was considered in the data harvesting process is that, as previously mentioned, not every MS made available IACS data, which sometimes can be found on National geoportals instead or other web-services. Agri-Food Data Portal proved to be a crucial connection and support to the research of data through MS services.

The following picture (***Figure 21***) shows all the IACS data (GSA, LPIS, plus some extra data as for example reference parcels) which were found on the original data sources, harvested and uploaded on the new database.

Figure 21. IACS data uploaded and currently present on the IACS database

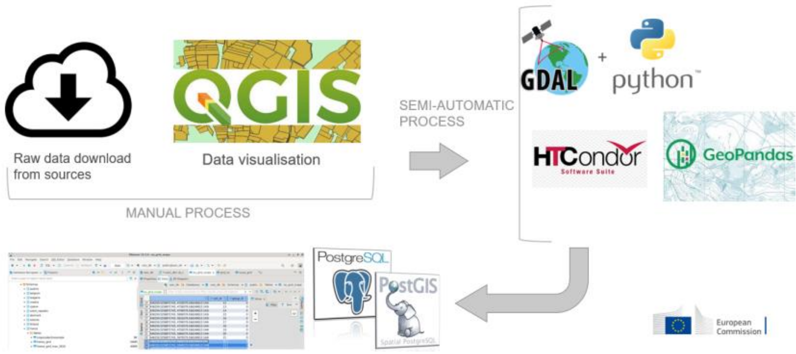
IACS Available data - SAIS Database
JRC

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Austria (AT)										GSA LPIS Extra data	GSA LPIS Extra data	GSA LPIS Extra data	GSA LPIS Extra data	GSA LPIS Extra data	GSA LPIS Extra data	GSA LPIS Extra data	
Belgium.Flanders (BE)											GSA		GSA		GSA		
Belgium.Wallonie (BE)										LPIS	LPIS		GSA LPIS	LPIS	GSA LPIS		
Bulgaria (BG)													LPIS				
Croatia (HR)							GSA										
Cyprus (CY)														GSA			
Czech Republic (CZ)													LPIS				
Denmark (DK)					GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA			
Estonia (EE)														GSA			
Finland (FI)										Extra data		Extra data			GSA LPIS Extra data	GSA LPIS Extra data	
France (FR)				Extra data	GSA Extra data	GSA Extra data	GSA Extra data	GSA Extra data	GSA Extra data	GSA Extra data	GSA Extra data	GSA Extra data	GSA Extra data	GSA	GSA		
Germany.Brandeburg (DE)													GSA LPIS Extra data				
Germany.Niedersachsen (DE)													GSA				
Germany.Nrw (DE)	Extra data	Extra data	Extra data	Extra data	Extra data	Extra data	Extra data	Extra data	Extra data	Extra data	Extra data	Extra data	Extra data	GSA LPIS Extra data	GSA LPIS Extra data	GSA LPIS Extra data	GSA LPIS Extra data
Italy.Sud Sardegna (IT)															GSA		
Latvia (LV)														GSA		GSA Extra data	
Luxemburg (LU)	LPIS	LPIS								Extra data	LPIS Extra data	LPIS Extra data	LPIS Extra data	LPIS Extra data	LPIS	LPIS	
Netherlands (NL)				GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA	GSA
Portugal (PT)						LPIS	LPIS	LPIS	LPIS	LPIS	LPIS Extra data	GSA Extra data	GSA Extra data	GSA Extra data	LPIS Extra data	LPIS Extra data	
Slovakia (SK)													LPIS	LPIS			
Slovenia (SI)														GSA Extra data	LPIS Extra data	GSA	
Spain.Andalucia (ES)													LPIS				
Spain.Castilla y Leon (ES)													LPIS				
Spain.Catalonia (ES)													GSA LPIS				
Spain.La Roja (ES)													LPIS				
Sweden (SE)								LPIS		LPIS	LPIS	LPIS	LPIS	LPIS			

In addition to the data illustrated in the table (***Figure 21***), QA points of all the EU Countries, from year 2015 to year 2022, were also made available on the database.

Data in the IACS database has been ingested in two steps schema provided below (***Figure 22).*** One more manual or non-automatized, like the download of the data from the different sources and first visualization of the data to check the CRS, attributes, etc. Once we have the raw data in our system we have been performing and semi-automatic process to upload all the data to the Postgres database stored in our big data analytics platform (BDAP) with high capability of processing to deal with big datasets.

