Use Cases of the Integrated Administration and Control System's Plot-Level Data: Protocol and Pilot Analysis for a Systematic Mapping Review

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Abstract

In recent years, land use data from the EU's Integrated Administration and Control System (IACS) have become increasingly available for research purposes. IACS data contain annual plot-level information on cultivation and location of the land farmed by agricultural beneficiaries, covering the majority of farmland in the EU. The data thus provide information on land use that is spatially and temporally highly disaggregated. Researchers from a broad range of disciplines already rely on IACS data for various applications and EU member states must make an anonymised, geospatially-referenced version of the data publicly available in the future. However, there is no complete and structured overview of the data's use, their benefits and limitations that future research could rely on. This calls for conducting a systematic review of the applications of IACS plot-level data in scientific literature. Preparing the ground for such a review, this paper presents a review protocol for identifying and analysing publications using plot-level IACS data from Austria, Czechia, France, Germany, and Sweden in a systematic map. To test and refine the protocol and to illustrate the planned review, we conduct a pilot analysis of 12 selected academic publications and present the results. The pilot analysis demonstrates that the review protocol is adequate and that novel insights will be gained by mapping out the already existing work that uses IACS data.

Keywords

Integrated Administration and Control System; InVeKoS; systematic map protocol; systematic mapping review; review protocol

1 Introduction

To administer and control subsidies to farmers under the Common Agricultural Policy (CAP), European Union (EU) member states operate an Integrated Administration and Control System (IACS). The IACS consists of a spatial land parcel identification system (LPIS) and a corresponding geospatial aid application (GSAA), among other systems. In LPIS and GSAA, authorities provide georeferenced information on the agricultural plots eligible for payments within the CAP and collect information on the crops grown on each plot (SAGRIS et al., 2013; EUROPEAN COMMISSION, n.d.). Since most farmers in the EU apply for payments and have to declare their farmed land and cultivated crops to IACS each year, the final dataset covers the vast majority of farmland in most EU countries. These IACS data thus provide highly disaggregated information on agricultural land use (e.g., the location of agricultural land, crops grown) on an annual basis; i.e. information that is useful for many scientific applications.

Although the primary aim of data collection is payment administration, researchers from various disciplines have used these IACS land use data, as authorities provided them for scientific use under security constraints. Likewise, some country authorities have made the basic data set of georeferenced plots with land cover information publicly available via the EU's Infrastructure for Spatial Information in the European Community (INSPIRE) initiative portal, but without farm ID or payment information for data privacy reasons. As decided in 2021, all member states are obliged to make these anonymized geospatially-referenced IACS land use data publicly and freely available (Regulation (EU) 2021/2116 (2021), Article

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67). As a result, the number of scientific uses will most likely increase in the future.

Such future applications would benefit from building upon the existing work and the experiences researchers have made with IACS land use data. Starting from established use cases, data cleaning and processing workflows, and interpretation standards will ensure a high scientific quality of the output. Among the few publications that offer a discussion of the IACS land use data's potential, SAGRIS et al. (2015) provide a brief, narrative, overview of scientific work until 2013. LOMBA et al. (2017) evaluate the potential of IACS data, but only for their specific use case of High Nature Value (HNV) farmland identification. TOMLINSON et al. (2018) find that IACS data are an invaluable source for the purpose of tracking land use and land cover change. Others discuss IACS as a source for sustainability indicators for agricultural production systems that complement the EU's Farm Accountancy Data Network (FADN) (KELLY et al., 2018; UTHES et al., 2020). In remote sensing research, IACS data are also acknowledged as a highly valuable source of ground truth data (e.g., KYERE et al., 2019). However, to the best of our knowledge, no comprehensive, up-to-date overview and synthesis of the existing work that goes beyond individual use cases exists to date.

In addition, exchanges of ideas and data handling strategies between researchers from different disciplines using IACS data and information flows between researchers and other data users such as professional policy evaluation teams seem to be limited. Together with a lack of harmonization of datasets and data access across EU countries and federal states this creates inefficiencies in data handling workflows and limits the exploitation of the data's full potential. While it has been challenging for researchers to access IACS data, their use is mandatory for evaluating European agricultural fund for rural development (EAFRD) programs and for climate reporting. These reports, however, are often published as grey literature, in national languages (creating language barriers to exchange), and without necessity to meet research data management standards. Scientific data management standards such as those from the GO FAIR initiative (FAIR: findable, accessible, interoperable, re-usable) offer improved knowledge generation through transparency in data generation and processing. Such transparency enhances the inference from, and the interpretation and external validity of results (HECKELEI et al., 2023).

To address the lack of a collection and synthesis of the available applications of IACS land use data in the scientific literature, to foster knowledge exchange between data users, and to evaluate the data management transparency standards in the data's use we propose to conduct a systematic literature review. Given our aim to provide a comprehensive overview, the review must take the form of a systematic map (JAMES et al., 2016), a method that accounts for the diverse nature of the scientific publications to be reviewed. To make the literature review process rigorous and transparent and thus improve its reliability, preparing an externally reviewed protocol before conducting the review work is highly recommended or, in some disciplines, even required (JAMES et al., 2016; KUGLEY et al., 2017; for published examples of systematic map protocols on agri-environmental topics see, e.g., APRIYANI et al., 2021; BROWN et al., 2018; OTTOY et al., 2018). This pre-analysis step is comparable to pre-registration of research plans or pre-registered report studies that have been proposed as a remedy to the replicability crisis (ARPINON and ESPINOSA, 2022; FERRARO and SHUKLA, 2023). The aim of this paper is to present such a review protocol for the outlined systematic map of scientific work using IACS land use data. It serves to inform the scientific community about the ongoing project, to receive feedback from external review that strengthens the a priori literature review guide on how to search and extract information, and to provide a basis for future research projects that seek to replicate or expand on our work. We present the research questions we address in the systematic review, the search process to be employed, the criteria for including/excluding relevant/irrelevant work, and the planned methods of analysis (JAMES et al., 2016). To complete the paper, we enrich the protocol with a pilot analysis of a sample of papers that illustrates the planned full analysis, but also potential pitfalls. The pilot analysis should be understood in a qualitative research spirit, where deep knowledge on the research object's context is seen as helpful for drawing conclusions from small selected samples (BODDY, 2015).

