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A harmonized data set of ruminant livestock presence and grazing data for the European Union and neighbouring countries

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Improving the sustainability of the European livestock sector requires recent data at high spatial resolutions. Only then can we analyse potential negative impacts of livestock related to ecosystem degradation, and positive ones such as preserving cultural landscapes through grazing. Data on livestock numbers in Europe are provided by the European statistical office but at a coarse spatial resolution aggregated to statistical regions like NUTS2 or even coarser. While data on a more detailed level, such as local administrative areas, are available from individual national statistical offices, a collection of harmonized data has not been available until now, limiting the use of livestock data in environmental and agricultural studies. We collected data from all European Union Member States and neighbouring countries, resulting in the most up to date and spatially explicit dataset on livestock numbers publicly available to all researchers. We provide data on livestock numbers for more than 70,000 administrative units in 43 countries and territories. In addition, we provide data on the share of cattle that are grazing.

Background & Summary

Ruminant livestock production has important impacts on the economy, society and environment of Europe[1], one of the main global livestock production regions globally[2]. Data on the spatial distribution of ruminant livestock are crucial for different applications including the assessment of impacts related to different agricultural practices[3] and inputs[4], grassland productivity[5] and biodiversity[6], food security[7,8], self-sufficiency[9] and ecosystem provisioning[10], animal welfare and human health[11], spatially explicit greenhouse gas (GHG) emissions reporting[12], and analysing changes to livestock sectors[13]. Detailed and recent spatial data on ruminant livestock are therefore needed to further support policies on agriculture, rural development and increasing the sustainability of the European livestock sector.

Data on the number of different livestock types for the European Union and many neighbouring countries have been systematically collected and provided publicly by Eurostat – the European Statistical Office at national, NUTS1 or NUTS2 administrative zones, depending on the level at which member states want to disclose this information and the confidentiality regulations of the EU and Eurostat[14]. Data are available for years in which there are agricultural censuses, e.g., 2010 and 2020, as well some years in between for agricultural surveys. However, the coarse resolution of the information means that spatial variations at subnational level are not captured. Moreover, some data are still suppressed, even at this coarser resolution.

The other main product available for scientific analyses of environmental and societal issues related to livestock is the Gridded Livestock of the World (GLW), produced by the United Nations Food and Agriculture Organization (FAO) at a 10 km resolution for the years 2005[15], 2010[16] and 2015[17–19]. This product provides livestock population densities of cattle, buffaloes, horses, sheep, goats, pigs, chickens, and ducks downscaled using two different approaches: a random forest model and an area-weighted model in which livestock are distributed to areas considered suitable for livestock[15]. These two approaches also ensure that the total livestock numbers reported to FAO by member countries at the national level match the downscaled data when aggregated. The

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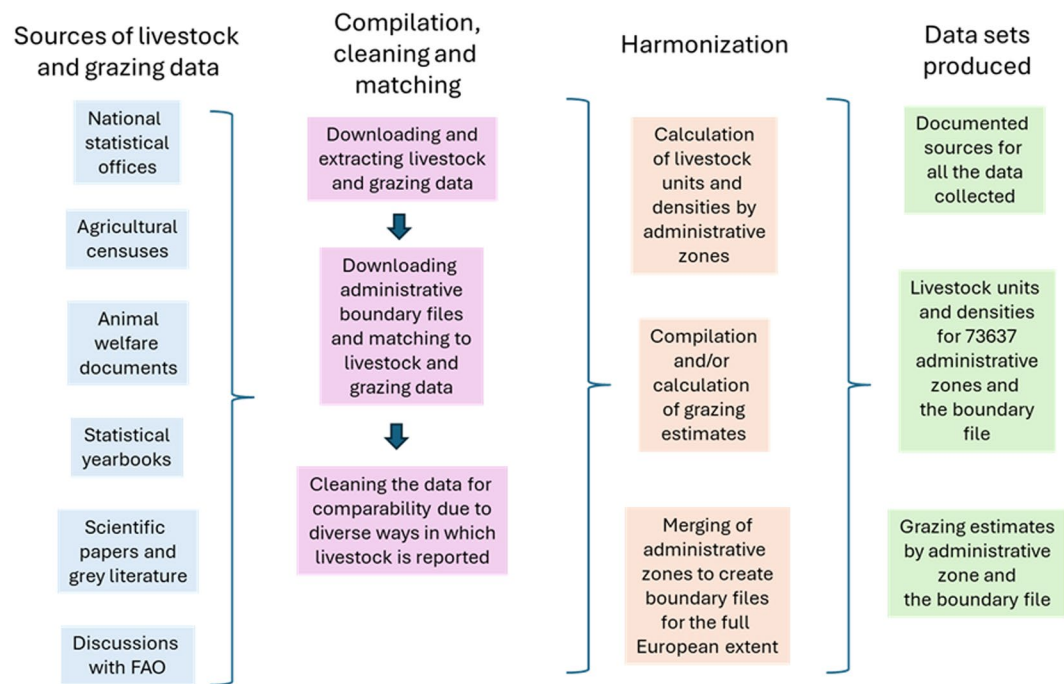
Fig. 1 Flowchart of our data collection, processing and harmonization.

