

Soil Health Descriptors and Socio-Demographic-Economic Context: A Dataset for the European Union

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Abstract

Soil degradation is a pressing concern in the European Union, affecting all major land use types, including agriculture, forests, and urban areas. Existing studies often identify explanatory variables for soil degradation, but large-scale, comprehensive datasets are limited. This dataset, compiled at the NUTS2 (Nomenclature of Territorial Units for Statistics, level 2—a European regional classification system) level, integrates socio-demographic factors, land use changes, and soil health descriptors from 2005 to 2023. It includes variables such as population dynamics, material deprivation, land tenure, and soil health challenges (erosion, compaction, salinity, soil organic carbon levels, and industrial pollution). The soil descriptors used were derived from secondary geospatial datasets, including ESDAC, processed via GIS techniques. Designed for use in spatial planning, agriculture, and environmental research, this dataset facilitates multivariate and regression analyses to explore socio-economic impacts on soil health. By merging diverse descriptors from multiple sources, it provides a valuable resource for understanding soil degradation and supporting evidence-based policymaking.

Dataset: <https://maps.bonares.de/mapapps/resources/apps/bonares/index.html?lang=en&mid=25f6ea0b-3f54-4335-8017-d17874b41c0d> (accessed on 27 March 2025).

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1. Summary

While existing studies identify explanatory variables for soil degradation, comprehensive datasets that integrate these variables at the European scale remain scarce. For instance, land-user characteristics are more important than landowner characteristics [1,2]. Consequently, we included data on both landowners and land users, hypothesizing that regions with differing proportions of agricultural tenure (e.g., rented, owned land, common land) might exhibit differing levels of soil health. Furthermore, socio-demographic conditions, including population density, population change rates, and economic

deprivation, are documented drivers of soil degradation [2,3]. We therefore included descriptors of population dynamics and severe material deprivation, with the latter providing a more direct measure of regional economic stress than GDP per capita. Severe material deprivation represents a more accurate metric than GDP per capita for the economic status of a region. The climate risk categories represent a consequence of soil degradation.

The objective of this dataset is to provide an integrated, analysis-ready resource for examining relationships between regional socio-economic conditions and soil health in these regions. By combining soil health descriptors from ESDAC with socio-demographic and land use data at consistent NUTS2 spatial units, this dataset addresses the current gap in comprehensive, harmonized datasets suitable for multivariate regional analyses. The dataset was developed to support both academic research on soil degradation drivers and evidence-based policy implementation under the EU Soil Mission framework. The dataset was compiled as part of the EU-funded project PREPSOIL (Preparing the Soil Mission). We chose the NUTS 2 level because it represents an administrative unit within EU member states and thus offers a consistent scale for analysis. Figure 1 provides a spatial overview of the regional coverage of the NUTS 2 level used in our dataset.

The dataset integrates six primary soil health descriptors covering key degradation processes relevant for European soil policy: 1. soil erodibility; 2. susceptibility to compaction; 3. salinity risk in agricultural areas; 4. soil organic carbon saturation capacity, indicating potential for carbon sequestration; 5. potential challenges to soil biological functions, encompassing risks to soil microorganisms; and 6. industrial pollution risk based on heavy metal concentrations from point sources. Additionally, two climate change risk descriptors, drought hazard (aridity index) and river flood hazard, are included to contextualize soil health challenges. These descriptors were selected based on their policy relevance to the EU Soil Mission and the Common Agricultural Policy, their availability as harmonized pan-European datasets from ESDAC, and their established links to socio-economic drivers documented in the literature [1–3]. All soil health descriptors were extracted from ESDAC geospatial products using GIS-based zonal statistics and aggregated to NUTS2 administrative units, providing a standardized analytical framework for exploring relationships between regional socio-economic conditions and soil health descriptors.