With our paper we offer a base for comparison, replication, and expansion of the review results. By following the protocol, our study can be directly replicated with another draw of the intensely reviewed papers and the sampling following the same procedure (FINGER et al., 2023). It can also be replicated in the future to evaluate the scientific impacts that the EU's open data policy has had, or to compare the effects of differences in country access strategies on research possibilities. Finally, our review can be expanded by using the identified publications and/or the search strategy for addressing different or discipline-specific questions. Our results also offer an improved understanding of how the results of a systematic review are produced, and how sensitive results can be to selection decisions. We thus contribute to increasing calls for more (method) transparency and open science. Our enriched protocol further paves the way for standardizing the method of systematic literature review in the AgEcon domain. We expect that systematic literature reviews, as a method for synthesizing and condensing knowledge, will gain increasing importance in the future due to the large and growing number of papers (BORNMANN et al., 2021; VAN DIJK et al., 2023), including fake papers produced using artificial intelligence (BRAINARD, 2023; SABEL et al., 2023).

The remainder of this article is organized as follows. The next section presents the protocol for the proposed systematic mapping review, including its aims and scope, relevant terms and definitions, and a description of the review method and process. Section 3 presents and discusses the results of the pilot analysis. Section 4 concludes and gives a brief outlook on the planned full review.

2 Protocol for the Proposed Systematic Mapping Review

2.1 Aims and Scope

In the proposed review, we seek to provide an overview of the existing scientific work that uses IACS land use data, of the implementation of data management transparency standards in this work, and of the benefits and limitations associated with using the data for research purposes. Our goals are to raise awareness among researchers and data-providing authorities about the possibilities that the data offer, and to increase efficiency of data use, e.g., avoid double work among data users. IACS land use data comprise the plot-level data from the LPIS and the GSAA, we hence refer to "plot-level data" in the remainder of the text. We address the following research questions (RQ):

1. Who has used IACS plot-level data, in which disciplines and time periods?
2. What research questions have been answered by using the data?
3. For which purposes have IACS data been used?
4. What indicators have been derived from the data and for what purposes?
5. What information from IACS data has been used at which spatial and temporal levels?
6. What other datasets have been linked to IACS data and how?
7. How do publications using IACS data address the principles of findability, accessibility, interoperability, and reusability of data and methods?
8. What critical evaluations and suggestions for using and improving the IACS datasets have been made?

To reduce the vast amount of publications, we will focus on five selected countries: Austria, which has a diverse farming structure and authorities that provide good data access since early on; Czechia, which has a post-collectivist agricultural structure and many published studies that use IACS data; France, which has a wide variety of farming systems from Mediterranean to Alpine; Germany, which is an important player in EU agriculture but has comparatively limited access to IACS data; and Sweden, which has a diverse farming structure and good IACS data availability for research.

2.2 Terms and Definitions

In RQ2, "research questions" refers to the research aims addressed in or questions answered by the reviewed studies in a broad sense, i.e., the overall aims of a study. These aims or questions are usually explicitly stated in the introductory section of a publication. In contrast, the "purposes" of data use in RQ3 refer to the narrower content-related or methodological purposes of using IACS data in the context of a study. These purposes are usually a means of addressing the research aim and are often only implicitly described.

RQ4 reflects that IACS data often serve as a basis for indicators. We, therefore, define the term "indicator", based on HEINK and KOWARIK (2010) and adapted to our analysis, as "an indicator is a component or a measure of a phenomenon of interest, used to depict or evaluate conditions or changes". Following HAMMOND et al. (1995: 1), who state that "Indicators represent an empirical model of reality, not reality itself", we also stipulate that an indicator must have an *indicandum,* meaning a phenomenon of interest that the indicator intends to represent. Thus, we define the raw components of the IACS data, such as plot size, as indicators if they have an indicandum (e.g., plot size as a measure of land use fragmentation), and define the raw components as metrics if they do not.

We note too, that landscape analysis, ecology, and ecosystem sciences may categorize indicators into thematic groups, using different classification systems (NIEMI and MCDONALD, 2004; DALE and POLASKY, 2007; UUEMAA et al., 2013; MEDEIROS et al., 2021). For our purpose we choose a classification that is broad enough to encompass applications from various disciplines and group indicators into measuring "composition", "configuration", or "management (outcomes)" of/in a landscape, farm, or field. Composition describes the number and proportion of land cover/use types in or of a landscape or farm, configuration describes the spatial arrangement of land cover/use types (FAHRIG et al., 2011), and management (outcomes) describes the practices or outcomes of individual behaviour.

2.3 Review Method

Due to the diverse nature of the publications we will review, traditional systematic reviews that analyse and compare quantitative effect sizes are not appropriate. Instead, a scoping review (MUNN et al., 2018) or a systematic mapping review (JAMES et al., 2016) are adequate methods as they are used to "explore the breadth or depth of the literature, map and summarize the evidence, inform future research, and identify or address knowledge gaps" (PETERS et al., 2020, p.2121). The two methods share great similarities but have different disciplinary backgrounds. Since scoping reviews are used mostly in the medical sciences and systematic maps in the environmental sciences (among others), we use the latter term and related guidelines.[1] We rely on the associated methodology promoted by the Centre for Environmental Evidence (CEE) (JAMES et al., 2016), and associated RepOrting standards for Systematic Evidence Syntheses (ROSES) (HADDAWAY et al., 2018).

The review process consists of 5 stages:

1. Searching publications
2. Screening and selecting publications
3. Extracting information
4. Analysing and synthesizing information
5. Reporting results

Sections 2.4 to 2.7 explain the stages.

[1] Moreover, the term "scoping review" is sometimes also used to describe a type of review preceding a systematic review which does not produce a final output in its own right (GRANT and BOOTH, 2009).

As our aim is to synthesize scientific uses of IACS data, we restrict our search to peer-reviewed, scientific literature in English language. This focus ensures that the applications we synthesize follow scientific standards of data use, handling, and analysis, which will improve the comparability and usefulness of results. It will also provide insights into the establishment of the FAIR principles in research data handling and will likely capture the most novel, innovative use cases of IACS data. We acknowledge that ignoring grey literature, which does not need to follow the same scientific standards as peer-reviewed literature, might result in not giving the full picture of existing IACS use cases. Such literature, including national EAFRD evaluations, remains also hard to access through existing search engines using complex search strings, and extracting information may suffer from language barriers.

2.4 Review Stage 1: Searching Publications

Prior to developing the search strategy, we establish a test-list of 12 sample papers to evaluate search result comprehensiveness. We refine our search strategy until all 12 papers are found. The test-list covers different disciplines, journals and publishers, all countries included in the review, and includes some publications that do not mention the dataset name in their abstract. We consider the 12 papers of particular importance to our research fields or are co-authors. We also use the test-list publications for the pilot analysis (see Section 3). Please refer to Table A.2 in Appendix 3 for the list of papers.

In collaboration with a librarian from Humboldt-Universität zu Berlin, we develop a search strategy based on three concepts: the IACS dataset, the agricultural plot, and the countries of interest. Table A.1 in Appendix 1 lists the core terms, synonyms, related terms, and related but irrelevant terms that characterize each concept.