sources of data used by FAO are sometimes listed or they are referenced as personal communication with member countries. Hence the full sources of the data are not currently transparent, making it impossible for researchers to update the data themselves, or to check for more detailed subclasses of individual livestock types.

As part of the EU-funded Land use and management modelling for sustainable governance (LAMASUS) project and driven by the need to produce a high-resolution grassland management map for Europe[20], we prepared a multi-temporal harmonized livestock data set for cattle, sheep and goats, the main European ruminant animals, for each European country at the scale of local and regional administrative units. The decision was based on the considerable amount of openly available data online from sources such as national statistical offices and reports from agricultural censuses. Here we present the resulting data set, harmonized by livestock unit, for the highest resolution of administrative zone available. We also provide the sources of the data for transparency and future updating, as well as the grazing shares by sub-national zones where available. This data set is being used in the development of a European grassland management map but can also be used for applications such as greenhouse gas emissions accounting and models (e.g., economic and biophysical land use models) that require supply-side inputs from the agricultural sector. Since the data have been downloaded from national statistical offices, they have not been further validated nor have they been compared with FAO's GLW. This is because FAO data are for total livestock numbers, and they have been developed using less detailed data for most of the countries (e.g., the total number of administrative units globally for cattle in the FAO data are similar to the number of administrative units we collected for Europe alone). We compare our data to Eurostat statistical data by preparing a livestock density map, which clearly demonstrates the usefulness of having livestock density data at a higher spatial resolution.

