APPLICATIONS OF LAND-USE DATA FROM THE INTEGRATED ADMINISTRATION AND CONTROL SYSTEM (IACS) IN SCIENTIFIC RESEARCH: A SCOPING REVIEW PILOT ANALYSIS

Heidi Leonhardt, Silke Hüttel, Tobia Lakes, Maximilian Wesemeyer, Saskia Wolff

Heidi.leonhardt@boku.ac.at

Universität für Bodenkultur Wien, Department für Wirtschafts- und Sozialwissenschaften, Institut für nachhaltige Wirtschaftsentwicklung, Feistmantelstraße 4, 1180 Wien, Österreich

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Applications of land-use data from the Integrated Administration and Control System (IACS) in scientific research: A scoping review pilot analysis

Abstract

Georeferenced data from the Integrated Administration and Control System (IACS) that contain plot-level information on the land use of agricultural beneficiaries in the European Union have increasingly become available for scientific purposes. While researchers from various disciplines are using these data for a wide variety of applications, there is currently no complete and structured overview of their use. The work presented here targets at contributing to closing this gap and provides an analysis of twelve purposely-selected publications, serving as a pilot analysis for a systematic scoping review.

In this scoping review – and, correspondingly, the pilot analysis presented here – we aim to identify all scholarly publications that use IACS data from Austria, Czechia, France, Germany, or Sweden. We then analyze these publications with respect to the following research questions: (1) Which research has been conducted using plot-level IACS data in the five countries of interest? (2) What are the opportunities that the IACS plot-level dataset provides for science, and what limitations to its use exist?

The pilot analysis demonstrates that IACS data are used by various disciplines, for the purposes of describing landscape and farm structure, farm management outcomes, and for conceptual purposes. The analyzed publications derive and apply 27 different indicators from the data to indicate landscape or farm configuration, composition, and management outcomes. Moreover, the pilot analysis shows that there is a lack of common terminology, and identifies the main benefits and challenges associated with IACS data use.

With these results and the scoping review in a next step, we hope to demonstrate the powerful potential of the plot-level information contained in IACS to policy makers as well as scientist from various disciplines. By sharing information on existing use cases, we hope to help others to avoid double work and to inspire novel applications of the data.

Keywords

Integrated Administration and Control System, agricultural beneficiaries data, scoping review, InVeKoS.

1 Introduction

To administer and control subsidies to farmers under the Common Agricultural Policy (CAP), European Union (EU) member states are obligated to operate an "Integrated Administration and Control System", abbreviated by the acronym IACS. The IACS consists of several databases and systems; two of which are a "land parcel identification system" (LPIS) and a corresponding "geospatial aid application" (GSAA). These systems identify agricultural plots eligible for subsidies and allow farmers to graphically declare their farmed land at the plot level for subsidy application (European Commission, n.d.). Both systems are based on a geographical information system (GIS) application, such that the resulting information is georeferenced. In the annual process of declaring their farmland, farmers also specify the crops they grow on each of their farmed plots every year. Since most farmers in the EU apply for subsidies, the final dataset of georeferenced information on cultivation and location of farmed plots covers the vast majority of farmland in most EU countries, making it a detailed and valuable data source.

In the past years, efforts have been made to make these rich data available for research purposes. The basic dataset of georeferenced plots with crop information (but without any farm-level information) is now publicly accessible via the European Commission's INSPIRE geoportal for several countries. Farm-level information including farm IDs that enable linking the plots of one farm is collected by authorities for subsidy administration, and is accessible for research purposes in some countries. As a result, access modalities to IACS data, restrictions on their use, and the level of detail available vary between countries. Nevertheless, researchers from different disciplines have begun to make use of the data for various applications ranging from use as training data for crop identification from satellite images (e.g., KYERE, 2019) to identifying landscape types (WOLFF et al., 2021) and to calculating measures of agricultural land use fragmentation to estimate its effects on farm's economic performance (LATRUFFE and PIET, 2014).