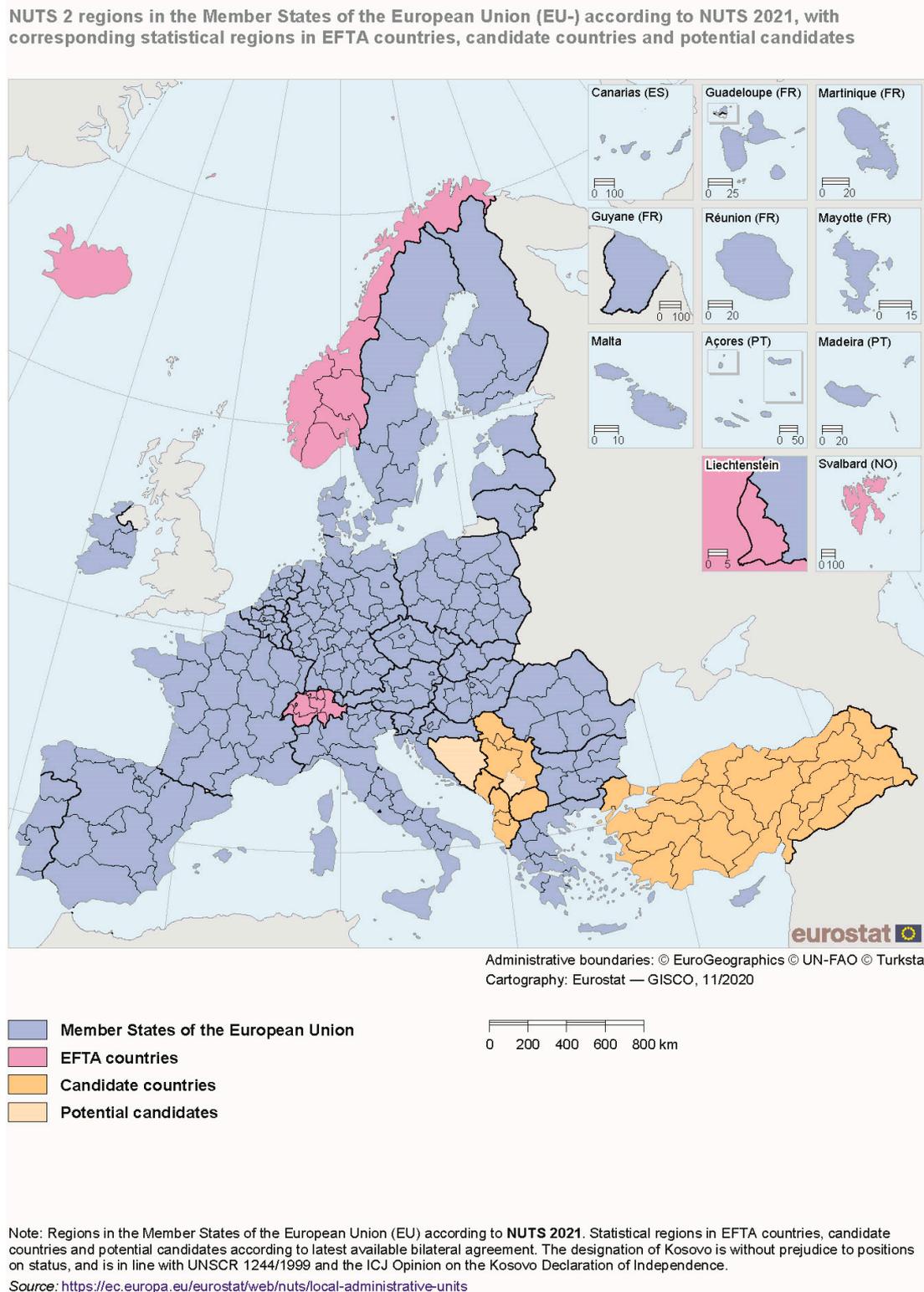


Figure 1. Overview of NUTS 2 in the European context.

2. Data Description

The dataset includes raw data for all NUTS 2 (Figure 1) regions in the EU. As for some NUTS 2 regions, the year of reference has changed, and discontinued regions are included until the year of discontinuation.

The dataset includes data for the following variables, which are hereafter organized in Tables 1–3 for better visibility:

Table 1. Land use descriptors in Europe.

Land Use Categories							
Variable name	Land covered by artificial surfaces	Land covered by forestry	Arable land	Permanent grassland	Permanent Crop	Utilised agricultural area	Unutilised agricultural area
Variable name in dataset	Artificial_Surface	For_land	Arab_land	Perm_grass	Perm_crops	UAA	UnUAA
Additional description	Total land covered by artificial surfaces	Forest Land	Total arable land	Total permanent grassland	Total permanent crops	Total main farm land use	Total main unutilised farm land
Unit of Measure	Square kilometer	Square kilometer	Hectare	Hectare	Hectare	Hectare	Hectare
Time	2009, 2012, 2015, 2018	2005, 2007, 2010, 2013, 2016, 2020	2005, 2007, 2010, 2013, 2016, 2020	2005, 2007, 2010, 2013, 2016, 2020	2005, 2007, 2010, 2013, 2016, 2020	2005, 2007, 2010, 2013, 2016, 2020	2005, 2007, 2010, 2013, 2016, 2020
References	Eurostat. (2024a). Land covered by artificial surfaces by NUTS 2 region. https://doi.org/10.2908/10.2908/LAN_LCV_ART [4]	Eurostat. (2024b). Land use overview by NUTS 2 region. https://doi.org/10.2908/10.2908/LAN_USE_OVW [5]	Eurostat. (2023). Main farm land use by NUTS 2 regions. https://doi.org/10.2908/10.2908/EF_LUS_MAIN [6]	Eurostat. (2023). Main farm land use by NUTS 2 regions. https://doi.org/10.2908/10.2908/EF_LUS_MAIN [6]	Eurostat. (2023). Main farm land use by NUTS 2 regions. https://doi.org/10.2908/10.2908/EF_LUS_MAIN [6]	Eurostat. (2023). Main farm land use by NUTS 2 regions. https://doi.org/10.2908/10.2908/EF_LUS_MAIN [6]	Eurostat. (2023). Main farm land use by NUTS 2 regions. https://doi.org/10.2908/10.2908/EF_LUS_MAIN [6]