Methods

We collected the most recently published data on livestock numbers for 73,637 administrative units for 43 European countries and territories in which 27 of them are European Union Member States (Figs. 1–3, Tables 1, 2). For each country, we collected data from the official webpages of statistical offices, agricultural censuses, animal welfare documents and statistical yearbooks. We provide the sources for the data for each country as a separate table in the data record[21], enabling potential updates in the future. Some data were not available in English, so we used Google Translate to extract the relevant categories. Our rule for inclusion of data was to prioritize the more detailed spatial level and the more recent data. For example, while Romania reports livestock numbers on municipal level only for the year 2006, other, coarser data for Romania indicated drastic differences in the livestock sector. Therefore, in such cases, we relied on coarser resolution, but more valid data. For some countries, multi-temporal data were not available. In this case, we checked the changes reported at the NUTS2 level from Eurostat for such countries. While data on small ruminants (sheep and goats) are generally comparable between countries, data on bovines is not. Some countries only report the total number of bovines on a very detailed spatial level, while others report different bovine categories (i.e., cows, among them dairy, heifers, bulls, calves). Therefore, harmonization of the data to livestock units had to be done for cattle. In countries, where no other national data on different distributions for cattle were available, we used Eurostat NUTS2 livestock unit coefficients, calculated by dividing the NUTS2 reported livestock unit numbers with the total livestock numbers. An overview on how we calculated livestock units for individual countries is also provided in the Data Record.
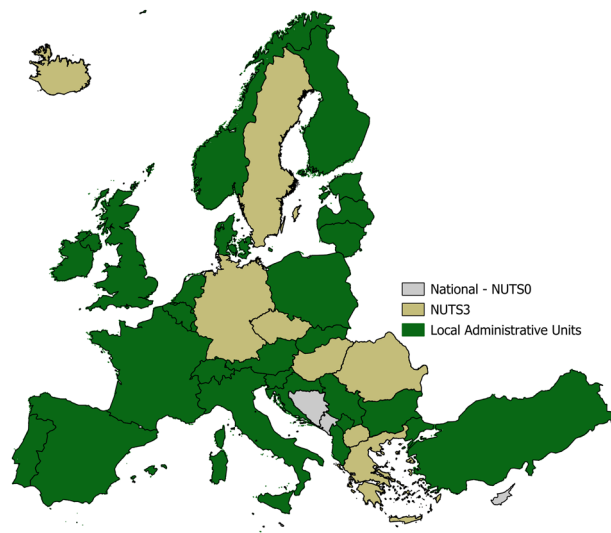
Fig. 2 Overview of the administrative level of the data collected.
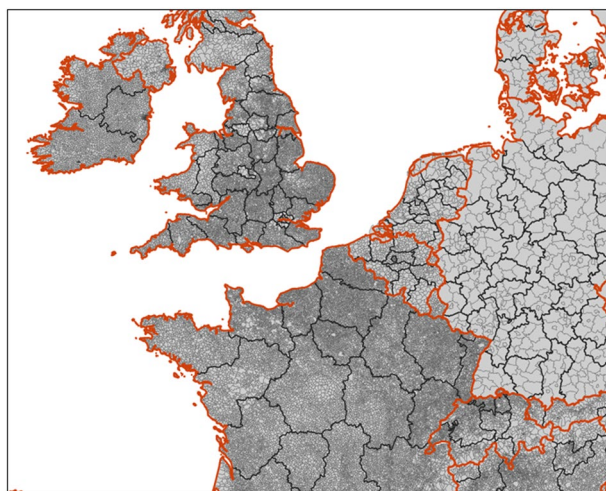

Fig. 3 Visual comparison between NUTS0 (national, red), NUTS2 (most detailed subnational data published by EUROSTAT, black), and our collected data (NUTS3 or below, local administrative units, gray), focused on Western Europe.

A country where more calculations were necessary to develop detailed livestock data was France. While France provides detailed data on livestock numbers for the year 2020 for all French municipalities, the data have two main drawbacks. First, a minor share of municipalities has data reported as "confidential". In this case, we used 2010 data for such municipalities. Secondly, France only reports data on dairy and nursing cows for municipalities, and no data for other cattle types. Here we calculated the share between dairy and nursing cows, and total livestock unit numbers per department level (which is available), and then used the same coefficients to obtain total livestock units for the municipal level. Similar data were available for Spain; however, the share of municipalities with "confidential data" was in this case considerable, without the possibility to use older data (as it is confidential also for older years). For this reason, we used data at the level of comarcas, a local administrative unit in Spain, which still represent local-scale administrative units.

We also collected data on the direct grazing of cattle (Fig. 4). Many grazing animals in the EU do not actually graze, as they are housed indoors without spending time outdoors[11]. It is important to include this type of livestock management account for animal welfare concerns, as well as potential pressures on ecosystems and fodder availability due to trampling[22,23]. Animals that do not graze do not directly impact grassland ecosystems, but they potentially impact ecosystems in distant places (e.g., by consuming feed produced in regions far away)[24]. Data on grazing are very difficult to obtain at a high spatial resolution (or any spatial resolution at all), and they are rarely systematically collected and presented on official webpages of national statistical offices[11]. We collected data on grazing from animal welfare statistics and documents, or indirectly from statistics on payments for keeping animals outdoors (e.g., animal welfare subsidies). In countries, where