This variety of use cases from disciplines including agricultural sciences, agricultural economics, ecology, geography, and remote sensing has become apparent to our team of authors at a workshop on the benefits and challenges of IACS data use in spring 2021. At the workshop, a wide range of possible use cases, applications, and indicators derived from the data were presented and the need for a systematic reflection on application fields became apparent. We expect that an even greater variety of applications of the data must additionally exist in the literature. Such, often discipline-specific, knowledge is presumable scattered across research fields, countries, and individual research groups, and the full range of use cases remains most likely unknown to many scientists. This in turn may hinder more efficient and creative use, such that double work may arise. Moreover, while many stakeholders in data providing agencies are aware that the data are used by some researchers, they are often not aware of the full range of applications and may even underestimate the need for support services, including sufficient and sustainable documentation of the data (use).

To address this lack of an overview of possibilities of IACS data for science, we plan to conduct a review of the scope of scientific research that uses information from the IACS plot-level dataset (including LPIS and GSAA). To reduce the vast body of existing work to a manageable amount, we focus on a purposely selected sample of EU countries in this planned review: Austria, Czechia, France, Germany, and Sweden. Our review will address the following research questions:

1. Which research has been published using plot-level IACS data from Austria, Czechia, France, Germany, and Sweden?
    i. Researchers from which scientific fields have used these data? How many publications exist and from which time periods?
    ii. Which research questions have been addressed using the dataset?
    iii. For which purposes have IACS data been used (methodological, content-wise)?
    iv. Which information from the IACS dataset has been used, at which spatial and temporal level?
    v. Which indicators have to date been derived from these data for which purposes?
    vi. How and to which other datasets have IACS plot-level data been linked?
    vii. Which critical evaluations and suggestions for use or improvement of the dataset have been made?
2. What are the opportunities that the IACS plot-level dataset provides for science, and what limitations to its use exist?

We plan to address these questions by means of a scoping review (MUNN et al., 2018). Our strategy for conducting and publishing this research involves two steps. First, we develop and publish a scoping review protocol that details our search strategy, paper selection process, and planned analysis. This review protocol is developed by means of a pilot analysis of a small sub-sample of publications using IACS data, the results of which are presented here. Second, we conduct the full review, the results of which will be presented later in time. The present publication comprises the first of these two steps and therefore serves to share first insights on the breadth and scope of IACS applications, giving an outlook on what to expect from the final review.

To date, to the best of our knowledge, no attempts have been made to systematically collect and analyse all use cases of IACS data or indicators derived thereof. Some recent works exist that strongly refer to IACS data as a source of valuable information or that test the use of IACS for various individual purposes. For example, LOMBA et al. (2017) evaluate the potential of IACS data for identifying High Nature Value farmland, and successfully apply IACS-derived indicators to do so. Similarly, UTHES et al. (2020) test whether and to what extent IACS data could serve as an addition to data from the EU's Farm Accountancy Data Network (FADN) for measuring agricultural sustainability. They derive and apply several indicators of crop and landscape diversity from IACS data, conclude that they "can be a cost-free data source to increase and validate the indicator portfolio of the FADN", and recommend that the tested indicators be included in the FADN. This result contrasts a conclusion drawn by KELLY et al. (2018), who discuss IACS data as a source of information on agricultural sustainability, but discard their usefulness in favour of expanding FADN data by additional variables. Finally, TOMLINSON et al. (2018) use IACS data to analyse gross and net agricultural land use change and conclude that the dataset is an invaluably detailed source of information on land use that provides great potential. These endeavours into testing the usefulness of IACS data already demonstrate the potential of the dataset for addressing particular questions. Comparing these publications to our current project, the difference lies in the "direction" of the questions asked: the existing publications address questions of "can IACS data be used for *X*", whereas our intention is to ask "for what *X* can IACS data be used"?

