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Spatio-Temporal Distribution and Trends of Major Agricultural Crops in Romania Using Interactive Geographic Information System Mapping

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Abstract: This research study presents the spatio-temporal distribution of the main agricultural crops in Romania using a modern digitalisation technique, namely interactive GIS mapping. Interactive GIS mapping includes various features specific to the development of sustainable Romanian agriculture, including the arable area of Romania, information on the area (hectares) cultivated with corn, wheat, sunflower, and rape during the 1990–2018 period, the degree of mechanisation, the number of tractors, and information regarding the landforms, a natural factor in relation to cultivated surfaces. Agricultural land should be properly used based on its ability to meet the demands of consumers of traditional Romanian products with an ecological label, but also the needs of the local population, and, at the same time, to ensure the sustainability of the natural environment through the practice of ecological agriculture. The purpose of this research is to provide an overview of the current state of the main agricultural crops in Romania. From a theoretical but also practical point of view, this research presents, for the first time, a retrospective analysis of each county in Romania in terms of the geospatial distribution of major agricultural crops using interactive GIS mapping. Geospatial data were processed in ArcGIS Geographic Information System 10.7.2. The results of this study show that the most extensive cereal areas at the county level in Romania are corn and wheat. The largest areas cultivated with corn and wheat in 2018 were recorded in the Western Plain, the Romanian Plain, and the Moldavian Plateau. For wheat, increases were also recorded in the Dobrogea Plateau. The intensification of labour productivity and the promotion of the sustainability of the natural environment in Romania is presented through the main indicator (the number of tractors) of the degree of mechanisation of agriculture. The higher values of this indicator are in the counties of Bihor, Timiș, and Maramureș. Limitations in Romania's agricultural data present substantial challenges to the sector's development and sustainability. Addressing these challenges is essential for informed decision making, policy formulation, and effective resource allocation.

Keywords: GIS; interactive mapping; sustainable agriculture; agricultural crops; urbanisation index; arable land area; cultivated area; technical crops; oilseed crops; mechanisation

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1. Introduction

Agriculture represents the most important branch of the primary sector of the Romanian economy. Within this actual context, the Romanian economy has faced three dangerous recessions in the 2020–2023 period, the first of which was the start of the COVID-19 pandemic, the second was the unexpected start of the war against Ukraine, and the third was the earthquake in Turkey. These factors have resulted in the loss of jobs in agriculture, significant increases in fuel prices, and an increase in fertilisers for agricultural crops. Taking into account climate change, there are several meteorological causes affecting the agricultural sector (e.g., significant increase in temperatures, floods, and pedological droughts) and very tense geopolitical situations, meaning that ensuring the supply of food and water to the population [1–5] represents a national and international priority for countries worldwide.

In the case of agricultural crops that represent a large share of Romania's cultivated area, such as wheat, corn, and sunflower, their spatial distribution in the most favourable areas creates conditions for obtaining important yields proportional to the share of these crops without needing to increase cultivated areas. At the same time, for agricultural crops that present favourable conditions in smaller areas (for example, rice), it is necessary to know in advance the most favourable areas for cultivation in view of the ecological development of cultivations.

From a physical–geographical point of view, a detailed analysis of this problem is of great interest because the appropriate degree to which the biological requirements of plants grown in different counties in Romania are met determines how the ecological potential of agriculture is distributed across Romania.

"Organic agriculture, unlike conventional practices, requires ensuring soil fertility without the use of chemical fertilisers and pesticides, the prohibition of genetic modifications to plants, crop rotation and waste recycling" [6], a list to which can be added the prohibition of genetic modifications to seeds. These genetic changes affect, first, the production of agricultural crops; second, the population; and third, the possible characteristic forms of each crop plant.

For the overall production of organic agricultural crops in Romania, a viable export strategy for the countries of the European Union is the "creation of ecological labels" with all the details of the fertilisers and pesticides used, as well as the fertilisers used for the soil. Ecological agriculture represents an energetic and strong system that has been in a continuous upward evolution throughout the 21st century [7]. One of the important objectives of the European Commission is to identify effective solutions so that 25% of agricultural land is used for ecological culture [8] by 2030.