Figure 22. Data ingestion process in the IACS database



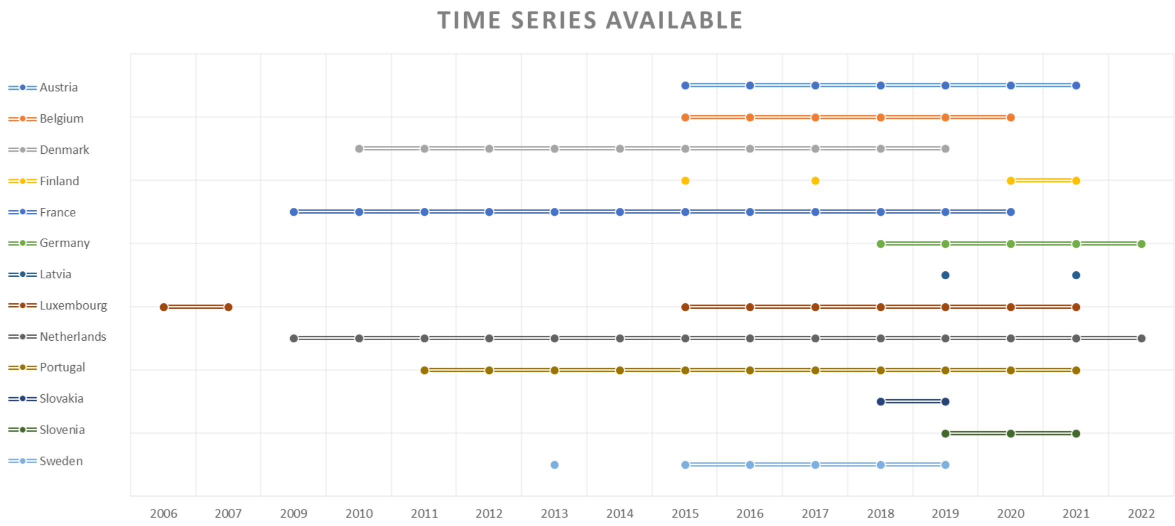
Numbers and statistics of the available data:

In the database we can find information of different nature to support the analyses and complement spatial information with sources of administrative, physical or other thematic nature. The first statistical summary is just about geographical IACS information polygons. Some kind of parcel, can be GSA, LPIS, reference parcels or other kind of delimitated plot in the agricultural space of the EU. In total we can find data of **20 different countries** (complete or regional datasets) in **16 years** (from 2006 the oldest one to 2022 the last) spread over **180 tables** containing about **300 million** of geographical features (polygons) with agricultural information from national or regional systems managing the CAP.

We could highlight some countries and years as the most complete in terms of information. Although more and more countries are gradually being completed, we currently find cases such as **France, Austria** or **Portugal**, with **millions of parcels** in different years as the most successful cases when it comes to finding and incorporating data into our system. In relation to the years with the highest number of data incorporated, we would highlight the year **2018** with more than **50 million** plots from different countries. As we have mentioned before we also have quality assessment reference LPIS centroids. With more than 70 million of points in several years from 2015-2020, these would be the only data sources with complete annual coverage of the entire EU territory.

It is of utmost importance to analyze the evolution of land parcels. To this end, we aim to present examples of countries or regions where time series or datasets are available at various points in time (***Figure 23***). This will allow us to observe the stability or changes in land cover or land use in a precise and reliable manner. The use of such datasets enables us to scrutinize the evolution of land cover or land use at a highly detailed scale, as it provides accurate geometry and up-to-date information on crops or coverage. While we acknowledge that other datasets or tools, such as Corine Land Cover or remote sensing analysis-based classifications, can also reveal the evolution of land cover or land use, we emphasize that the accuracy of such information is not as reliable as that obtained through the use of datasets with a level of detail comparable to that of the IACS data, which provides exceptional accuracy in terms of geometry and attributes.

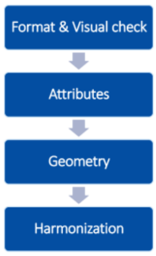
Figure 23. Available time series in the IACS database



Sometimes errors were encountered on data before ingestion, such as invalid geometries, duplicates of the same geometries in what should have been different regions, gaps of geometries, ecc. These errors are not very frequent (for example in 2018, 17 out of 9.5 millions of parcels have invalid geometries), but still they represent a problem when operating with data, since one invalid geometry can give an error in a query.

For this reason, when ingested in the new database, data are subjected to a **consistency and quality check** process (***Figure 24***)

Figure 24. Consistency and quality check process



The first step of this process consists in format and a visual check, followed by the attributes check, in details answers to the following questions are given:

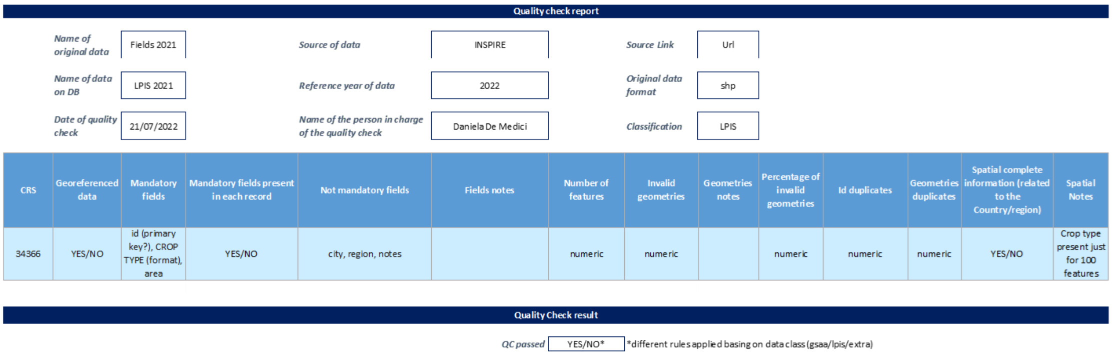
- "Fundamental" fields of the attribute table (are they present?)
- Is there a metadata field explanation?
- Is there an alphanumeric code for fields information/Legend?
- Are there any null fields, or not coded values, (with the focus on fundamental fields as crop type)?