Country/ territory	Nr of Eurostat administrative units	Average size of Eurostat reported unit (ha)	Level and type of administrative units	Nr of collected administrative units	Average size of administrative unit (ha)	Years for which the data are prepared
Austria	9	931900	LAU - municipality	1903	4407.3	1999, 2010, 2022
Belgium	11	278981.8	LAU - municipality	581	5281.9	2000, 2010, 2020
Bulgaria	6	1849900	LAU - municipality	265	41884.5	2005, 2010, 2020
Catalonia	1	3210800	LAU - local territory/ comarque	41	78312.2	1999, 2009, 2020
Cyprus	1	925100	NUTS0	1	925100	2005, 2010, 2020
Czechia	8	985837.5	NUTS3 – region/kraje	13	606669.2	2002, 2010, 2022
Germany	38	941031.6	NUTS3 – district/Kreis	411	87005.4	1999, 2007, 2016
Denmark	5	859040	LAU - municipality	98	43828.6	2000, 2010, 2020
Estonia	1	4533900	LAU – county/maakond	15	302260	2004, 2010, 2018
Spain (without Catalonia)	18	2632900	LAU - local territory/ comarca	285	166288.4	2006, 2010, 2020
Finland	5	6769240	LAU - municipality	320	105769.4	2000, 2014, 2022
France	27	2014593	LAU - municipality	34839	1561.3	2000, 2010, 2020
Greece	13	1015054	NUTS3 - region	52	253763.5	2002, 2010, 2020
Croatia	4	1414850	LAU - municipality	556	10178.8	2003, 2011, 2022
Hungary	6	1550433	NUTS3 - county	18	516811.1	2000, 2010, 2020
Ireland	3	2814033	LAU - electoral area	3409	2476.4	2000, 2010, 2020
Italy	21	1438443	LAU - municipality	7456	4051.4	2000, 2010, 2020
Lithuania	2	3265000	LAU - municipality	60	108833.3	2003, 2010, 2020
Luxembourg	1	258600	LAU - municipality	100	2586	2001, 2012, 2020
Latvia	1	6458900	LAU - municipality	109	59256.0	2003, 2010, 2020
Malta	1	31600	NUTS0	1	31600	2005, 2010, 2016
Netherlands	12	348750	LAU - municipality	345	12130.4	2000, 2010, 2020
Poland	17	1897500	LAU – municipality (cattle), NUTS3 – district (sheep and goats)	2451 (379)	131.6 and 851.1	2000 (2005 for sheep and goats), 2010, 2020
Portugal	7	1316457	LAU – parish/freguesia	3267	2820.7	1999, 2009, 2019
Romania	8	2979975	NUTS3 - county	42	567614.3	2000, 2010, 2020
Sweden	8	5628688	NUTS3 - county	25	1801180	2000, 2010, 2022
Slovenia	2	1013550	LAU - municipality	212	9561.8	2000, 2010, 2020
Slovakia	4	1225875	LAU – district/okres	71	69063.4	2005, 2015, 2021
Total EU	**240**	**1734760.1**		**54495**	**7640.0**	

Table 1. Comparison of existing data from Eurostat available on NUTS 2 level, with the administrative level and number of spatial units in our data set for European Union Member States.

we could not obtain any data on the share of animals that actually graze, we used UNFCCC estimates on manure deposited on pastures[25] or FAO's Global Livestock Environmental Assessment Model – GLEAM-I[26], which also reports on the share of animals on pastures. We used the highest estimate of these two proxy data sources.

After all data were collected, we associated them with spatial data on administrative units. We used publicly available data on municipalities and other local administrative units from official country, European or other repositories of public spatial data, and we provide the links to these data in the Data Record. In many countries, administrative units have changed in the last 10 years, for example, by combining or splitting municipalities. We accounted for these changes and used the larger spatial unit (either before the split, or after the aggregation of numerous municipalities). Our data, therefore, present a combination of local area delineations for the years between 2010 and 2020.