The development of sustainable agriculture represents prosperous, extensive, and intensive economic development through improved yield and productivity of land use, the extremely rich exploitation of the internal resources of each region or country, the minimal use of non-renewable resources, profitable and safe harvests, the maintenance and care of natural resources that support this type of agriculture, the maximum use of appropriate agricultural practices at the local, regional, and national levels in Romania, and viable strategies meant to preserve the natural resources of the surrounding environment [9–11].

In the 21st century, also called the century of information digitalisation, it is very important that the development of information techniques and GIS analyse the statistical data on the distribution of agricultural crops, and the cartographic models must take into account the spatial self-correction between the cultivated agricultural area and its geographical area [12]. Interactive GIS mapping facilitates as directly as possible the visualisation of spatial data for any sector of economic activity [13].

The use of spatial methods that incorporate different sources of information, mathematical calculation tools, and statistical investigation represent the most efficient methods for spatio-temporal mapping of the main agricultural crops in Romania; however, they are not the only method [14].

Statistical data can be studied and examined for agricultural crops in Romania, using the storage of data in GIS software 10.7.2 [15], ArcGIS (Esri, Redlands, CA, USA) [16], in order to intensify the level of awareness of the population [17] and highlight the importance of the conservation of the main agricultural crops in Romania in a sustainable and ecological environment. In addition to using GIS software in the creation of interactive maps, graphic tools were also applied, for example, histograms and diagrams [18].

The cartographic spatial outline of the interactive maps for the distribution of agricultural crops in Romania shows the practical and efficient use of tools and techniques for the investigation, explanation, and generalisation of spatial data through the Geographic Information System software. The research itself was carried out in strict compliance with the spatio-temporal execution rules, starting with an analysis of the processing, gathering an understanding and interpretation of the data, as well as the geo-visualisation of the results in the form of interactive GIS cartography [19].

The following is the novelty of the research undertaken: we attempted to identify a link between the distribution of agricultural crops and the share of arable land to decipher to what extent they could contribute to the development of ecological agriculture. By "creating ecological labels", crops represent a viable export strategy for countries of the European Union. At the same time, by integrating the elements that define ecological agriculture, this expresses the degree of mechanisation (the tractor) and family farms as a source of social–economic and professional development in the rural environment of Romania's counties.

The use of digital information technologies with the help of GIS software in the field of agriculture, especially the distribution of major agricultural crops in Romania (wheat, corn, sunflower, and rape) and the ecological potential of agriculture, is a key topic because all the available statistical data needed to implement or develop such studies can be collected very quickly and with maximum efficiency.

The successful development and implementation of the spatio-temporal distribution and trends of agricultural crops in Romania's counties is unique, as it presents for the first time the development of standardised methodology regarding the visualisation and spatial design of agricultural crops using interactive GIS mapping.

The aim of this study is to analyse the spatio-temporal distribution and trends of major agricultural crops in Romania using the "interactive" mapping of GIS software.

The motivation of this research is driven by the importance of the value given to the efficiency of any economic activity, but especially of ecological agriculture, in the limiting context of natural resources, and is very important in the context of the implementation of the 2030 Agenda for Sustainable Development. As a result, the Food and Agriculture Organization (FAO) has identified a total of eight Sustainable Development Goals (SDGs) as the most relevant for organic farming, among which we list the following: SDG6: Clean water and sanitation; SDG13: Climate action; SDG14: Aquatic life; SDG15: Land life; SDG2: Zero hunger; SDG3: Health and well-being; SDG8: Decent work and economic growth; and SDG12: Responsible consumption and production [20].

Consequently, each country's response to the challenges of developing, implementing, and creating eco-labels, in correlation with the implementation of the Sustainable Development Goals and the successful achievement of these proposed targets by the horizon of 2030, varies both from a temporal and spatial perspective of the agricultural practice areas.