Table 2. Socio-demographic and economic descriptors.

Socio—Demographic—Economic Categories										
Variable name	Total population	Population change—Demographic balance and crude rates at regional level	Severe material deprivation	Agricultural holdings/ utilized area	Agricultural holdings with tenure owner	Percentage of total: owned land	Agricultural holdings with tenure status: tenant	Percentage of total: rented land	Agricultural holdings with tenure status: common land	Percentage of total: common land
Variable name in dataset	Pop_Total	Pop_Change	Sev_Mat_Depri	Ag_Hol_UUA	Ag_Hol_Own	Per_own	Ag_Hol_Ten	Per_rent	Ag_Hol	Per_com

Additional description	<p>Material deprivation covers indicators relating to economic strain, durables, housing and environment of the dwelling. Severely materially deprived persons have living conditions severely constrained by a lack of resources, they experience at least 4 out of 9 following deprivations items: they cannot afford i) to pay rent or utility bills, ii) keep home adequately warm, iii) face unexpected expenses, iv) eat meat, fish or a protein equivalent every second day, v) a week holiday away from home, vi) a car, vii) a washing machine, viii) a colour TV, ix) a telephone.</p>									
Unit of Measure	Absolute value	Crude rate of net migration plus statistical adjustment	Percentage	Hectare	Hectare	Percentage	Hectare	Percentage	Hectare	Percentage
Time	2005–2023	2005–2022	2019–2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020
Citations References	Eurostat. (2022a). Population on 1 January by age, sex and NUTS 2 region. https://doi.org/10.2908/DEM	Eurostat. (2022b). Population change—Demographic balance and crude rates at regional level (NUTS 3). https://doi.org/10.2908/DEM	Eurostat. (2024c). Severe material deprivation rate by NUTS region. https://doi.org/10.2908/ILC_MDDD21 [9]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of manager.	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm

	O_R_D2JAN [7]	08/DEMO_R_GIND 3 [8]		farm manager.	farm manager.	https://doi.org/10.2908/EF_MP_TENURE [10]					
Variable name	Agricultural holdings with tenure status: shared or other tenure modes	Percentage of total: shared or other tenure modes	Number of agricultural holdings	Number of agricultural holdings with tenure status: owner	Percentage of owned holdings from total	Number of agricultural holdings with tenure status: rented	Percentage of rented holdings of total no. Of holdings	Number of agricultural holdings with tenure status: common land	Percentage of these holdings on common land from total no. Of holdings	Number of Holdings in shared or other tenure modes	Percentage of these holdings in shared or other tenure modes of total no. Of holdings
Variable name in dataset	Ag_Hol_Shar_Oth_Ten	Per_Hol_Shar_Oth_Ten	Num_Ag_Hol	Numb_Ag_Hol_Own	Per_Own_Tot	Num_Ag_Hol_Rent	Per_Rent_Ag_Hol	Num_Ag_Hol_Com	Per_Ag_Hol_Com	Num_Ag_Hol_Sh	Per_Ag_Hol_Sh
Additional description											
Unit of Measure	Hectare	Percentage	Absolute	Absolute	Percentage	Absolute	Percentage	Absolute	Percentage	Absolute	Percentage
Time	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020	2016, 2020
References	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]	Eurostat. (2024d). Tenure of agricultural holdings by utilised agricultural area, sex and age of farm manager. https://doi.org/10.2908/EF_MP_TENURE [10]

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Table 3. Soil health descriptors and climate change risk.