We search only for publications in English but include IACS local names and acronyms. We use the search engines (and corresponding databases) ProQuest (publicly accessible content database, natural science collection, GeoRef), Web of Science (Core Collection, Biosis Citation Index, MEDLINE), Livivo (all databases), and Science Direct. Depending on the search engine, we use one of two search string setups: one for searches in metainformation (titles, abstracts, keywords), and one for searches in full texts. Table 1 gives the details of the two setups.

Table 1. Search string setups for searches in metainformation and full texts

Search in	Search engines	Included concepts
Metainformation	Livivo Web of Science	IACS dataset, synonyms including acronyms, related terms Agricultural plot, synonyms, related terms
Full texts	ProQuest Science Direct	IACS dataset, synonyms without acronyms, related terms Country names, synonyms, related terms

Note: Metainformation searches occasionally include an exclusion term covering the most common other full expressions used by the included acronyms (e.g., International Annealed Copper Standard, used by the IACS acronym).
Source: own compilation

Below is a sample search string for the Web of Science search engine, based on the main concepts included in metainformation searches.

A search string for the Web of Science search engine

TS=(("Integrated Administrat* and Control System" OR "Integrated Area Control System" OR "Integrated Accounting and Control System" OR "Land Parcel Information System" OR "Land Parcel Identification System" OR "Land Use Identification System" OR "Geospatial Aid Application" OR "Graphical Land Parcel Registration" OR "Land Parcel Registration System" OR "cartographic field pattern registry" OR "IACS" OR "LPIS" OR "GSAA" OR "Agricultural beneficiaries data" OR "Integriertes Verwaltungs- und Kontrollsystem" OR "Invekos" OR "système intégré de gestion et de contrôle" OR "système intégré" OR "SIGC" OR "integrerade administrations- och kontrollsystemet" OR "IAKS" OR "register för arealbaserade stöd" OR "Registre Parcellaire Graphique" OR "RPG" OR "système d'identification des parcelles agricoles" OR "SIPA" OR "Blockdatabasen" OR “Jordbruksblock” OR “Díl půdního bloku”)

AND (agri* OR farm* OR crop* OR arable OR cultivat* OR plot OR field OR block OR parcel OR patch))

NOT TS=("electric* conductivity" OR "International Annealed Copper Standard" OR “recurrent parent genome" OR "rumen*protected glucose" OR "role-playing")

Each search is conducted from multiple institutions to maximize search results despite restricted institutional access to databases. Where filters are available, we filter search results for document language and document types according to our focus on peer-reviewed, scientific literature in English language. We document search strings, number of search results, date of searches, and other relevant information.

2.5 Review Stage 2: Screening and Selecting Publications

In this stage we first download and deduplicate the metadata using the reference management software Mendeley. Next, we filter the metadata of all results against a list of taboo terms (see Appendix 2 for the list) that contains the most common full expressions that also use acronyms such as IACS, LPIS, and RPG, using a custom-written script in Python (VAN ROSSUM and DRAKE, 2009). After deduplication and taboo-term filtering, we consecutively perform abstract and full text screening for inclusion in the review. Each abstract and full text is screened by a single reviewer. To guarantee screening consistency, our research team of 7 reviewers participates in a workshop designed to test and clarify the inclusion/exclusion criteria. To evaluate inter-reviewer consistency and to identify systematic differences in inclusion/exclusion decisions between reviewers, we assign a set of 40 randomly selected abstracts (for abstract screening) and 20 full texts (for full text screening) to two reviewers each and compare the results.

Table 2 lists our specific inclusion and corresponding exclusion criteria.

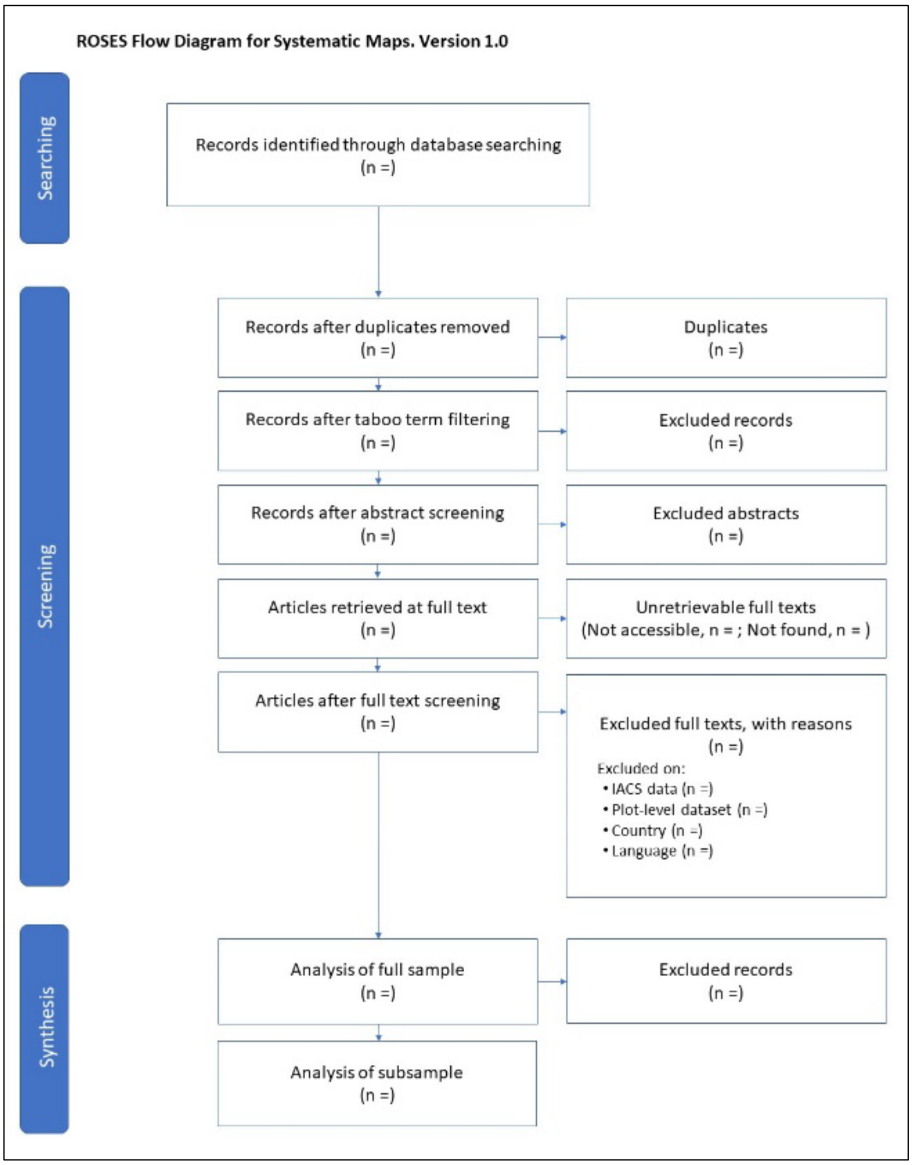
We use a flow diagram from CEE/ROSES as provided in Figure 1 to summarize the screening results (HADDAWAY et al., 2018).