2 Methods

Given our aim of an evaluation of the *scope* of existing research (rather than an evaluation of interventions or outcomes), the appropriate review method is a scoping review (MUNN et al., 2018). Scoping reviews are *"exploratory projects that systematically map the literature available on a topic"* (GRIMSHAW, 2010, p. 34) and that 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). These exemplifications of the method precisely correspond to our research aim of providing a comprehensive overview of the literature.

To conduct and report on our scoping review, we follow the guidance provided by the Centre for Environmental Evidence (CEE) as well as the associated ROSES reporting standards (HADDAWAY et al., 2018). Our pilot analysis follows the same analysis and reporting procedures as the full review.

For the pilot analysis, we compiled a list of twelve articles using IACS data. Given that this list was initially developed to evaluate and refine our search strategy, it is not – and cannot be – representative of the final list of publications that the scoping review will cover. Instead, the sample papers were known to the team of authors prior to the review process as important to their own research fields, or were co-authored by one or more team members. We selected the sample papers to:

- Cover all selected countries (Austria, Czechia, France, Germany, Sweden)
- Cover various disciplines that we know and expect to use IACS data
- Have been published in various journals from different publishers

- Rely on IACS data to varying degrees and as a consequence do or do not place the dataset name in a prominent place such as the title or abstract

The selected papers are marked with an asterisk in the literature list.

From the papers we first extract the general information/metadata for all articles, including year of publication, author information, journal, discipline/field, based on journal subject categories as categorized in SCImago (SCIMAGO, n.d.), and the country/countries of data use. Next, we extract the following information from full texts:

- Importance of IACS data use (minor/major)
- Combination with other datasets (yes/no; dataset names; link)
- Year(s) of data use
- Research question(s) or aim(s) or objective(s) (text)
- Methodological purpose(s) of IACS data and derived indicators (inductive categories)
- Content-related purpose(s) of IACS data (text)
- Indicators generated/derived (indicator names)
- Indicandum of each indicator (text)
- Raw information from IACS used (categories)
- Spatial unit of analysis (categories)
- Discussion of IACS data use (text)

We synthesize open text in a narrative manner and using wordclouds, which help to identify the breadth of research topics as well as particularly common terms. We collect all indicators derived from IACS, link them to their indicanda, and group them by topics in order to provide an exhaustive overview of applications. We analyze categorical, binary, and numerical variables by providing counts, descriptive statistics, and corresponding tables and figures. In addition, we aim to identify country-related differences in IACS data use that may be due to differing data availability and quality; and to identify critical discussion points, suggestions, limitations, etc. that have been raised by the researchers working with the data.

3 Results and Discussion

In summary, the papers analyzed in this pilot analysis

- were published between 2008 and 2021,
- in nine different journals,
- are associated with eleven different disciplines;
- use IACS data from the years 2005 to 2018
- from Germany (5), and fewer from Czechia (2), France (2), Austria (2), Sweden (1),
- nine out of twelve combine IACS data with other datasets, and
- all make “major” use of the IACS data.

We find that IACS data are used to address a wide variety of scientific problems and a broad range of research questions. Notable differences exist with respect to the spatial unit of analysis of the research objects, ranging from the plot or block level (KYERE, 2019; SKLENICKA et al., 2014) to the farm or farmer level (e.g., BARBOTTIN et al., 2018; EDER et al., 2021), the landscape level (KIRCHWEGER et al., 2020; WOLFF et al., 2021), or a mix of several levels (UTHES et al., 2020). The objects of research also differ, covering land ownership structures, land fragmentation, farms’ eco-efficiency, landscape structure, the performance of crop prediction models, generalist predator communities, IACS data usefulness, and more. The methodological approaches that are implicitly contained in the research questions range from economic analysis (EDER et al., 2021; LATRUFFE and PIET, 2014) to ecological analysis (RUSCH et al., 2014), geospatial analysis (WOLFF et al., 2021), remote sensing (KYERE, 2019), and more.