All provided data are in livestock units, meaning that we harmonized all livestock numbers for 43 countries and territories in Europe. This harmonization enables ease of use of the data, as well as the possibility to make comparisons between countries that have considerably different livestock sectors, for example, a different share of dairy and beef stocks. We used standard livestock unit coefficients from Eurostat[27], which are also used by other international organizations such as FAO (Table 3). All data comes from publicly accessible sources (national statistical offices), with more details provided in the data[21]. Only for Germany and United Kingdom (England, Scotland and Wales), this is not the case. For Germany, we obtained local data aggregated to NUTS3 level, as for more local data permission needs to be obtained. For the UK, we obtained gridded livestock data from livestock censuses (at a 2×2 or 5×5 km grid), which needed to be aggregated to admin level. Users who want more detailed data for the UK, need to obtain them by themselves. In addition, users who wish to use raw, unprocessed data on livestock headcounts, can obtain them from the sources provided in the data sources file, or from the authors.

Country/territory	Nr of Eurostat administrative units	Average size of Eurostat reported unit (ha)	Level and type of administrative units	Nr of collected administrative units	Average size of administrative unit (ha)	Years for which the data are prepared
Albania	1	2874800	LAU - municipality	61	47127.9	2000, 2010, 2022
Bosnia and Herzegovina	1	5120900	NUTS0	1	5120900	2000, 2010, 2020
Switzerland	7	589785.7	LAU - municipality	2126	1941.9	2000, 2010, 2022
England	30	434263.3	LAU - parish	10607	1228.2	2000, 2010, 2016
Iceland	1	10359200	NUTS3 - region	7	1479886	2000, 2010, 2020
Kosovo	0	N.A.	LAU - municipality	38	28650	2014, 2020
Liechtenstein	1	16000	LAU - municipality	10	1600	2000, 2010, 2020
Montenegro	1	1381200	NUTS0	1	1381200	2011, 2021
North Macedonia	1	2571300	NUTS3 - region	8	321412.5	2000, 2010, 2022
Northern Ireland	1	1413000	LAU - ward	582	2427.8	2000, 2010, 2020
Norway	7	5502957	LAU - municipality	357	107901.1	1999, 2010, 2020
Scotland	1	7791000	LAU - parish	871	8944.9	2000, 2010, 2019
Serbia	5	1769980	LAU - municipality	171	51753.8	2012, 2018
Wales	2	1038950	LAU - parish	878	2366.6	2000, 2010, 2018
Türkiye	26	3013700	LAU – district/ilçe	973	80530.5	2004, 2010, 2022
Total non-EU countries	**85**	**2076335.3**		**16691**	**10573.9**	
All countries in the data-set	**325**	**1827445**		**73637**	**8065.5**	

Table 2. Comparison of existing data from Eurostat available on NUTS 2 level, with the administrative level and number of spatial units in our data set for countries outside the European Union.
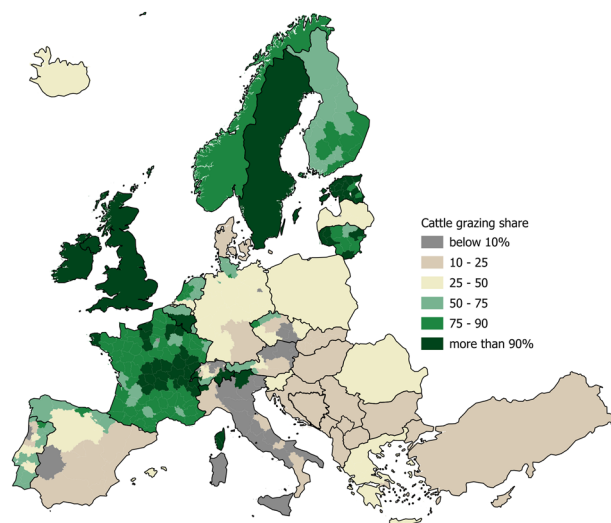

Fig. 4 Share of cattle grazing on outdoor pastures for different European countries and territories and their regions (% of cattle).