Table 2. Inclusion and exclusion criteria for abstract and full text screening and selection

Inclusion criteria	Exclusion criteria
The language of the full publication is English	Language is not English
The publication uses IACS data • originating in the agricultural plot-level database (LPIS, GSAA), which contains georeferenced information on plot location, plot geometry, and crops grown • in their original geospatial format or a derived version • for original research or to discuss IACS data setup, usefulness, etc.	Publication contains no IACS data, or • IACS data are not from the plot database (e.g., farm animal list, farm subsidy income, municipality-level information) • IACS data are not used for original research (e.g., referred to as agricultural statistics data) or to discuss IACS data setup, usefulness, etc.
The data are from Austria, Czechia, France, Germany, or Sweden.	The data are not from Austria, Czechia, France, Germany, or Sweden.

Source: own compilation

Figure 1. Sample flow diagram for results presentation



Source: adapted from HADDAWAY et al. (2018)

In Table 3, 'methodological' (variable 5) refers to using the data in a technical sense irrespective of content, and 'content-related' (6) refers to using the data in a substantive sense. We use the 'indicandum' variable (8) to identify the authors' stated purpose for using and applying an indicator. When it is ambiguous whether a particular measure is an indicator or a metric, the review team decides based on the definition presented in Section 2.2. We use the 'raw information' (9) variable to identify the information derived from the data. Given the georeferenced format of IACS land use data this primarily includes the geometry of polygons and their locations in space, the year of data collection, and the thematic information (attributes) on land use and management collected in LPIS and GSAA. During data extraction, we note for geometry and thematic information which information components authors use, and for location and year whether the information is relevant for the study (e.g., we consider plot locations relevant if their precise locations in space matters, and consider temporal information relevant if authors analyse changes or developments including crop rotations over time). We use the variable 12, 'identifier/link for combination', to identify how authors merged other datasets to IACS data. This can include spatial matches, where data are spatially intersected, or merging on thematic attributes such as farm IDs, crop types, etc. Variables 13-18 serve to review how and to what extent publications address the Findability, Accessibility, Interoperability, and Reusability (FAIR) principles in the description of data and methods used. 'Data provision and access' (13-14) refers to the findability and accessibility of IACS data, while the description of the dataset and the data cleaning and pre-processing categories (15-17) refer to interoperability and reusability. Similarly, the

2.6 Review Stage 3: Extracting Information

In this stage we extract author information, publication date, journal title, journal topics (journal subject categories from SCImago (SCIMAGO, n.d.)) and country/countries of data use for all publications retained after full text screening to identify the researchers who use IACS data, disciplines, and publication years (RQ1). If the final dataset exceeds 80 records, we take a random sample from all publications for further analyses. We decide on the sample size and sampling method once we know the properties of the full dataset. From the sample, we extract the information needed to answer the remaining research questions RQ2-RQ8. Table 3 lists the variables for data extraction and our instructions to the review team.

Table 3. Variables to be extracted from full texts and guidelines and instructions to reviewers

No.	Variable	Type	Details/instructions to reviewers
1	Year(s) of data use	Numerical	One or multiple years
2	Combination with other datasets	Binary	Yes, no
3	Importance of IACS data use	Binary	Categories: Major: essential to study purpose (e.g., variable(s) of interest both outcome or explanatory, complex indicator(s) derived, training or reference data, selector variable based on transformed/combined data) Minor: not essential to study purpose, not variable of interest (e.g., grouping variable, control variable(s) in an econometric sense, selector variable without data transformation) A paper is not relevant when it only refers to IACS as a data source for descriptive purposes (e.g., introducing the country of study).
4	Research question(s) or aim(s)	Open text	Copy relevant text passages verbatim for content analysis Only questions that are addressed using IACS data where distinguishable
5	Methodological purpose(s) of IACS data and derived indicators	Open text	Copy relevant text passages verbatim for content analysis
6	Content-related purpose(s) of IACS data	Open text	Copy relevant text passages verbatim for content analysis Distinguish from indicator purpose where relevant and possible
7	Indicators generated/derived from IACS	Open text; where applicable	Indicator name (each indicator must contain some IACS information) and formula/verbal description as provided Raw data may or may not be an indicator; see Section 2.2
8	Indicandum of each indicator	Open text; where applicable	Verbatim from indicator description (e.g., methods section)
9	Raw information from IACS used	Categorical; add categories if needed	Categories (multiple possible; specify both main category and sub-categories): Spatial information: geometry: plot shape, size, edge georeferenced location: relevant yes/no (e.g., distance measures; spatial combination with other datasets) Temporal information: temporal dimension (e.g., change in variable; crop rotation): relevant yes/no Thematic (land use) information: crop type, land use type (e.g., cropland, grassland), landscape elements, organic farming, agri-environmental schemes (AES) Other: farm ID; others as needed
10	Spatial unit of analysis	Categorical; add categories if needed	Categories (multiple possible): Plot Farm Municipality Grid cell (state size, shape) Additional categories as needed
11	Datasets combined with IACS	Open text; where applicable	Name(s) of dataset(s)
12	Identifier/link for combination	Open text; where applicable	Categories as needed: e.g., spatial join, farm ID, crop type, year
13	Information on data provision and access	Categorical	Yes, no, partly Yes, if authors provide information on data providing authority/platform and access modalities
14	Information on data provision and access: text	Open text; where applicable	Copy information verbatim from paper Data provision: information on who provided the dataset for the study Data access: Information on data availability for others
15	Description of dataset	Categorical	Yes, no, partly Yes, if authors unambiguously state the data set used (GSAA/LPIS/other), the year of data use, and the raw information used
16	Description of data cleaning and pre-processing	Categorical	Yes, no, partly Yes, if all steps are described in a replicable way. Data cleaning and pre-processing may comprise (e.g.): treatment of sliver polygons, outlier detection and treatment, error detection and treatment, data harmonization over time and/or space, dataset merging, crop code selection/merging, rasterization, other data pre-manipulation prior to analysis.
17	Information missing from description of data cleaning and pre-processing	Open text; where applicable	Summarize the pre-processing steps that are missing for full reproducibility.
18	Provision of source code	Binary	Yes, no Is any source code provided? Note: source code will not be checked for completeness.
19	Discussion of IACS data benefits and limitations	Open text; where applicable	Copy relevant text passages verbatim for content analysis Focus: advantages/potentials of IACS data; problems with/limitations to IACS data; future directions/research perspectives regarding IACS data

Source: own compilation

provision of source code (variable 18; if applicable) also facilitates reusability. Categories can be added to the extraction table as needed.