3.1 Purposes of IACS data use

Most applications (9) use information from IACS for the methodological purpose of indicating (an aspect of) a phenomenon, creating and using *indicators* to address their research question(s). These indicators use either untransformed raw data (e.g., plot sizes as indicators for land use fragmentation) or transformed and/or combinations of raw data components (e.g., Shannon diversity index as an indicator for landscape diversity). Fewer of the selected publications (3) use raw data as source of information directly in form of a *metric*, with no indicandum (e.g., to measure plot sizes).

Indicators and metrics then enter various types of models, e.g., for statistical analysis, that appear, however, too diverse to structure for this subsample. Thus, we base our further structuring of methodological purposes on those issues that we expect to occur somewhat frequently in the full review: First, site selection and grouping (2), which refer to the use of IACS-derived information for selecting study sites/farms/landscapes (e.g., RUSCH et al. 2014) or for grouping farms/landscapes/etc. for e.g., comparison (e.g., SKLENICKA and SALEK 2008). Second, typology creation based on IACS data (2), which refers to cases where IACS data (sometimes plus additional data) are used to identify (and describe) landscape and farm land use patterns (e.g., LÜKER-JANS et al. 2016, WOLFF et al. 2021). Last, we identify data use for the purpose of reference data or "ground truth data" (1), which is mainly used in remote sensing applications (KYERE et al. 2019).

Next, we turn to content-related purposes of IACS data use that we extracted verbatim from the sample texts. To structure our findings, we group these content-related purposes into three categories: (1) describing landscape and farm structure, (2) describing farm management activities and outcomes, and (3) conceptual discussion of the data.

(1) Examples of IACS data uses grouped in the category of landscape and farm structure include:

- "[characterizing] agricultural landscapes ... in terms of landscape structure [and] diversity" (WOLFF et al., 2021)
- Identifying "landscapes with similar levels of complexity" (RUSCH et al., 2014)
- Describing "structural aspects of the landscape, namely field size and landscape elements" and "location and length of edges along agriculturally used fields" (KIRCHWEGER et al., 2020)
- Deriving "farm-level indicators for crop and landscape diversity" (UTHES et al., 2020)
- Characterizing "annual changes in farm area" and "farm size distribution" (BARBOTTIN et al., 2018).
- Describing farmland parcel sizes (SKLENICKA et al., 2014; SKLENICKA and SALEK, 2008, among others) and land use fragmentation (BARBOTTIN et al., 2018; LATRUFFE and PIET, 2014)
- Using crop information and "crop field shapes from the IACS database" to "train a multi-temporal field-based model, which can predict crop types from a satellite image" (KYERE, 2019).

As these examples demonstrate, the terminology used for describing landscape and farm structure varies: Terms such as "patterns", "diversity", "complexity" or "fragmentation" describe similar issues.

(2) The applications grouped in the category of farmer management activities and outcomes use IACS data to describe (the results of) farmer behavior with corresponding outcomes at the plot or farm level. 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 farmers' land management decisions. To tackle this problem, we adopt a narrow notion of management (outcomes) for this category and group only activities that are at the farm level

and under very direct control of farm managers. The corresponding uses of IACS data in the sample papers include:

- Providing information on agri-environmental practices (funded through agri-environmental schemes, AES) such as “erosion control measures” (EDER et al., 2021) or “participation in soil-enhancing AES” (LEONHARDT et al., 2019)
- Providing information about organic farming (RUSCH et al., 2014; WOLFF et al., 2021)
- Indicating “soil conservation efforts” (LEONHARDT et al., 2019) or deriving “a measure of soil conservation inactivity of farmers” (EDER et al., 2021) from crop choice
- “Rating land-use change” (LÜKER-JANS et al., 2016)
- Using crop information to derive crop yields and farm gross margins (KIRCHWEGER et al., 2020)

Not all of the purposes listed here can be served by all types of IACS datasets: whether a plot is under organic farming or a farm participates in AES is typically not published e.g., in the datasets available on the INSPIRE portal, but may only be available from national authorities. Crop information may then be the main source of information on farmer management decisions.