The research objectives of the study are (1) the analysis of the urbanisation index for all counties in Romania; (2) the examination of the areas dedicated to the main cereal crops in Romania (period 1990–2018); (3) the retrospective analysis of the dynamics and distribution of cultivated areas with wheat, corn, sunflower, and rapeseed by county; (4) to carry out research on the areas dedicated to the main categories of technical plants at the national level in the period of 1990–2018; and (5) the investigation of an agricultural area according to land use patterns (period 1990–2014).

This study aims to fill certain gaps related to the limited number of studies focused on the development of sustainable agriculture in Romania, and at the same time to help the authorities by identifying the main crops that would require financial support for sustainable development. We also aim to identify which counties have potential for socio-economic development and which require a doubling of investments regarding the development of the activity sector of agriculture.

The research paper explores the county level distribution of the main major agricultural crops in Romania, placing maximum emphasis on the following specific research questions/objectives:

RQ1: What are the spatio-temporal trends in the cultivation of major crops (wheat, corn, sunflower, and rapeseed) across Romanian counties over the period of 1990–2018?

RQ2: How can GIS-based interactive mapping techniques help characterise and analyse the distribution patterns of key crops in Romanian agriculture?

RQ3: What factors influence differences in crop distributions across geographic regions of Romania?

We believe that the perspective of the previously recorded research questions will provide extremely important information to farmers in the agricultural sector in order to outline in the near future sustainable agricultural development projects in the medium and long term in the most efficient way possible.

This study is structured in five consecutive sections, as follows: The first section, the Introduction, analyses the key concepts regarding the importance of agriculture as a sector of economic activity and the development of sustainable agriculture, which represents a novelty for prosperous, extensive, and intensive economic development through improved yield and productivity of land use in an appropriate manner for an ecological agriculture. The Section 2 encapsulates a detailed analysis of the specialised literature, more precisely the concept of the "urbanisation index", land reform of the transformation process of agricultural lands, and the definition of GIS as a fundamental tool for the cartographic creation of agricultural crops at the county level. The Section 3 describes the research context and methodology, along with the authors' field of interest. The Section 4 presents the main analyses and findings of the spatial distribution of major agricultural crops in Romania using interactive GIS mapping. And the Section 5 includes a brief integration and interpretation of the research results in correlation with studies in the reviewed literature. Finally, a number of conclusions are outlined, as well as the limitations of the research, but also the main future research directions of the study.

2. Literature Review

The urbanisation index or urbanisation rate is used to design the social, human, and economic activity [21] of a geographical space, be it a city, county, or country, such as Romania. The rate of urbanisation in a stage of economic development, the sharp increase in urbanisation in some cities, counties, or regions, is accompanied by the increased demand for urban land for construction and, at the same time, the elimination or damaging of vegetation under the amplified pressure of the man–land conflict [22,23].

Presently, it is very complicated to draw a cohesive, unitary, or common conclusion regarding the consequences of urbanisation on vegetation protection as a result of the heterogeneous relationship between them [24]. In this study, the urbanisation rate of the Romanian population was analysed for the year 2018 as an indicator that can represent the evolution of the transformation and economic development of some cities to a great extent.

Agriculture represents a very important economic sector in the European Union [25–27], having a well-established and as heterogeneous as possible goal of ensuring food security for the nation and employment in rural areas, even in the maintenance and protection of the natural ecological environment [28].

Throughout the 21st century and presently, the food sector has been exposed to a series of challenges due to climate change [29]. To ensure global food security, it is considered that cereal crops, in particular corn, represent the most important pillar [30]. In this regard, according to the 2009 World Summit on Food Security Declaration, to catch up with the numerical growth of the global population, the production of agricultural crops needs to increase progressively to about 70% by the year 2050 [31].