The third step is represented by Geometry check:

- reference system (is it defined?)
- completeness of data (is there any geometry gap?)
- is there any duplicates of records, or intersection with Countries borders?

The quality check process results in a quality check report with the following format (***Figure 25***):

Figure 25. Format of the quality check report



Quality check report					
Name of original data	Fields 2021	*Source of data*	INSPIRE	*Source Link*	Url
Name of data on DB	LPIS 2021	*Reference year of data*	2022	*Original data format*	shp
Date of quality check	21/07/2022	*Name of the person in charge of the quality check*	Daniela De Medici	*Classification*	LPIS

CRS	Georeferenced data	Mandatory fields	Mandatory fields present in each record	Not mandatory fields	Fields notes	Number of features	Invalid geometries	Geometries notes	Percentage of invalid geometries	Id duplicates	Geometries duplicates	Spatial complete information (related to the Country/region)	Spatial Notes
34366	YES/NO	id (primary key?), CROP TYPE (format), area	YES/NO	city, region, notes		numeric	numeric		numeric	numeric	numeric	YES/NO	Crop type present just for 100 features

Quality Check result

QC passed YES/NO* *different rules applied basing on data class (gsaa/lpis/extra)

Fourth and last step is represented by data **harmonization**: at the moment data are ingested in the new database keeping the original structure and information. The intent of the future though, is to transform the original table in a final conversion table.

Data harmonization in fact, is a crucial step, as it was found also during the Workshop in March 2023, to be important when data from different Countries are considered by users. In many scientific papers it is underlined how a data harmonization, especially for what concerns the fundamental information (e.g. crop type), in terms of classes or language, would greatly improve the utility of IACS data and their operability.

IACS data has been the main source for the production of mapping products which, alone or in combination with other sources, have produced a number of intelligent dashboards for dynamic visualisation or analysis. It allows us to have a better understanding of the data and visualize it in a way that is intuitive and easy to interpret. These dashboards have been developed in the BDAP platform with a tool called voila, a python library to simplify the creation of Voilà dashboards. It contains functions and classes that allow for fast development of data analytics dashboards containing charts (using Plotly python library), datatables from Pandas DataFrames, SVG plots, and interactive maps. We have developed several dashboard to show dynamically the data available in the database (***Figure 26***), the information available about crop-classification in parcels (***Figure 27***), land cover percentage per pixel (***Figure 28***) and the combination of IACS data with RS imagery, extracting NDVI per parcel between 2 referenced dates (***Figure 29***):

Figure 26. Dashboard showing in a dynamic way the available data in the database

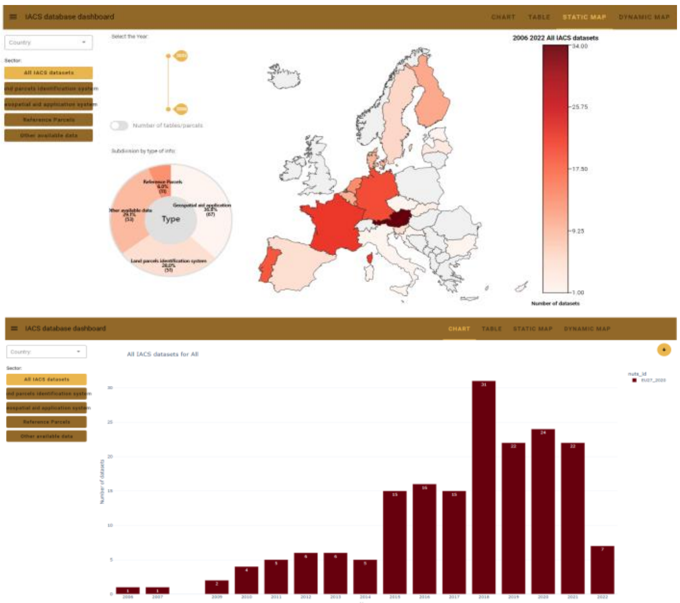


Figure 27. Dashboard showing information available about crop-classification in parcels