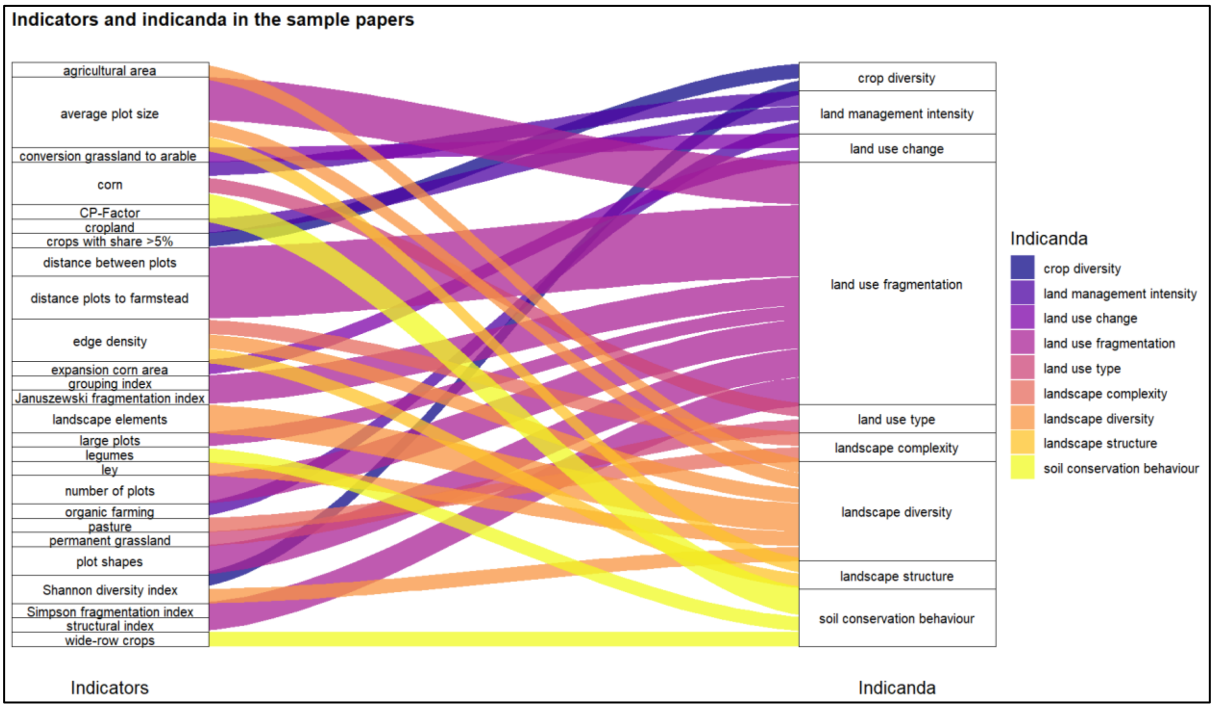
(3) We collect applications in the group of “conceptual discussion of the data” that address conceptual questions in terms of IACS data structure or usefulness. Among the sample papers there is only one such case; an evaluation of the possibilities of IACS as an extension of the EU’s FADN data (UTHES et al., 2020).

3.2 Indicators derived from IACS data

As shown above, a common use of IACS data is to derive indicators. We find that the twelve sample papers alone already use a very large number of 27 different indicators. Average plot size is the most commonly used (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, we observe that land use fragmentation is the most commonly measured indicanda (17 occurrences) in the twelve sample papers, followed by landscape diversity (7) and soil conservation behavior (4). Note that all but one publication use multiple indicators to measure one indicandum, causing these large numbers. When considering the main, overarching indicanda of landscape/farm structure, composition, and management, “management” is the least frequently occurring category (12), with “composition” (19) and “configuration” (22) occurring more often (multiple per indicator possible).