		Soil and Environmental Data				Climate Change Risks		
Variable name	Erosion	Compaction	Salinity	Soil organic carbon Saturation	Potential threats to soil biological functions	Soil Pollution (Industrial)	Climate change risk-Droughts	Climate change risk-River Floods
Variable name in dataset	Erosion_1	Compaction	Salinity_1	SOC_potential	Soil_bio_func	Pollution_Ind	Drought_risk	River_Flood_risk
Additional description	Soil erodibility map of Europe including a continuous numerical map between 0 and 1.	Soil compaction risk map of Europe indicating the natural susceptibility of agricultural soils to potential compaction derived from the European Soil Database (ESDB)	Saline and acidic soils showing the area distribution of saline, sodic and potentially salt affected areas in the EU	SOC saturation capacity, expressed as the ratio between the actual and the potential SOC stock	Maps of potential threats to soil biodiversity, including soil microorganisms, soil faunas and soil biological functions	Industrial pollution map indicating potential cadmium susceptibility to	Aridity index calculated as the ratio between the mean annual precipitation and the mean annual potential evapotranspiration	River flood hazard maps of Europe
Unit of Measure	500 m	1 km	1 km	1 km	Thematic (from low to high)	500 m	mm	m
Time	2014	2008	2008	2016	2016	2016	2017	2022
Categories	Low, Low-Moderate, Moderate, Moderate-High, High	Low, Low-Moderate, Moderate, Moderate-High, High	Low, Low-Moderate, Moderate, Moderate-High, High	High risk, Moderate risk, No risk	High, Low, Low-Moderate, Moderate	Low, Low-Moderate, Moderate, Moderate-High, High	Low, Low-Moderate, Moderate, Moderate-High, High	Low, Low-Moderate, Moderate, Moderate-High, High
References	Panagos, P., Meusburger, K., Balabio, C., Borrelli, P., & Alewell, C. (2014). Soil erodibility in Europe: A high-resolution dataset based on LUCAS. The Science	European Commission—Joint Research Centre. (2008). Map of natural susceptibility to soil compaction in Europe:	Toth G, Adhikari K, Varallyay Gy, Toth T, Bodis K, Stolbovoy V. Up-dated map of salt affected soils in the European Union. in: Toth,	Lugato, E., Panagos, P., Bampa, F., Jones, Y., Montanarella, L. A new baseline of organic carbon stock in European	Orgiazzi, A., Panagos, P., Yigini, Gardi, C., Montanarella, L. et al. 2016. A knowledge-based approach to	Orgiazzi, A., Panagos, P., Yigini, Y., Dunbar, M.B., Gardi, C., Montanarella, L. et al. 2016. A knowledge-	Právělie, R., Borrelli, P., Panagos, P., Balabio, C., Lugato, E., Chappell, A., Miguez-Macho, G., Maggi, F., Peng, J., Niculiță, M., Roșca, B., Patriche, C., Dumitrașcu, M.,	Právělie, R., Borrelli, P., Panagos, P., Balabio, C., Lugato, E., Chappell, A., Miguez-Macho, G., Maggi, F., Peng, J., Niculiță, M., Roșca, B., Patriche, C.,

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Each soil variable was extracted from raster datasets using zonal statistics in a GIS framework applied to NUTS3 polygons. Soil health descriptors were computed as average values per region, then aggregated to NUTS2 using weighted area proportions. Metadata for all soil health descriptors, including units and sources, is provided in the Supplementary File. The dataset's metadata were structured in accordance with the BonaRes Repository metadata schema [20] and deposited in this repository to ensure compliance with domain-specific standards for soil and agricultural data. The dataset is available in CSV format. The soil data utilized in this study are secondary in nature, derived from publicly available geospatial datasets provided by the ESDAC, which offer harmonized, pan-European raster layers based on satellite observations and modelled environmental descriptors. Definitions and data sources for each descriptor, including the source, is provided in Table 4.

Table 4. Soil descriptor definitions and sources.

Soil Descriptor	Measurement Type	Data Source
Compaction	Bulk density (g/cm ³)	ESDAC—Soil Compaction Map [4]
Erosion	Estimated annual soil decline (ton/ha/year)	Pan-European Soil Erosion Map [21]
Salinity	Electrical conductivity (dS/m)	ESDAC—Salinity Risk Map [14]
Soil Industrial Pollution	Pollutant concentration thresholds (e.g., heavy metals, organics)	ESDAC—Soil Pollution Map [4]
Soil Organic Carbon Saturation	Saturation percentage of soil organic carbon	ESDAC—SOC Potential Map [15,16]
Potential threats to soil biological functions	Potential threat to soil microorganisms, fauna and biological functions	ESDAC—Soil Pollution Map [4]

Additionally, the soil industrial pollution data used in this study is derived from the ESDAC Soil Pollution Risk dataset, which assesses regional susceptibility based on the presence and concentration of pollutants exceeding European environmental thresholds. Key descriptors include heavy metal pollutants (e.g., cadmium, lead, mercury, zinc), persistent organic pollutants such as PAHs and PCBs, nutrient overloads from excess nitrogen and phosphorus inputs, and residual pesticide concentrations.