Data Records

The data records are accessible for download from the LAMASUS community in Zenodo (https://doi.org/10.5281/zenodo.11058509)[21], under a Creative Commons Attribution 4.0 License. These consists of files organized under the following three categories:

1. **Data sources (data_source.xlsx)**. We provide detailed information on where to obtain data on livestock numbers for each individual country, describing the spatial units, years, potential sub-classes of livestock, and how the data were processed, provided as a spreadsheet. The attributes in the file are listed in Table 4.
2. **Harmonized livestock data (livestockYEAR.gpkg)**. The harmonised database contains data for 73,637 administrative spatial units for each year. We provide data on 3 livestock types, namely cattle, sheep and goats, expressed in livestock units for the period roughly corresponding to the years 2000, 2010 and 2020, described in detail in Table 5. For Poland, we provide an additional separate file, as sheep and goat data are provided on a different level.
3. **Cattle grazing shares (grazing_share.gpkg)**. Here, we provide estimates on cattle that are actually grazing, meaning they have access to outdoor pastures where they graze during part of the year. We provide grazing shares (Table 6) for 331 administrative units as a a geopackage file, as most countries only report these data at a national scale.

Livestock class	Livestock subclass	LSU coefficient
Bovine animals	Below 1 year	0.4
	1 to 2 years old	0.7
	Male ≥ 2 years	1
	Heifers ≥ 2 years	0.8
	Dairy cows	1
	Female buffalo	1
	Other cows ≥ 2 years	0.8
Small ruminants	Sheep and goats	0.1

Table 3. Coefficients to calculate livestock units (LSU). We multiplied the number of total livestock subclasses (where available) with the LSU coefficient. Summarized from[27].

Attribute name	Description
Country	Country or territory
Name in national language	The name of the statistics as provided by national authorities
Livestock types	Livestock types for which the data are available (cattle, sheep, goats)
Subclasses	Detailed livestock subclasses for which the data are available (e.g., cattle: calves, heifers, dairy cows, etc.)
Data provider	The authority providing the data
Public source	Public web link or publication of the data
Unit	Unit of reported data, livestock numbers or livestock units
Admin level	The administrative level at which the data are provided: e.g. NUTS0 - national, NUTS2, NUTS3, Local Administrative Units
Type and name of admin units	More detailed information on the type of admin level: e.g., if local, whether these are parishes, electoral areas, municipalities, etc.
Nr. of admin units	The number of administrative units for which the data are available
Years	Years for which the data are available
Notes	Details on how the data were processed: e.g., in case there are no local data for 2000, how these were derived, etc.
Spatial data	Source for administrative layer spatial data

Table 4. Attributes in the file containing the data sources.

Attribute name	Description
Co_code	Country or territory code
Country	Country or territory name
Lo_code	Official code of the administrative unit of the data (to enable updates with future livestock statistics)
Local	Name of the administrative unit of the data
GIS_id	ID enabling the link to the harmonized livestock numbers
Cattle_LSU	Total cattle livestock units per administrative unit
Sheep_LSU	Total sheep livestock units per administrative unit
Goat_LSU	Total goat livestock units per administrative unit

Table 5. Description of the attributes in the files containing the harmonized livestock numbers.

Technical Validation

Livestock number statistics. The statistics provided by this study were all collected from publicly available sources, such as national statistical offices, agricultural censuses and similar. These were then harmonized to livestock units, to enable comparison between different countries and territories, and to make it easier to use in environmental, agricultural and climate studies. The accuracy of the harmonization – the number of livestock expressed in livestock units – is subject to uncertainties for countries that do not report livestock in different subclasses. Countries still report on the numbers for different livestock categories for cattle (e.g., age, sex, type), however, often on a coarser scale, such as regions or even countries. We, therefore, used the ratios between total cattle numbers and total livestock units for cattle in many instances, meaning that on a local scale, the data are not always completely accurate. Nevertheless, we still used the most local total livestock to livestock unit ratio. In the data sources file, we provide information on the countries to which this applies, and how we harmonized the data.