Figure 1 summarizes and illustrates connections between indicators and indicanda, connecting each instance of an indicator used in one of the papers to its indicandum. Highlighting some interesting connections and differences when reading the figure from left to right, e.g., average plot size is used to indicate land use fragmentation, landscape diversity, and landscape – three different indicanda. Similarly, edge density is used to indicate the (however, closely related) three indicanda of landscape complexity, diversity, and structure. Reading figure 1 from right to left, indicators of land use fragmentation range from simple average plot sizes to sophisticated measures such as the “structural index” (a measure of the scattering of plots in space). Landscape complexity is measured by such different approaches as the share/amount of pasture (as aspect of landscape composition) and edge density (an aspect of landscape configuration). Landscape diversity is measured through indicators from all three main groups, including shares/occurences of ley, landscape elements, and agricultural area; average plot sizes, edge density, and the Shannon diversity index. Although “landscape diversity” is certainly a broad concept, it is still surprising to see so many different approaches to depicting or measuring it.

Figure 1: Relationships between indicators and their indicanda. Each connection represents one instance of an indicator-indicandum pair.



Source: own presentation and data. Created with R (R CORE TEAM, 2018).

3.3 Raw data used from IACS

We classify the raw data that is contained in IACS into the four main groups of spatial information, temporal information, thematic (land use) information, and other information. First, we observe here that the most used IACS raw data components are plot geometries (12) and crops grown (10, including land use classes such as cropland and grassland), in line with the main data contents. Half (6) of the analyzed papers make full use of geometrical information, while the other half (6) uses plot sizes as the only information on geometries. For most – but not all – papers the exact location of plots is relevant (8), as datasets are merged spatially or distances between objects are calculated. Somewhat surprising is the uncommon use of temporal information (3), since analyzing changes over time can provide valuable insights. One reason for this may be that it is difficult to trace plots over time, as plot boundaries change due to plot divisions, plot mergers, and digitization differences in farmers' yearly process of reporting their land.

Second, we know from our own experience and suspect from the results that the information contained in the data that is available for research purposes varies between countries or access pathways. Whereas landscape elements, organic farming, and farmers' AES participation is used in some publications and therefore must be available from (some) data providing agencies/authorities, the freely available IACS datasets on the INSPIRE portal usually do not contain this information. Similarly, farm or user IDs and farmstead location information are provided in some countries, but not all.

3.4 Spatial unit of analysis

The farm level is the most common unit of analysis found in the sample papers (5), followed by the plot or block level (4). While these two terms – "plot" and "block" – may appear to be synonyms, they are not necessarily so. In some countries, an "agricultural production block" represents a set of contiguous plots that are all farmed by the same farmer or all have the same land use. However, we also observe that the terminology for each of those two levels is used inconsistently: “Plot”, “parcel”, “patch” and “field” are all names for the smaller unit, while “production block”, “field” and “islet” are names for the larger unit, within the twelve sample papers alone.

Aside from farm- and plot-level analyses, five of the analyzed papers (also) aggregate data to a larger level such as administrative units (3), or the “landscape” (2, left undefined). Two papers analyze the data at the grid level, where several different options in terms of grid size and cell shape exist.

The chosen unit of analysis largely depends on the research question or aim. Likely (but not substantiated here), the chosen unit of analysis differs between disciplines due to their focus: Ecologists or geographers are often interested in sites or landscapes that cover contiguous areas, such that the question of which piece of land is farmed by which farmer is irrelevant. Economists or researchers studying (impacts of) individual behavior will, on the other hand, find it more adequate to examine farms or single plots, even if this means analyzing non-contiguous patches of land.

3.5 Datasets combined with IACS

A host of datasets have been used in conjunction with IACS data in the twelve sample papers. They are listed below, including information on how the data have been linked – most often through spatial matching.