Thus, land reform, i.e., the transfer of land into private ownership and individual use by citizens, represents one of the most difficult "transformation" transition tasks for all countries in Central and Eastern Europe [32]. The transition "transformation" process was represented by the "strengthening of private ownership through the retrocession of approximately 95.6% hectares of agricultural land between 1991 and 2005" [33]. After this extremely difficult period for farmers, the agriculture of the Romanian rural areas experienced substantial changes, concretely individual farms began to grow numerically, and thus, a new economic structure of the rurality of the geographical area was created.

Following this land transformation, there have been many changes in Romania's agricultural structure, but the task of creating an agricultural system capable of producing competitive products at the county level for international promotion has not yet been completed [34,35]. "During the communist period (1947–1989), Romania's agriculture was

organised mainly in state farms/agricultural cooperatives, which during the transition period, more precisely in 1989, controlled over 89% of Romania's agricultural land" [36].

Agricultural cooperatives are well known worldwide as very important institutional commitments used to counterbalance the pressures faced by small farmers in developing countries [37], but they are also used for the good management of the achievement of an effective or high-performing agriculture sector [38] which will last in the long term. Nowadays, the agricultural sector faces the problem of increasing productivity to feed the growing global population and increasing the efficiency of the use of resources, while at the same time reducing the minimal impact on the ecosystems in Romania and the health of the population [39].

Statistical data are key in the development and analysis of interactive maps based on GIS software. The construction of interactive maps using a graphic technique is one of the structures of data editing and visualisation [40,41]. On the other hand, visualising all geographic relationships on a single interactive map is more cost-effective than using two maps side by side and presents an overall perspective on the knowledge of the mapped phenomena in correlation with the reality on the ground [42].

Throughout the 21st century, GIS software has stood out in the specialised literature as the most used method. Despite the fact that it is not free software, its interface is a penetrating one, and the transformation and explanation of the collected data are cost-effective for the majority of people. However, there are some universities worldwide that have licenses to use this software for research purposes; that is, they can concretely support the introduction of this geographic information software in the methodology of research works [43].

Geographical Information Systems provide the possibility of supporting the learning of geographical notions by analysing the problems which exist within the specialised literature in interdependence with the problems faced in the real world (field practice), having a positive effect on the researcher's development of spatial thinking skills [44]. GIS is a fundamental tool for the cartographic and spatial creation of agricultural crops at the national and international level, facilitating the immediate and accurate examination and merging of data collected from multiple sources, resulting in the production of new information in interactive maps.

The creation of new spatial, diverse cartographic models involves the practice of using some GIS tools that take a remarkable time to create interactive maps, but the software also requires specific skills to be used by students, teachers, and researchers [45].

Geographic Information System software tools have been used in several studies to create the spatial variables needed to predict agricultural production [46–53]. Some researchers chose to use the ArcGIS software 10.7.2, which we also used in this study, whereas others used an open-source GIS software variant, such as QGIS [54,55].

In addition to ArcGIS, there is also the QGIS software 3.14, which is free and open-source and effectively facilitates the visualisation, processing, correction, and analysis of georeferenced data, obtaining interactive maps of the spatio-temporal distribution of major agricultural crops in Romania.

3. Materials and Methodology

3.1. Study Area

Romania (Figure 1) is located in Central Europe ([56], p. 17); in [57], some authors consider it to be the largest country in Southeastern Europe [58]. It is about halfway between the Atlantic side of the continent and the conventional border with Asia, which determines the temperate–continental climate with aridification specific to the steppe ([56], p. 18). From the physical–geographical perspective, Romania is in the Carpathian–Danubian–Pontic Domain ([56], p. 18). The Carpathian chain turns in the eastern part into a mountainous circle on which Romania is located; the circle is called the Romanian Carpathians. It occupies 2/3 of the entire chain ([56], p. 21), with the maximum altitude being 2544 m in the Moldoveanu Peak located in the Făgăraș Massif. As for the Danube, 38% of its length is

on the territory of Romania, but this is also the most important portion in terms of flow and navigation, including the Delta and its mouths of flow into the sea ([56], p. 21). Towards the Black Sea, Romania opens to a width of 245 km and beyond to the entire Planetary Ocean ([56], p. 21). Summarising the information from the specialised literature, Romania is a Carpatho-Danubian–Pontic country.