To ensure inter-reviewer consistency in the data extraction process, all reviewers participate in a second workshop with detailed instructions and examples on the data extraction procedure. Ambiguities will be discussed among the team. Reviewers who have authored publications using IACS do not review their own work.

2.7 Review Stages 4 and 5: Analysing and Synthesizing Information; Reporting Results

For the dataset containing the metainformation of all publications retained after screening, we identify the number of publications by discipline, year, author, and country. We summarize results in charts and in writing, and publish the original dataset in a public data repository. For the data extracted from the random sample, we additionally analyse the variables presented in Table 3. We analyse the categorical, binary, and numerical variables by providing counts, descriptive statistics, and corresponding tables and figures. We collect the indicators derived from IACS, link them to their indicanda, and group them by topics to obtain a comprehensive overview in an alluvial plot. We also collect and group the datasets combined with IACS data in a table. We analyse the text extracted verbatim from publications (i.e., text on research questions, purposes of IACS data use, and discussions of IACS data) using techniques from qualitative content analysis such as inductive category formation (MAYRING, 2022) in the software atlas.ti. In this technique, text parts are summarized using codes of a pre-defined abstraction level and can then be grouped and put in relation to each other. We create visualizations using the software R (R CORE TEAM, 2021) and appropriate packages, including packages ggplot2 (WICKHAM, 2016) and ggalluvial (BRUNSON and READ, 2020). We will publish results in the form of a scientific paper and will disseminate core findings to policy makers (e.g., as a policy brief). We will publish our dataset of publications identified in the search and screening process publicly using scientific data sharing infrastructure.

3 Illustrating the Protocol: a Pilot Analysis

To test and illustrate stages 3-5 of our review protocol, we conducted a pilot analysis of the 12 selected publications of our test-list. As explained in Section 2.4, we selected these papers for evaluating our search strategy. They are well-suited for a pilot analysis since we know most of these papers well, giving us background knowledge on their context and enabling us to better judge the adequacy of the protocol. The analysis presented here should therefore be understood in a qualitative research spirit, where deep knowledge on the research object's context is seen as helpful for drawing conclusions from small selected samples (BODDY, 2015). From each publication we extracted the variables provided in Table 3, and analysed their content. The following sections present the results of the analysis, followed by a brief discussion.

3.1 General Information (RQ1)

RQ1 aims to provide an overview of IACS data use by country, year, disciplines, journals, authors, and other metainformation. While this aim cannot be meaningfully illustrated by presenting just the 12 selected publications, we use this section to introduce the analysed papers to our readers. Table A.2 in Appendix 3 summarizes metainformation and general information (importance of IACS use, year(s) of data, and combination with other datasets) of the publications. In summary, the 12 papers

- were published between 2008 and 2021,
- in nine different journals,
- are associated with eleven different journal topics,
- use data from Germany (5), and fewer from Czechia (2), France (2), Austria (2), and Sweden (1),
- nine papers combine IACS data with other datasets, and
- all make "major" use of the IACS data.

3.2 Research Questions and Aims (RQ2)

To analyse the research questions and aims, we first rephrased each individual question stated in the sample publications using a uniform structure and level of abstraction. We then categorized them into main groups of research question *types* and sub-groups based on *content*. Each question or aim can relate to multiple sub-groups. Table A.3 in Appendix 4 shows the summarized questions and associated main and sub-groups. Of the 29 research questions and aims addressed in the sample publications, 11 analyse relationships and influences, another 11 identify or describe states or changes, five are methodological or conceptual, and two analyse trade-offs. Of those questions addressing relationships, five relate to *farm and landscape structure*, two to *farms' business/economic performance*, one to *crop choice, crop and landscape diversity*, and three questions relate to multiple topics each, including *ecosystem conditions and services or biodiversity*. Among those questions that identify or describe states or changes, five relate to *farm and landscape structure*, one to *crop choice, crop and landscape diversity* and to *farms' business/economic performance* each, and three to a combination of *farm and landscape structure* and *crop choice, crop and landscape diversity*. Of the methodological research aims, two relate to *ecosystem conditions and services or biodiversity* and to *crop choice, crop and landscape diversity* each, and one addresses multiple topics. The two trade-off analyses both concern a combination of *farms' business/economic performance* and *ecosystem conditions and services or biodiversity*. The topics that the publications address most commonly are therefore *farm and landscape structure* (17 occurrences) and *crop choice, crop and landscape diversity* (11), illustrating the most prominent use cases of IACS plot-level data in our sample.

3.3 Methodological Purposes of IACS Data Use (RQ3.1)

We address RQ3 on the purposes of IACS data use in two parts, covering methodological and content-related purposes, respectively. First, we inductively develop categories of the methodological purposes of IACS data use in the 12 selected papers (a paper may fall into one or more categories).
The categories are:

1. Indicator derivation and/or use of indicator(s), which refers to the use of IACS data to *indicate* (an aspect of) a phenomenon.
2. Use as metric(s), which refers to the use of raw data in the form of a metric with no indicandum.
3. Site selection and grouping, which refer to the use of IACS-derived information for selecting study sites/farms/landscapes or for grouping farms/landscapes (e.g., organic vs. conventional farms).
4. Typology creation, which refers to cases where IACS data, and sometimes additional data, are used to identify (and describe) types of landscape and farm land use patterns.
5. Reference data or "ground truth data", which is mainly used in remote sensing applications.

We find that nine of the sample publications use information from IACS to create and use indicators. Three publications use raw data in the form of a metric; two use IACS data for site selection/grouping and typology creation, respectively; and one uses IACS as reference data. Several publications use indicators and/or metrics for additional methodological purposes (e.g., statistical analyses, land use modelling) that are, however, too diverse to develop meaningful categories.

3.4 Content-Related Purposes of IACS Data Use (RQ3.2)

Second, we use inductive coding to analyse the content-related purposes of IACS data use that we extracted verbatim from the sample texts. To structure our findings, we group the coded content-related purposes into three categories:

1. Describing landscape and farm structure, which refers to the use of IACS data to describe the composition and/or configuration of landscapes or farms.
2. Describing farm management activities and outcomes, which refers to the use of IACS data to describe (the results of) farmer behaviour.
3. Conceptual discussion of IACS data, which refers to uses of IACS data that are not primarily empirical but that discuss the dataset's set-up and structure or evaluate its usefulness.