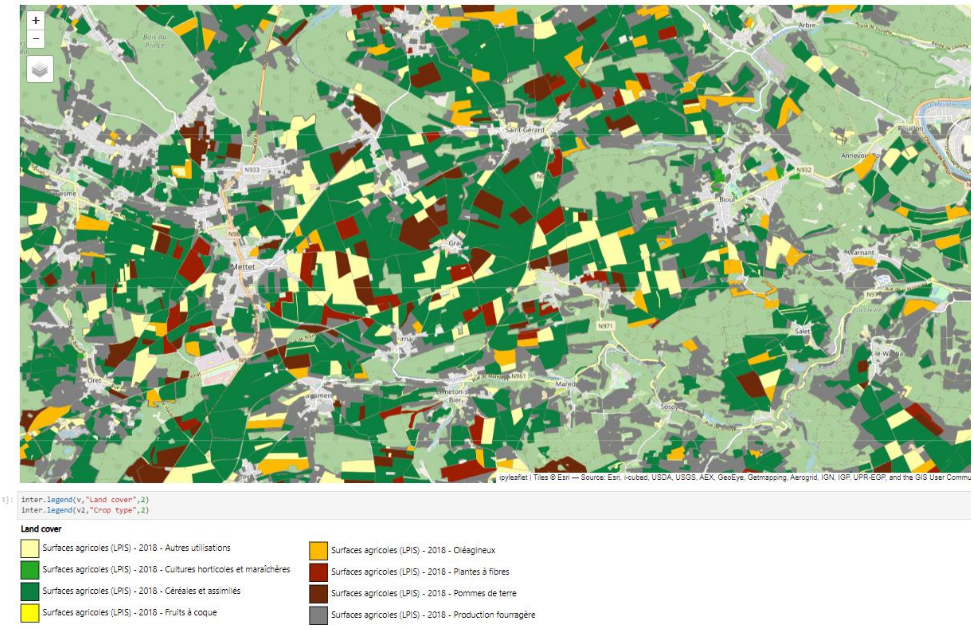


Figure 28. Dashboard showing land cover percentage per pixel

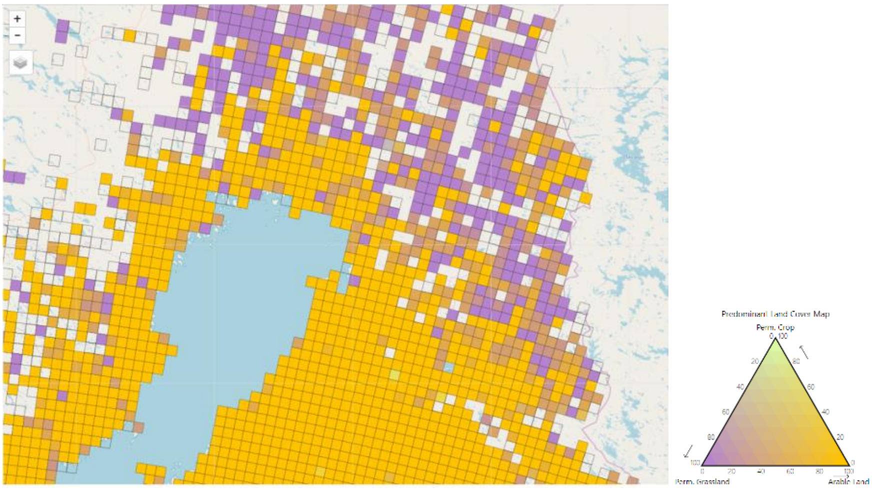
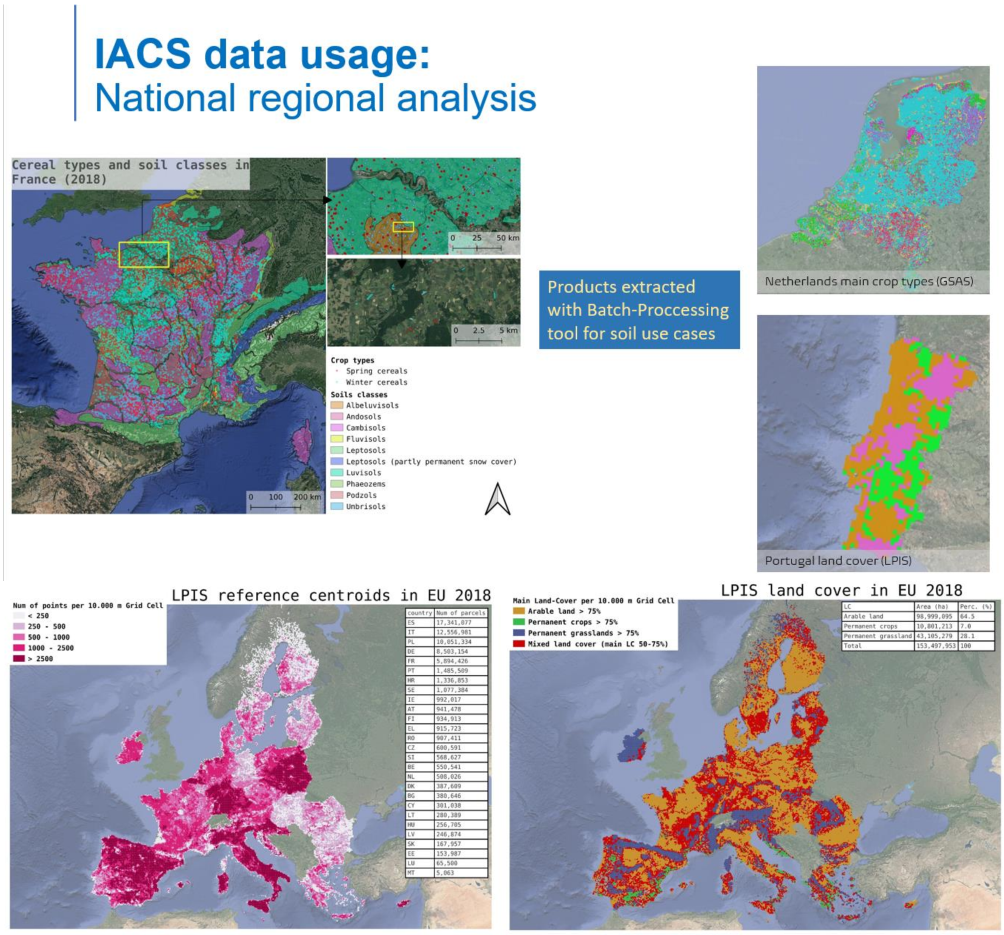