- Weather data (temperature, precipitation) – space
- Landsat satellite data – space
- CORINE land-use cover layer – space
- Species sampling data – space
- Digital elevation model (topographic data) – space
- Open street map data – space
- Regional planning data – space
- Municipality borders – space
- Soil quality rating/data – space
- Digital cadastre map – space
- Land register – farm ID
- Farm Accountancy Data Network (FADN) data – farm ID (AT); municipality (FR)
- Agricultural structure survey (ASS) data – municipality

This list shows how valuable spatial datasets are, as they allow for merging data on very different topics to analyze large areas or landscapes. Similarly, linking different farm-level datasets via farm IDs allows researchers to address questions relating to farm business structures and farmer behavior (e.g., linking IACS data with FADN or ASS data). However, farm IDs are rarely available for research due to data privacy protection concerns.

3.6 Points of discussion of IACS data raised

Last, we collect all points of discussion of IACS data use, availability, benefits, or difficulties that the analyzed papers raise, including future outlooks concerning the data. We summarize and categorize them into “benefits of IACS data”, “problems with IACS data (use)” and “suggestions for IACS data collection”. Eight of the sample papers made at least some mention of IACS benefits or problems, while the remaining four did not discuss IACS data use or the dataset’s limitations to, e.g., data completeness at all.

The texts that explicitly discuss benefits of IACS data praise the level of detail and comprehensiveness of the dataset. In many countries, IACS data covers the vast majority of agricultural land and provides detailed plot-level information (tens or even hundreds of different crops are recorded, see NIVA CONSORTIUM (2021)) on a yearly basis – indeed a very comprehensive dataset that cannot easily be replaced. Moreover, the fact that all member states collect these data and they are therefore (in theory) available EU-wide is mentioned frequently, although none of the papers we have analyzed actually uses data from more than one country. Moreover, collection by authorities and the link to payment entitlements means that data are subject to checks that farmers are aware of, such that the data are considered reliable despite being self-reported. In addition, the collection for payment administration means the data are already "there", and it is therefore only sensible to use them for scientific purposes in addition to their original function.

Concerning problems with data use, several publications note limitations that originate in the nature of IACS data gathering. Data from IACS, despite being quite comprehensive, do not cover all farmland, but only the land that farmers use to claim payments. This means that not all farms register in IACS and some farms register only part of their land. For the same reason, registered farms and farmland may change every year and especially between CAP periods. Other issues arising from the specific backdrop of IACS data are that plots' sizes and outlines may change over time, making it difficult to track plots for multiple years; and that the reporting of landscape elements may be incomplete (or has been so in the past). These troubles, even if cumbersome, arise from farm management necessities and farmer considerations related to subsidies, such that it will not be possible to eliminate them. Therefore, researchers using IACS data need to be aware of these limitations and should consider and discuss their impact on their work. Where necessary, using additional satellite data to impute missing information or "fuzzy" techniques to track plots over time may be valuable tools to confront the challenges of incomplete or time-inconsistent data.

Moreover, some authors discuss data availability restrictions and a lack of standardization as obstacles to wider and better data use. Some of our results also reflect these issues. For example, while some authors criticize the lack of farm IDs that help linking plots of one farm together, other publications use farm IDs for this purpose. It appears that although access to IACS data has become easier in recent years, this is not true for all countries and for all variables. Moreover, information e.g., on crop types differs between countries (NIVA CONSORTIUM, 2021) and even between federal states of the same country. This means that using data from several regions or countries will imply additional efforts and work, making multinational work unattractive.

Last, several authors suggest adding additional variables to IACS that are currently either not collected or not shared over concerns about data privacy. Some of these variables are available in theory (or even available in some countries, as mentioned above) or could be implemented easily. These include farm IDs (anonymized or linkable to other datasets), farmstead locations, information on livestock, and more precise crop categories (e.g., for different types of grassland). More difficult to implement – because they go beyond the original purpose of IACS – are variables such as soil management practices at the plot level (e.g., fertilizer information) or qualitative information at the farm level. Some of this information is available in other datasets (ASS and FADN), which is likely a reason for some authors to express a desire to have the possibility to link those datasets. From a science perspective, such a mergeability indeed appears desirable, as this would allow for answering comprehensive, multidisciplinary research questions. However, data privacy concerns over combining several data sources need to be taken seriously, requiring careful consideration of the benefits to science and the potential harms for individual farmers if identifiable through an increase in data content.