The distinction between farmer management outcomes and farm or landscape structure is not always straightforward, since existing structures are to some extent an outcome of land management decisions. Therefore, we use a narrow notion of management (outcomes) and only group farm-level activities under the direct control of farm managers. Table 4 lists and groups the purposes of IACS data use as stated in the sample publications by providing the inductive codes and their frequencies. The most common content-related purposes in the analysed papers are therefore the identification of agricultural land use types (SKLENICKA and SALEK, 2008; SKLENICKA et al., 2014; LÜKER-JANS et al., 2016; KIRCHWEGER et al., 2020) and the identification of land fragmentation (SKLENICKA and SALEK, 2008; LATRUFFE and PIET, 2014; SKLENICKA et al., 2014; BARBOTTIN et al., 2018), followed by the identification of crop types (KYERE et al., 2019; WOLFF et al., 2021), landscape diversity (UTHES et al., 2020; WOLFF et al., 2021), and organic farms or fields (RUSCH et al., 2014; WOLFF et al., 2021).

Table 4. Content-related purposes of IACS data use in the sample publications

Category	Inductive codes	Freq.
Describing landscape and farm structure	identify agricultural land use type/pattern	4
	identify land fragmentation	4
	identify crop types	2
	identify landscape diversity	2
	identify changes in farm area	1
	identify crop diversity	1
	identify field edges	1
	identify field shapes for crop classification	1
	identify field structure	1
	identify landscape complexity	1
	identify landscape elements	1
	identify landscape structure	1
	identify plots with maize	1
Describing farm management activities and outcomes	identify organic farms/fields	2
	derive crop yields and farm gross margins	1
	identify AES participation	1
	identify crop choice to measure soil conservation	1
	identify land management	1
	identify land use change	1
	identify soil conservation behaviour (tillage type, soil cover)	1
	identify UAA of an area	1
Conceptual discussion of IACS data	discuss usefulness of IACS data	1

Source: own compilation

For both methodological and content-related purposes of IACS data use we expect that the categories/groups of purposes we identify in the full analysis will differ from the ones identified here.

3.5 Indicators Generated/Derived from IACS Data and their Indicanda (RQ4)

Many researchers rely on IACS data to derive indicators. In our pilot analysis, we list and group all indicators and indicanda used in the 12 papers; just as planned in the full review. We identify 26 different indicators measuring 9 different indicanda. Table A.4 in Appendix 5 gives the details.

Average plot size is the most common indicator (5 publications) followed by edge density, distances between plots and the farmstead, and the share or amount of corn (3 publications each). Considering the indicanda of all indicators, land use fragmentation is the most commonly measured indicandum (17) followed by landscape diversity (7) and soil conservation behaviour (4). Considering the overarching indicanda of landscape/farm configuration, composition, and management, configuration is the most common (22) followed by composition (19) and management (12). Note that only two indicators refer to a change over time.

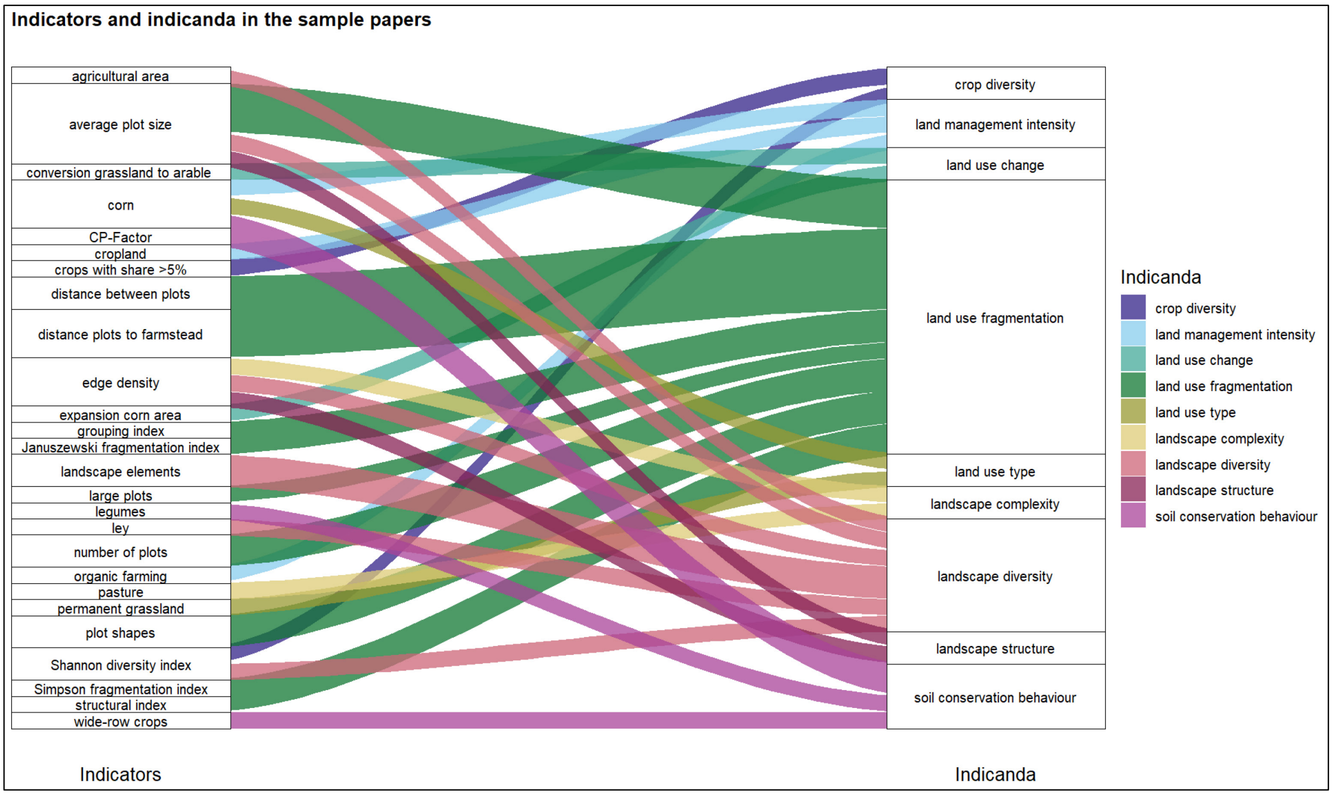
Figure 2, which is based on columns 6 and 7 in Table A.4, illustrates the connections between indicators and indicanda. The occurrence/share/amount of corn is an interesting example of one single indicator indicating different indicanda (land management intensity, land use type, and soil conservation behaviour). Similarly, average plot size is used to indicate land use fragmentation, landscape diversity, and landscape structure. Figure 2 also shows how different indicators measure a single indicandum. For example, 10 different indicators (from 3 of the 12 sample publications) measure land use fragmentation. Similarly, indicators from all main groups measure landscape diversity; including shares/occurrences of ley, landscape elements, and agricultural area; average plot sizes, edge density, and the Shannon diversity index.