Figure 29. Dashboard showing the combination of IACS data with RS imagery, extracting NDVI per parcel between 2 referenced dates

Other mapping products, tables and graphs have been created for the elaboration of articles, reports, and other scientific documents, for which IACS data have been a fundamental source of analysis in combination with other data. Also, in order to increase the scale of analysis from the parcel level to more general to less detailed scales (regional and national), processes of generalisation of these data have been developed, creating other products based on the IACS data showing cells showing the combination of possible land use and land cover in a more generic or disaggregated way (***Figure 30***).

Figure 30. National regional analysis - Products extracted with Batch-Processing tool for soil use cases



As the project involves the analysis of large volumes of data related to land management and land use. While this data presents us with a wealth of valuable insights, we also face various challenges related to data consistency, organization, and translation. We have encountered a big number of parcels per county region and complex geometries, which require the development of batch processing techniques and topology rules to optimize data processing. Additionally, we deal with time series data that can result in duplicated data, so we have implemented a database parcels management system to ensure data accuracy. Finally, we encounter terminology questions that require semantic harmonization rules to ensure consistent use of terminology across different data sources. In this report, we present some of the specific strengths and weaknesses we have encountered in our project and explain the strategies we have implemented to address them.

Heterogeneity of data:

- Language. Automatized translations: To overcome the challenge of working with data in multiple languages, we utilize automated language translation tools to quickly and accurately translate large volumes of data.
- Crop/cover classes. Grouping land covers/land uses: To simplify the analysis of different crop and land cover classes, we group similar categories into broader categories to more efficiently analyze and interpret the data.
- Attributes. Group/divide split useful columns: To better organize relevant data attributes, we group or divide columns to make the information more clear and accessible for analysis.
- CRS. Global transformations: To address the challenge of working with global data in different coordinate reference systems, we use techniques for global transformations of CRS, allowing us to integrate data from different sources and facilitate analysis and comparison.
- Parcels management information. Further and deeper analysis (RS): To gain deeper insights into parcel management information, we utilize advanced analysis techniques, such as remote sensing (RS), to

obtain a more detailed and accurate understanding of land management and land use patterns and trends.

Massive raw data:

- Big number of parcels per county region. Development of batch processing: With a large number of parcels to process in each county region, we implement batch processing techniques to optimize data processing and ensure efficient use of resources.
- Complex geometries. Topology rules: To handle complex geometries, we implement topology rules to ensure data consistency and accuracy during data processing.
- Time series. Data duplicated. Database parcels management: To manage time series data and avoid data duplication, we implement a database parcels management system to ensure data accuracy and integrity.
- Terminology questions. Semantic harmonization rules: To ensure consistent use of terminology across different data sources, we implement semantic harmonization rules to standardize terminology and avoid confusion during data processing and analysis.

b. Project conclusions

The IACS65 project by its nature succeeded in bringing together different communities of practice, from Common Agricultural Policy Paying Agencies, through Mapping Agencies, Agricultural Ministries, Statistics Agencies, INSPIRE-related contact points, farming industry, practitioners in these aspects and finally European Commission and EU Agencies.

Additionally, the final 3rd IACS data sharing workshop provided place for exchanges, debate and discussions and indicated potential steps forward.

The discoverability and accessibility work package was extremely helpful for showcasing how the INSPIRE infrastructure is re-used for IACS data sharing purposes, promoting the use of the INSPIRE tools currently available for IACS, and discussing on the basis for the upcoming European Data Spaces, and the European Agricultural Data Space in particular. The Technical Guidelines part 1 on data discovery were produced and delivered.

The outcomes will be taken into account in potential actions that could be organised as a continuation of the IACS65 project effort, actively contributing to future projects aimed to improve an efficient access and effective reuse of IACS data in the coming years.

The interoperability aspects treated in the second work package managed to close all open questions connected to the draft Technical Guidelines part 2 on Interoperability. The agreements will be implemented in the UML interoperability target model and the TG. This version will go for the final review among the main stakeholders (Paying agencies, LPIS custodians, INSPIRE community). In order to achieve interoperability, in addition to the necessary data transformation, operational components (code list registries) should be put in place both in the MS and the Commission.

Four main soil-related aspects were discussed in details in the third work package and extensive reports were provided by soil health use-case followed by policy and scientific discussions. These were namely:

- soil erosion,
- soil contamination by pesticides,
- soil organic carbon and
- land degradation index.

The conclusions covered specifically the following topics:

- How could IACS contribute to the upcoming Soil Health Law? Generally, the attendees of the session agreed that IACS could help in EU soil monitoring. The soil health use-cases helped to come to four main outcomes.
- They give valuable and practical insights into the opportunities and challenges when using IACS data for policy indicators.
- Additionally, there are potentially strong opportunities to link science-based indicators directly with decision-makers by using parcel-scale information with efficient communication methods.
- The field-parcel scale is a key link between scientific output and informed decision-making on the ground, however reliable information on soil management practices beyond the IACS information content will have an important role for advanced risk assessment.
- The inclusion of accurate spatial and temporal information in soil health modelling frameworks can significantly reduce the uncertainty associated with the estimation of different properties or indexes (soil erosion, SOC stocks, pesticides contamination or land degradation index SDG 15.3.1) at a parcel scale.