4 Summary and Conclusions

The content of the twelve sample papers analyzed in our pilot analysis here shows that IACS data are widely used across disciplines. Irrespective of this wide range of disciplinary backgrounds, IACS data use can be grouped into three main purposes: describing landscape and farm structure in terms of configuration and composition, describing farmer management activities, and addressing conceptual aims. We identify almost 30 different indicators that researchers use to describe aspects of these purposes. To construct indicators and metrics, the most commonly used raw data components are plot geometry, location, and crop types. Other information, including temporal changes, is used more seldomly. We appeal to researchers to consider including all potential dimensions of information into their studies to make full use of the data's potential. However, we find that some information collected in IACS (such as farm IDs, information on organic farming or AES) appears to be available for research only in some countries, rendering their use impossible for researchers in others. Here, we appeal to data providing agencies to work on harmonization. The spatial unit of analysis that IACS data are used for ranges from plot level to farm level and landscape level, depending on purpose and discipline. Importantly, researchers should take care to clearly define this unit of analysis. The twelve sample papers combine a host of different datasets with IACS data, in most cases by spatial matching and in some cases by merging via farm IDs. The list of datasets that have been combined with IACS provides rich inspiration for future analyses.

We collected discussion points concerning the benefits and challenges of using IACS data, providing insights into how powerful the data are, which challenges researchers should be aware of, and how the data could be made more accessible and useful for researchers. First, the data can be considered very expedient, due to the dataset's comprehensiveness, level of detail, and (theoretical) comparability across the EU. However, in practice, challenges for scientists using the data remain, including difficulties in tracing plots over time, missing information from farms and land that is not registered in IACS, or restrictions on data use due to data privacy concerns. Second, suggestions for enhancing and simplifying the use and usefulness of IACS data by researchers range from gathering and providing additional pieces of information, to working on cross-country standardization of the datasets as well as access modalities. Especially the latter appears to be a barrier to multinational research that could easily be removed, but is in the hands of data providing agencies and policy makers. Individual researchers can help their fellow colleagues by describing data access options explicitly in their publications (e.g., whether the data is available freely or where it is available upon request). Third, we encourage researchers to critically discuss the limitations of IACS data and consequences for their results where relevant. Not all reviewed papers presented such a discussion. Relatedly, we did not find any attempts to validate IACS data through other data sources in the sample papers, and few discussions concerning data accuracy. Comparisons to other datasets (e.g., to the ASS, which covers the entire farm population in Europe) would allow for a better assessment of data quality and thus the contextualization of results. We encourage future research to undertake such data validation exercises.

On a more general level, we find in our pilot study that there is a lack of a common terminology both concerning IACS data as well as the objects of research that the data are used for. Two cases in point are (a) the inconsistently used names for the smallest spatial unit in IACS (plot, parcel, patch, field); and (b) the terms "landscape structure", "complexity", "patterns", "diversity", and "fragmentation" that appear to be used interchangeably and often without proper definitions. Concerning (a), we suggest using the term "plot" consistently; concerning (b) we appeal to Geographers, Environmental Scientists and Ecologists to work on unified concepts and definitions of these aspects of a landscape. In addition, we find that those authors who derive indicators from the data are not always clear about their indicators' indicanda and the theoretical or causal link between the two. Relatedly, the choice and use of indicators in the sample papers appears to be mostly data-driven and little theory-driven, which can be problematic (NIEMEIJER, 2002). We therefore encourage authors using IACS data (or any other data) to motivate, define and explain their (use of) indicators, i.e., to also rely on specifying their indicandum. Discussing such theoretical considerations and causal explanations of indicator use would increase the clarity and reliability of research (NIEMEIJER and DE GROOT, 2008).

Overall, we hope that already the first glimpse into IACS data use cases presented here provides inspiration and insights for research and policy. Moreover, we hope to have sparked interest in our full review and analysis that we will conduct in the upcoming months.

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