As we collected data from official statistics, direct comparisons to other sources are not possible. We, therefore, compared the livestock density per grassland area to visualize and compare our statistics with numbers aggregated to NUTS2 level, and combined them with those reported by Eurostat. We calculated the ratio between total livestock unit for cattle and grassland area, using the European Union's Copernicus Land Monitoring Service High Resolution Layer Grassland[28]. The comparison between the data available for the

Attribute name	Description
LEVL_CODE	Administrative level code, mostly corresponding to NUTS classification (0 to 3), can also be 4, meaning local administrative units
CNTR_CODE	Unique country code
NUTS_NAME	Name of country or subnational unit for which the grazing share is provided
id	Unique ID, mostly from the NUTS, can also be unique local administrative unit
graz_sh	Cattle grazing share in % of total cattle

Table 6. Description of the attributes in the file containing the cattle grazing shares.
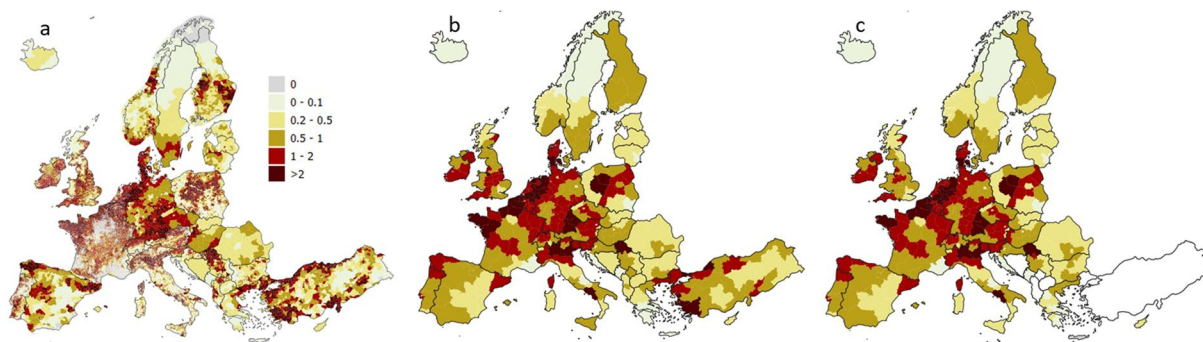
Fig. 5 Visual comparison for cattle densities (LSU/ha) for the year around 2020 between (**a**) our harmonized data set, (**b**) our data set aggregated to NUTS2 levels and (**c**) publicly available NUTS2 data from Eurostat. Here, we calculated cattle density using the high-resolution grassland layer from Copernicus, to demonstrate the usefulness of our data, enabling the identification of local patterns of livestock density.

different administrative units (Fig. 5) indicates that the overall pattern of cattle intensity corresponds to coarser data, and that our data, when aggregated to NUTS2 corresponds to official Eurostat statistics. There are a few regions where there is disagreement in cattle numbers; however, this can also be explained by the fact that for many regions, Eurostat reports data for different years than we present here (e.g., 2010 for Switzerland and 2013 for the United Kingdom). Moreover, it highlights that in regions with low to moderate cattle densities, localized high densities are observed, underscoring the necessity for detailed administrative-level livestock data.

Grazing cattle share statistics and estimates. We also collected and harmonized statistics on cattle that graze outdoors. However, these estimates are uncertain and difficult to validate, and even to compare to other sources, due to the lack of publicly available data. First, many countries do not report the number of animals that graze outdoors. Secondly, while many do report emissions or manure related to pasture grazing to the UNFCCC[25], these estimates represent values averaged for the whole year – for example, if an animal spends 6 months grazing outdoors, this is reported as 0.5 of an animal spending time on pastures. Third, the definition of what grazing animals are differs between countries. Some countries report statistics on animals grazing more than a certain number of weeks, while others report the total number of animals spending any number of days outdoors. Fourth, for some countries, estimates are only available for dairy cattle. Nevertheless, our data provides the most up-to-date and comparable data for other scientists to use when comparing animal welfare, grassland trampling, and feed availability among others. This way it presents the first step towards representation of ruminants that are grazing on outdoor pastures, presenting a considerable improvement over existing expert derived estimates[11].