The following aspects should be considered to improve the IACS data sharing process, improve the usefulness of these data for the policy making purposes and finally, to be able to take advantage and to process data at parcel scale:

- The communication with farmers should be improved, as a bridge to transmit knowledge and build trust, and to be able to treat some question at the parcel scale. Several attendees also agreed that helping farmers in the decision-making process was important.
- Data collection priorities, and working scale, should be determined by the type of answer, if scientific and/or policy related. Data at country or continental scale are useful for policy making, while data at field scale could be used for impact assessment or scientific developments.
- The soil health study findings and workshop conclusions highlight the importance of interdisciplinary collaboration and knowledge-sharing in advancing the field of soil health modelling. The integration of accurate spatial and temporal information along with agrotechnology information will enhance the accuracy of modelling frameworks and provide opportunities for informed decision-making on the ground.
- Full coverage and increased resolution when more IACS data become available. The expansion of the IACS data coverage and the resolution increase as beneficial for science and policymaking. The potential to predict the impact of pesticides residues on water soil would also benefit and support future impact assessments. However, the difficulties and uncertainties associated to those predictions were also comprehended and suggested to be tackled with further additional data.

Regarding future developments, it was suggested that modelling advances should progress to improve model predictions, but also assess future legislative scenarios on soil management practices, supported by scientific evidence for monitoring, modelling and providing indicators on physical, chemical and biological soil properties.

After synthesis of the workshop feedback, several broad areas of progress can be identified: 1) the integration of more relevant data for parcel-scale soil-health related indicators on top of the IACS database, 2) upscaling the previously developed methods by use-case to create indicators for the entirety of the available IACS database, 3) finding synergies between IACS case studies, e.g. using C-factor information to predict changes in soil organic carbon (SOC) due to the importance of cropping and other management practices in determining changes in SOC through time.

Finally, the potential use of data coming from agro-machinery data or the farmers' field books on soil and land management operations, involving directly farmers, just by increasing accessibility since the data already exists, would also increase significantly the quality of those results.

The data integration aspects have been discussed in work package four. It aimed at exploring and integrating IACS data with other (mostly soil) data. The results were presented on 27 September 2021 at the Expert Group on direct payments, showing the currently untapped potential to explore, integrate, process, model and visualise IACS data and other relevant soil data (LUCAS, for instance).

This brought DG AGRI data sharing efforts to another level, with the creation of a system, a Spatial Agricultural Information System that could be able to deliver relevant data (in the format of datasets, maps, and statistics tables) to satisfy the growing needs of DG AGRI in terms of data for the analysis, monitoring, and evaluation purposes.

The SAIS project will be developed in two main phases, namely:

- a development of a prototype,
- a development of an operational pilot.

The prototype will be allowing for IACS data harvesting from the Member States geoportals through INSPIRE, enriching and integrating these datasets with other relevant geographical data and finally, proposing how to make these data and analyses environmental available to potential stakeholders.

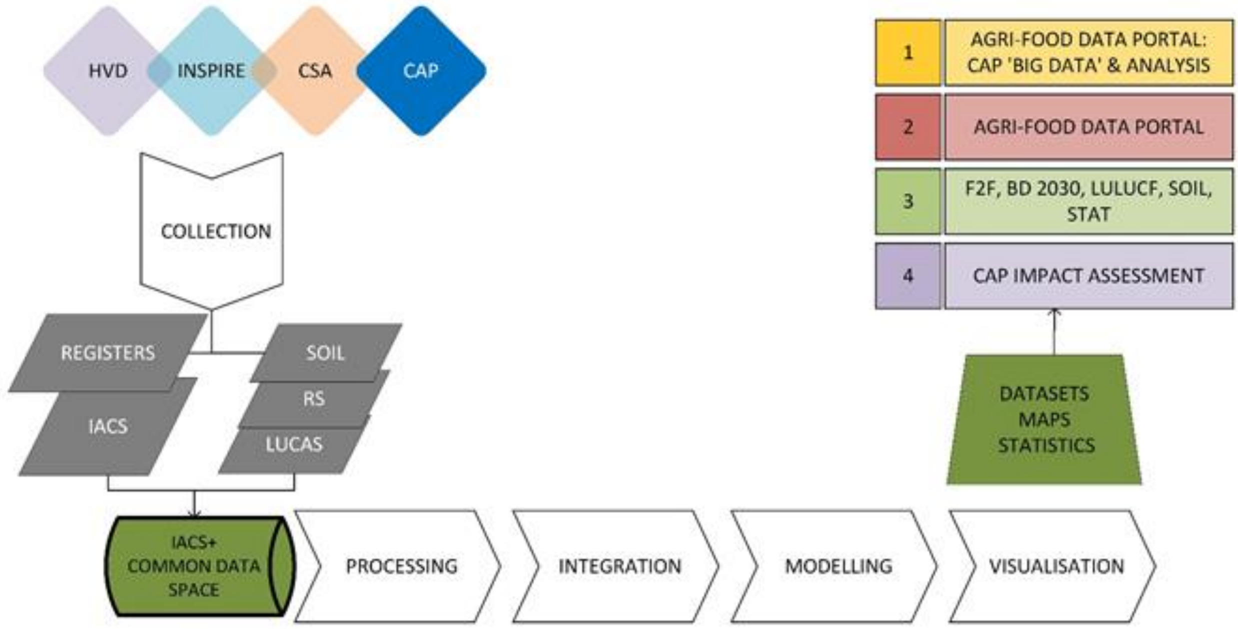
The operational pilot will further automate these processes: harvesting, enrichment and integration, publication, providing a more extensive MS datasets provided through the INSPIRE infrastructure.