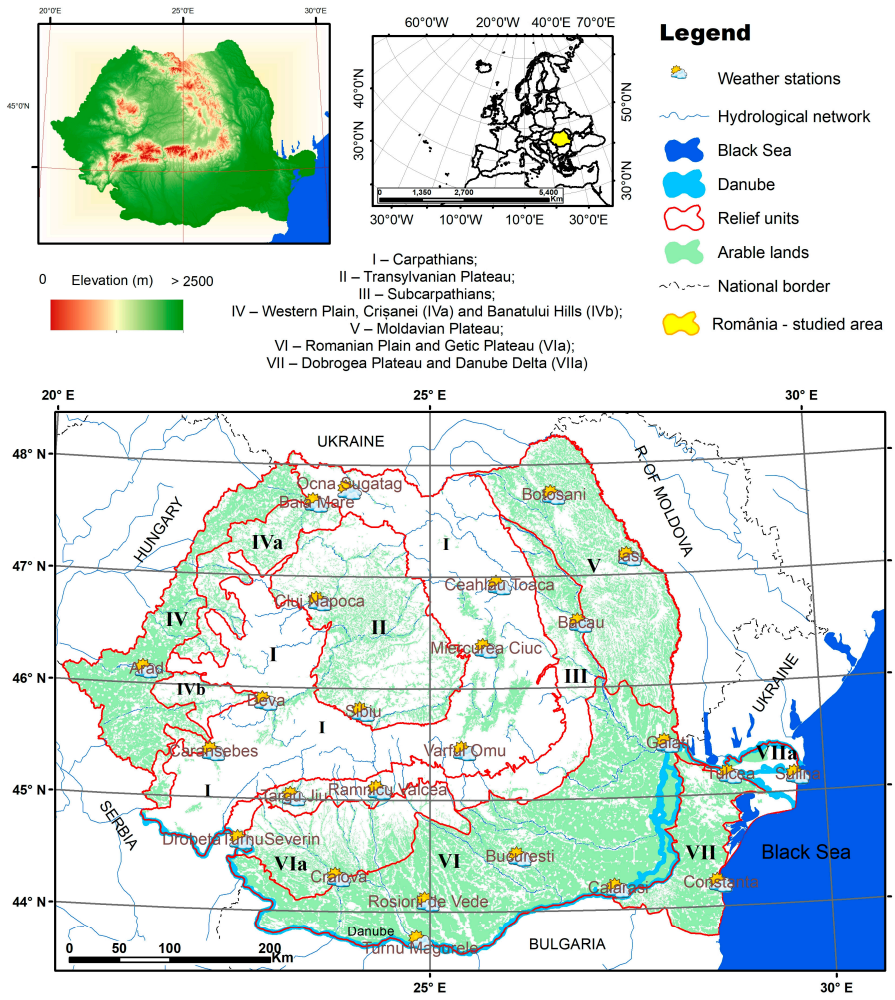

Figure 1. Romania's position on the continent and in the national context. Source: authors' data processing in ArcGIS 10.7.2.

The bio-physical and socio-economic conditions of Romania represent fundamental particularities that favour the great diversity of types of land use/cover, with a significant expansion of arable land and significant regional differences that can appear in large relief units [59].

3.2. Data Sources

The present study is based on general statistical data from the National Institute of Statistics (NISs) and has as its practical purpose the spatio-temporal analysis of the distribution of agricultural crops in the counties of Romania that took place in the period of 1990–2019. The assumption is made that there is a correlation between the reduction in the share of arable land and the expansion of urban areas (through the analysis of the urbanisation index).