Usage Notes

Since the livestock data have been harmonized through livestock units, they can immediately be used by other researchers, especially when comparing the livestock density and associated environmental pressures on a detailed spatial level. In addition, the novelty lies in the provision of data sources, enabling an update of livestock data in the future. We also provide multi-temporal data; however, these are not annual. Mostly, these are data from past agricultural censuses (e.g., 2000, 2010, 2020); however, many countries still only report for one or two particular years – either because they are preparing multi-temporal data, which will allow backdating our data, or because they only started reporting data for larger administrative units (NUTS2) to allow comparison between member states. Nevertheless, potential data users can focus on studying changes to recent livestock distributions (see e.g., Fig. 6), or the potential impacts of livestock on the environment, e.g., greenhouse gas emissions calculations, overgrazing, etc.

The harmonization process has demonstrated a method for how countries could improve the reporting of their livestock statistical data in the future. Ideally, all countries would provide data on different age structures and livestock classes, such as the distinction between dairy and beef cattle, or between cows, heifers, bulls and calves – on a detailed spatial and administrative level. Otherwise, the harmonization depends on the ratios
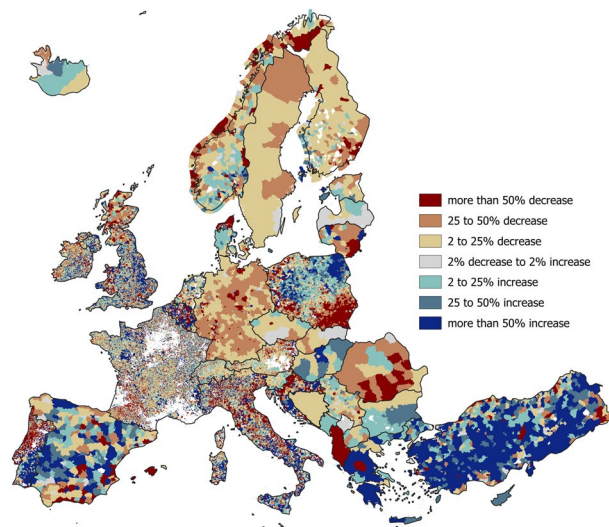
Fig. 6 Our harmonized data set enables the identification of changes to livestock density at a higher spatial detail than currently available data from Eurostat. The figure shows the changes in cattle numbers (in livestock units) for the period between 2000 and 2020. Detailed spatial data (e.g., for France) enables the identification of changes on a local level, as opposed to countries, which provide data on coarser level (e.g., Sweden).

between the reported livestock units and the total numbers at coarser administrative units, which can fail to capture regionally specific characteristics of the livestock sector. One such example are areas with very large, and intensive dairy farms in the Netherlands and the high number of total cattle, out of which a large share are calves, distorting the image when looking at the total livestock units, which have been subject to raised environmental concerns[29].

In addition, not all countries report on all livestock at the same administrative level (for example, by reporting cattle on a municipal scale, and sheep and goats on a NUTS3 level), or they do not provide subnational records for particular livestock types (e.g., goats are not reported for subnational units in many European countries). Nevertheless, for many areas, a much finer spatial pattern is now available, as changes can be tracked across over more than 70 thousand administrative units.

Code availability

No custom code was developed for this study; the data were processed using standard tools in statistical and GIS software.

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Acknowledgements

Author contributions

Ž.M. collected and harmonised the data and drafted the manuscript. Z.R. and O.Y. assisted in data collection tasks. Ž.M. and L.S. designed the study. All authors contributed to the interpretation of the data and wrote the manuscript.

Competing interests

The authors declare no competing interests.

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