The discussions about the setup of a full operational system will start after the prototype has been established (indicatively this will occur 18 months after the start of the project).

The following figure (***Figure 31***) shows the logical links for the future SAIS project:

- Policy / legal framework
- Enlargement to other public bodies (not limited to paying agencies)
- Integration with other datasets (notably those financed by the EC such LUCAS etc)
- Delivery of datasets in different format and statistics to measure policy performance in different domains

Figure 31. Logical links for the future SAIS project



Finally, the collaboration with the Member States was finalised through the 3rd IACS data sharing workshop. The objectives of the 3rd workshop were (i) to present the results of IACS 65 project in the context of the EU data strategy, (ii) to work on and discuss issues in four different thematic working groups and finally, (iii) to present and contribute to the actions foreseen for the coming years.

These three main objectives aimed at improving the efficient access and effective reuse of IACS data in the framework of the 'IACS data sharing process' setup by DG AGRI and associated DGs.

The EC units involved in this project established a list of experts in the following domains: agriculture, IACS (paying agencies mostly), INSPIRE experts (contact points, MIG representatives) and soil scientists. This workshop was conducted with their active participation.

All the experts were invited to the first plenary session, where recent policy developments related to the EU data strategy, agriculture and environment were presented. In addition, the results of IACS65 in the three last years were summarised. The plenary opening session ended with defining the tasks and the objectives of the parallel thematic working groups.

The experts joined a specific thematic working group and worked in different topics, explained below.

Finally, all experts participated to the closing plenary where the rapporteur of the working groups presented the results of the discussions. Finally, a proposal for a new project (Spatial Agricultural Information System – SAIS) was presented extending further the IACS data sharing activities

c. Further steps: SAIS

The purpose of this Administrative Arrangement (AA) between DG AGRI-A4 and JRC-D3/T4 is to develop a dynamic and centralized geographically based information system: Spatial Agricultural Information System (SAIS). This system will be first set up in prototype format followed by an operational pilot based on use cases.

This system consists firstly (A) in (***Figure 32***):

- collecting and sharing data on reference and agricultural parcels and animals
- harmonising them to the possible extent and
- processing those data.

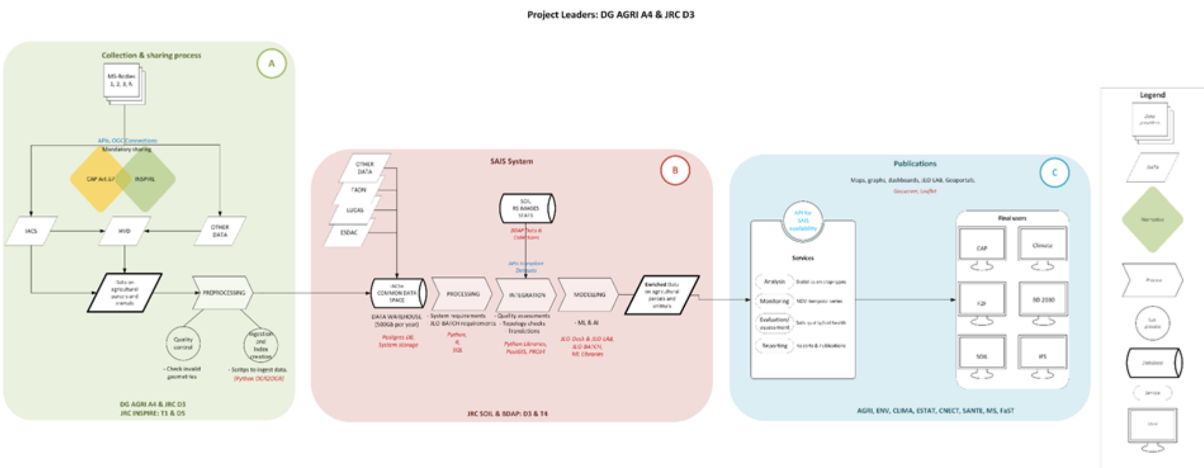
In addition (B), those data shall be supplemented with other data (data integration), statistics and collections (spatial and not spatial) in order to (C) provide datasets for analysis, monitoring, evaluation, assessment, and reporting capabilities to different AGRI services and other EC DGS. Additionally, a range of other stakeholders and users might be interested in accessing this platform, as farmers, CAP beneficiaries and public bodies. Their participation and access rights will be further evaluated taking into consideration data protection legislation.