3.6 Raw Information from IACS used (RQ5.1)

RQ5 has two sub-questions: Identifying the raw information from IACS used in the analysed publications (5.1), and the spatial and temporal levels at which analyses were done (5.2). To address RQ5.1 as outlined in Table 3 of the protocol, we classify IACS raw data into four groups: spatial information, temporal information, thematic (land use) information, and other information. Table 5 gives the details of their use in the 12 sample papers.

Frequent uses of geometries and crops grown (including land use classes such as cropland and grassland) are in line with the main data contents of IACS. Six papers use complete geometrical information, and six use plot sizes only. For most papers the exact location of plots is relevant, e.g., for merging datasets spatially or calculating the distances between objects. Infrequent uses of temporal information may be due to the difficulties (e.g., changing boundaries, digitization differences in farmers' annual plot-use reports to IACS, etc.) of tracing plots over time.

Figure 2. Relationships between indicators and their indicanda in the 12 selected papers



Note: Each connection represents one instance of an indicator-indicandum pair; each colour represents one indicandum.
Source: own illustration

Table 5. Raw data components from IACS and frequency of use in the sample papers

Raw data group	Raw data component	Frequency
Spatial information	Geometry Plot size only	12 6
	Location	8
Temporal information	Changes over time	3
Thematic information	Crop types	9
	Land use classes	3
	Landscape elements	3
	AES	3
	Organic agriculture	2
Other	Farm ID Farmstead location Ownership status Soil quality Topography	4 1 1 1 1

Source: own compilation

3.7 Spatial and Temporal Units of Analysis (RQ5.2)

The selected papers use different spatial units of analysis, sometimes multiple per paper. Five publications use the farm level as their unit of analysis, and four publications use the plot or block level. A block usually consists of several contiguous plots farmed by one farmer or with the same land use (depending on the country).[2] Even for our 12-paper sample, the lack of a common terminology is a problem (e.g., plot, parcel, patch, and field apply to the smaller unit of analysis, and production block, field, and islet to the larger unit). Five papers aggregate the data to larger units, such as administrative units (three publications), or landscapes (two). Both papers that use landscapes do not define the unit of aggregation. Two papers analyse the data at grid level, with different choices of grid size and cell shape.

[2] Official IACS terminology for the two units is agricultural parcel for the smaller unit and reference parcel for the larger unit, but both may also coincide (BILL et al., 2011).

The papers use IACS data from the years 2005 to 2018, with six papers using data from several years (either a range of years or two points in time); column 6 in Table A.2 gives the details. The longest period observed in a single publication is 11 consecutive years (2005-2015). Two publications use data from a single year, but do not specify the year itself.

3.8 Datasets Combined with IACS (RQ6)

A host of datasets are used in conjunction with IACS data in the 12 selected papers. Table 6 lists the datasets and the links to IACS. The spatial datasets allow researchers to merge data on very different topics for analysing large areas or landscapes, while the farm-level datasets allow them to merge IACS data with detailed information on farms and farmers. Farm IDs, which are necessary for merging at farm level, are generally unknown due to data privacy protection, with some exceptions.

3.9 FAIR Principles in Data Use (RQ7)

Table A.5 in Appendix 6 provides the detailed results on the sample publications' adherence to the FAIR principles of data transparency. The information that the publications provide on *data provision and access modalities* for IACS data is mixed. Only one study provides clear and detailed information on both data provision and access (LÜKER-JANS et al., 2016). Others provide limited information on the data-providing authority only (e.g., LATRUFFE and PIET, 2014; LEONHARDT et al., 2019; EDER et al., 2021), or on data access for research (KYERE et al., 2019), often in the acknowledgements. Nine out of the twelve studies *clearly describe the dataset* used, and three partly describe it. The nine studies all use the GSAA dataset, with varying years of data use ranging from 2005 to 2018. These studies also describe the spatial and thematic information used, such as crop types, farm IDs, and landscape features (e.g., LEONHARDT et al., 2019; UTHES et al., 2020). The other three studies do not describe clearly which IACS dataset they use, or which information they extract from the datasets.

Similarly, measures of *data cleaning and pre-processing* are sometimes not fully explained, posing challenges to reproducibility. Five studies provide detailed information on data preparation (e.g., SKLENICKA and SALEK, 2008; SKLENICKA et al., 2014; KIRCHWEGER et al., 2020), but five studies lack some information, mostly on crop type aggregation into classes or groups (e.g., KYERE et al., 2019; LEONHARDT et al., 2019; WOLFF et al., 2021). Two studies do not provide any information on data pre-processing or cleaning, but one of them refers to a different publication for this purpose (RUSCH et al., 2014, referring to RUSCH et al., 2013). Only one study provides code for data pre-processing (KIRCHWEGER et al., 2020) while the other studies offer only a verbal description of steps in GIS software or no description at all.

Table 6. Datasets combined with IACS data in the sample papers

Dataset	Link(s) to IACS		
	Spatial join	Farm ID	municipality
Weather data (temperature, precipitation)	X		
Landsat satellite data	X		
CORINE land-use cover layer	X		
Species sampling data	X		
Digital elevation model (topographic data)	X		
Open street map	X		
Regional planning data	X		
Municipality borders	X		
Soil quality rating/data	X		
Digital cadastre map	X		
Land register		X	
Farm Accountancy Data Network (FADN) data		X	X
Agricultural structure survey (ASS)			X

Source: own compilation

3.10 Discussion of IACS Data Benefits and Limitations (RQ8)

To illustrate how we will address RQ8 on discussions of IACS data in the full review, we collect all points of discussion on IACS data that the authors of the 12 selected publications raise, code them inductively, and categorize codes into three categories: benefits of IACS data, limitations of IACS data, and suggestions for IACS data collection and provision. Several of the selected publications discuss IACS data benefits and limitations in great detail (e.g., LÜKER-JANS et al., 2016; BARBOTTIN et al., 2018; UTHES et al., 2020), while others mention only few (LEONHARDT et al., 2019; KIRCHWEGER et al., 2020; EDER et al., 2021), or none (RUSCH et al., 2014; SKLENICKA et al., 2014).