By transforming heterogeneous ESDAC products into harmonized NUTS2-level soil health descriptors and integrating them with socio-economic data, the dataset extends the analytical potential of existing European soil data resources. For clarity, although the underlying soil health descriptors are derived from these raster inputs, for our study, the added value of this dataset lies in their systematic processing and integration. We extracted, aggregated, and harmonized to a common NUTS2 spatial framework and combined with socio-economic and land-use variables compiled from multiple sources (i.e., Eurostat). With this integration, we aim for a regional comparison across soil health descriptors and socio-economic data and support multivariate and regression-based analyses without the need for additional GIS preprocessing to enhance usability and facilitate interdisciplinary research and evidence-based decision-making.

Some aspects of potential uncertainty should be considered when interpreting this dataset. For instance, spatial aggregation of raster-based soil health descriptors to administrative units may have slight local-scale variability. In addition, these descriptors originate from different reference years, which may introduce minor temporal inconsistencies in comparative analyses. Moreover, soil variables are derived from secondary, harmonized, and model-based datasets, which inherently reflect assumptions related to input data and spatial generalization that should be considered when using the dataset for further analysis.

3. Methods

A comprehensive GIS analysis was conducted to derive the relevant data and maps for this study. Initially, input data were obtained from established sources, including ESDAC and Copernicus, and geometrically recorded to the ETRS89 (European Terrestrial Reference System 1989) projection system to ensure compatibility of each image. Then, the zonal statistics function in GIS was employed to extract key information from datasets such as “Soil Biological Functions” (Soil_bio_func), “Salinity,” “Pollution_Ind,” “Erosion,” “Compaction,” and “SOC Potential.” These attributes were mapped to NUTS3 polygons, resulting in a detailed data table.

All spatial analyses were conducted using ArcGIS Pro 3.3, employing built-in spatial analysis toolboxes and Python scripting within the ArcGIS Pro Python environment. During this process, pixel-based data from the projected input maps were aggregated using the “mean” function, and the resulting values were assigned to each NUTS polygon based on NUTS codes and site names. NoData values present in the input layers were excluded from the zonal statistics calculations. Mean values were computed using only valid raster cells intersecting each NUTS3 polygon. Raster layers were processed at their native spatial resolutions; no resampling was applied prior to extraction to avoid introducing additional spatial uncertainty. Zonal statistics were performed independently for each raster dataset and subsequently aggregated to NUTS2 regions using area-weighted averaging. Regarding administrative boundaries, raster extraction was conducted using the NUTS3 geometries corresponding to the reference year of each dataset. Aggregation from NUTS3 to NUTS2 was performed using area-weighted averaging, where NUTS3 values were weighted by their proportional spatial extent within each NUTS2 region. Discontinued NUTS regions were retained until their official year of discontinuation, and no retrospective harmonization of NUTS3 boundaries was applied prior to aggregation to preserve temporal consistency between spatial units and source data. Additionally, the shape area and length were calculated in hectares (ha), and they were excluded from the final data table as they did not directly influence the dataset within the scope of the study.

Following aggregation, results were subjected to quality control, including systematic monitoring for missing and NoData values following raster extraction, visual and statistical screening for extreme outliers at the NUTS3 and NUTS2 levels, and validation of zonal statistics outputs by comparing aggregated values against underlying raster patterns. Temporal consistency control was also performed to identify implausible changes across reference years and regions. Any anomalous values were cross-checked against source data and metadata prior to inclusion in the final dataset.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/data11010011/s1>, Table S1: Socio-demographic-economic-land; Table S2: Land tenureship

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Abbreviations

The following abbreviations are used in this manuscript:

NUTS2	Nomenclature of Territorial Units for Statistics, level 2
NUTS3	Nomenclature of Territorial Units for Statistics, level 3
ESDAC	European Soil Data Centre
GIS	Geographic Information System
EU	European Union
GDP	Gross Domestic Product
ETRS89	European Terrestrial Reference System 1989
SOC	Soil Organic Carbon
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
UAA	Utilized Agricultural Area
ESDB	European Soil Database

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