The core agricultural data in the scope are residing in the Integrated and Administrative Control Systems (IACS) established and managed by the Member States in the context of the Common Agricultural Policy. IACS includes different components; the data under the scope of this AA are mainly related to the Land Parcel Identification System (LPIS) and Geo-Spatial Aid Application (GSAA) sub-systems, therefore geographical and non-personal data.

The objective of this AA is to provide AGRI-A4 with expertise, technical support, and scientific evidence in different areas to ensure the availability, exchange and upgrading of IACS data across the EU.

Moreover, data sharing complies with the EU proposals on the evolution of EU data ecosystem. In particular with the evolution of INSPIRE Directive, with the Open data and its Implementing Act on High Value Datasets (HVD) and also with the CAP provision on IACS data keeping and sharing (i.e., Art. 67(3&4) of Regulation (EU) 2021/2116). Finally, last but not least with the EU digital & data strategy and the creation of common data spaces.

Figure 32. Overall approach of the project



2) Objective

The overall objective of the SAIS system is to ensure discoverability, efficient access (single entry point) and effective reuse of IACS spatial data and its enrichment with other information (interoperability and use cases) in a coherent policy environment, for subsequent use and exploitation by pre-defined stakeholders.

3) Use cases

Consequently, the use cases proposed in this AA allow to prototype, test, and illustrate the importance of data sharing in the fields of agriculture (CAP), environment and climate (Green deal), as well as the benefits for the administration in its monitoring, evaluation (including impact assessment), and reporting tasks.

The use cases shall address data sharing between public administrations first. The capacity to involve other stakeholders from different agro-environmental-climatic sectors will be analysed in the framework of the EU Common Data Spaces.

4) Work packages

To meet these objectives, the following work packages (WP) are planned for 36 months (the indicative period of 04/2023 until 03/2026), and will be conducted or coordinated by experts in the JRC:

- WP 1. Implementation of IACS data collection, pre-processing, and sharing process.

- WP 2. SAIS System development: IACS data integration with other available datasets, IACS-Soil/land enriched data system
- WP 3. Publication process.

In addition to the technical work packages, two others are foreseen and described in sections VII and VIII

- WP 4. Exchange and communication with Member States
- WP 5. Project coordination

To illustrate and to implement in practice, the following soil health modelling use-cases will be implemented:

- Use case 1 Soil erosion modelling at the parcel/farm scale
- Use case 2 Soil contamination by pesticides
- Use case 3 Soil Organic Carbon modelling
- Use case 4 Peatlands and wetlands in the new CAP
- Use case 5 Land degradation index
- Use case 6 Calculation of Soil health indicators
- Use case 7 Food Security and Sustainable Production

The SAIS project will be kicked off in April 2023.

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List of Abbreviations

Abbreviation	Definition
AA	Administrative Arrangement
AM	Area Management
APIs	Application Programming Interfaces
Av.C-factor	Average Cover Management Factor
BDAP	Big Data Analytics Platform
CAP	Common Agricultural Policy
CLC	Corine Land Cover
CROPPROD	Crop Production
CRS	Coordinates Reference System
CZ	Czechia
DB	Database
DE	Germany
EC	European Commission
EE	Estonia
EEA	European Environment Agency
EFA	Ecological Focus Areas
EFTA	European Free Trade Association
ES	Spain
ESDAC	European Soil Data Centre
EU	European Union
GAEC	Good Agricultural and Environmental Conditions
GAM	Generalized Additive Model
GIS	Geographical Information System
GREX	Group Of Experts
GSA	Geospatial Application
GSAA	Geospatial Aid Application

HVDs	High-value Datasets
HVDs	High-Value Datasets
IACS	Integrated Administration and Control Systems
IFS	Integrated Farm Survey
IT	Italy
JRC	Joint Research Centre
LC	Land Cover
LD	Land Degradation
LDN	Land Degradation Neutrality
LF	Landscapes Features
LPIS	Land Parcel Identification System
LPIS QA	Land Parcel Identification System Quality Assessment
LT	Lithuania
LU	Land Use
LUCAS	Land Use/Cover Area frame Survey
LULUCF	Land Use, Land Use Change and Forestry
MAE	Mean Absolute Error
MARS	Monitoring of Agriculture with Remote Sensing
MIG	Maintenance and Implementation Group
MS	Member States
NCPs	National Contact Points
NDVI	Normalised Difference Vegetation Index
NIVA	New IACS Vision in Action
NL	Netherlands
NRW	North-Rhein Westphalia
OGC	Open Geographic Consortium
PA	Paying Agency

PDPs	Partial Dependent Plots
PMEF	Performance Monitoring and Evaluation Framework
PT	Portugal
R2	Coefficient of Determination
REDES	Rainfall Erosivity Database at European Scale
RO	Romania
RS	Remote Sensing
RUSLE	Revised Universal Soil Loss Equation
SAIS	Spatial Agricultural Information System
SDG	Sustainable Development Goals
SMR	Statutory Management Requirements
SOC	Soil Organic Carbon
SWAT	Soil and Water Assessment Tool
TG	Technical Guideline
UML	Unified Modelling Language
UNCCD	United Nations Convention to Combat Desertification
WP	Work Package
WS	Workshop
Xa	Accuracy Coefficient

List of figures

List of tables

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