Table 7 lists the codes by category; topics mentioned more than once are listed first. The benefits mentioned most are the data's EU-wide availability and their temporal and spatial comprehensiveness. The data are considered reliable because authorities collect and verify them, and link farmers' self-reported information to payment entitlements. Limitations include that IACS only collects data on the land reported by the farmers seeking subsidies. Not all farms register and some register only part of their farmed land. Some sample paper authors note that

Table 7. Benefits, limitations and suggestions to improve IACS data discussed in the sample papers

Category	Summary of aspects mentioned
Benefits of IACS data	Available EU wide Yearly collection (Spatially) comprehensive coverage of agricultural land Comprehensive coverage of farms Spatially explicit Reliable and of high quality due to farm checks and sanctions Cost-effective data source due to collection purpose High level of detail (e.g., crops, plot level, farm level) Information on present and past land use Dedicated software for IACS data analysis exists Freely available for science Combines information on land use and farm structure Unique ground truth data for calibration and validation
Limitations of IACS data	Not all farmed land/farms included Data not publicly available Farm IDs cannot be linked to other datasets No agricultural parcels (only reference parcels) provided No information on farmstead location No management information Grassland usage types not comprehensively collected Differences in data setup and collection across the EU Differences in data collection/provision over time Plot shapes change over time Incongruences between IACS and FADN data Issues with data availability over time No qualitative information Incomplete reporting of landscape elements Farm IDs change over time (anonymization) No fallow land included
Suggestions for IACS data collection/provision	Information on farmstead locations Farm IDs Crop and livestock management information Differentiated/additional use categories (e.g., grassland types; maize for biogas) Qualitative information from farmers Enable link to other databases such as the FADN

Source: own compilation

IACS data or specific variables (e.g., farmstead locations) are subject to use restrictions, and that variables and data contents are not standardized across EU countries, hindering comparative analyses. Registered farm and land data differ annually, particularly between CAP periods. It is difficult to track plots across multiple years, and reporting of landscape elements may be incomplete. Several sample papers suggest that IACS should collect additional information (e.g., farm IDs, farmstead locations, additional crop information) or authorities should enable merging IACS with other datasets.

3.11 Discussion of Pilot Analysis Results

The pilot analysis primarily serves to illustrate the review protocol presented in Section 2. The presented results depend on the small number of selected papers that we deemed diverse enough for evaluating our search strategy. Nevertheless, the results show some findings that are of interest in their own right, which we discuss here.

The results of the pilot analysis demonstrate the potential of IACS plot-level data for addressing research questions on farm and landscape structure, crop choice and crop diversity, farm performance, and ecosystem conditions/services or biodiversity. They show that the data have already been used for deriving indicators or metrics of farm management or farm/ landscape structure, for site selection, typology creation, and as ground truth data in remote sensing applications. Our collection of these use cases as well as indicators and suitable datasets that can be combined with IACS data provide a starting point for others who aim to work with the data. However, our results also highlight the need for more comprehensive and transparent reporting of data handling procedures to enhance the findability, accessibility, interoperability, and reusability of IACS data use cases.

Our results also reveal differences in data contents, challenges to data use, a lack of common terminology, and inconsistencies and gaps in the analysed papers. Differences in data contents are apparent as, e.g., LEONHARDT et al. (2019) use information on farmstead locations, while BARBOTTIN et al. (2018) criticize a lack thereof. Several authors use information on AES and organic farming, while open IACS data on the INSPIRE portal do not provide this information. Some authors use farm IDs, while others note that IDs are not provided. Such differences hinder scientific data use across countries. Data-providing authorities should harmonize how they construe data privacy protection regulations for scientific use, and researchers using IACS should be transparent about data access and contents. The smallest data unit (plots or blocks) in IACS also differs between countries, which likely originates from different IACS setups (publication of agricultural parcel or reference parcel data; cadastre or production blocks as foundation (c.f. BILL et al., 2011; SAGRIS et al., 2013; SAGRIS et al., 2015)). The analysed papers do not always clearly define this unit, making it difficult to judge whether a difference in terminology results from a difference in data content. Such observations on country-related differences are in line with the NIVA CONSORTIUM (n.d.), who find that IACS thematic information on crop types differs greatly between countries and between federal states.

Other challenges to IACS data use include difficulties in tracing plots and farms over time, and dealing with land not under payments that is missing from the dataset, as discussed by some authors of the selected papers. These problems cannot be avoided easily as they arise from the nature of IACS data gathering, and require additional processing steps. Not all analysed sample papers discuss the limitations of IACS data, making it difficult to judge their impact on results. Similarly, not all publications describe whether and which data cleaning steps were necessary and undertaken. We also do not find any attempts to validate IACS data or derived indicators using alternative datasets among our sample papers either. ASS or FADN data could be used for validation, and could also provide additional information (e.g., farm management practices, farmer information) that some authors suggest adding to IACS.

As briefly noted above, the pilot analysis reveals the lack of a common terminology. Two cases in point are the inconsistent use of names for the smallest spatial unit in IACS (plot, parcel, patch, field), and the interchangeable use of landscape structure, complexity, patterns, diversity, and fragmentation without proper definitions. We also find that authors who derived indicators from the data are not always clear about their indicators' indicanda and the theoretical or causal link between them. The choice of indicators appears mostly data-driven and little theory-driven, which can be problematic (NIEMEIJER, 2002). Discussing theoretical considerations and causal explanations of indicator use would increase the clarity and reliability of research (NIEMEIJER and DE GROOT, 2008).

The results of the pilot analysis are limited by the number and choice of sample papers. In the planned full review, additional or different categories may arise, e.g., with respect to content-related or methodological purposes; and we expect to find additional and/or different indicators and datasets linked to IACS.

4 Summary and Conclusion

This paper presents a review protocol for identifying and analysing scientific publications that use data from the Integrated Administration and Control System (IACS) in five countries of interest: Austria, Czechia, France, Germany, and Sweden. A pilot analysis of 12 papers illustrated the data extraction, analysis, and result presentation processes that the protocol specifies.

We propose to conduct a systematic mapping review of work using IACS data as outlined in the systematic mapping review protocol next. While the protocol has proven to be well-suited for the pilot analysis and has been refined through this process, we acknowledge that some disagreements and ambiguities will remain since the uses of IACS data span disciplines with different research paradigms, methodologies, and methods. It may be difficult to develop categories that apply to any and every potential use. We expect that the proposed full review will produce additional and more diverse results than the pilot analysis. The framework for data extraction must be flexible to accommodate differences while still providing structure. In summary, we hope that this first glimpse into IACS data use sparks interest in our future review and analysis. To improve the future process and results, we are open to suggestions and comments from readers, researchers, and policymakers.

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