Although Romania boasts a rich agricultural heritage in order to make informed decisions regarding agricultural practices, resource allocation, and policy development, comprehensive and reliable statistical data are essential. Unfortunately, Romania faces substantial data limitations when it comes to its agricultural sector. These limitations have

far-reaching implications, affecting the country's ability to harness its agricultural potential effectively. Thus, the available secondary data found in the national statistics were collected until 2018–2019, so these sets were used in the current study.

The structure of the population by residential area can be highlighted and analysed by means of the indicator called "Urbanisation index/rate". This calculation formula was used based on the methodology developed by Iordache, 2009 ([60], p. 99), and adapted from Kang et al., 2023 [61], considering that in Romania, human settlements form only an intelligent part of the geographical space [62].

$$\mathrm{Ru} = \frac{\mathrm{PU}}{\mathrm{PT}} \times 100, \quad (1)$$

where

R_u = urbanisation rate/index;
PU = urban population;
PT = total population.

In order to produce the agricultural maps, the data sources used are as follows (Figure 2): ref. [63]—general datasets about Romania (border limits, county limits, relief units, digital elevation model); ref. [64]—the extraction of statistical data by county of the main agricultural crops and utilities related to them (number of tractors); and ref. [65]—for environmental data and [66] Corine Land Cover 2018, providing detailed information on Land Cover in Romania, such as non-irrigated arable land, permanently irrigated land, and rice fields.

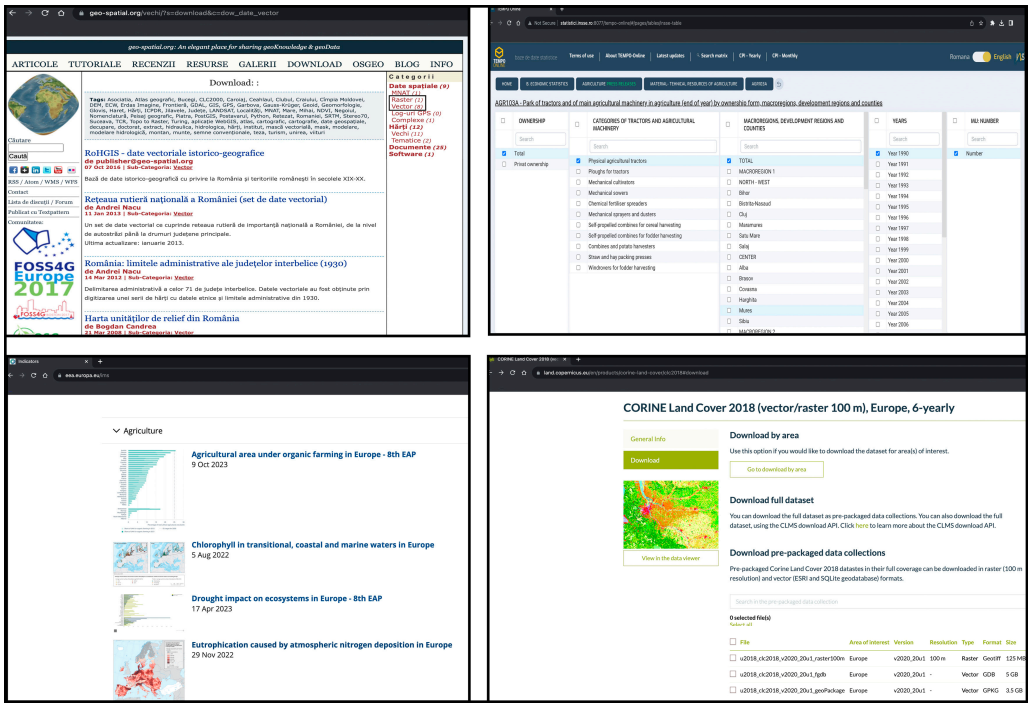

Figure 2. Sites used for data sources.

In order to create the interactive maps, four consecutive stages were carried out with the help of the Geographical Information System software [67]. First, (1) we gathered and created the database for the analysis of counties in Romania, more precisely an office documentation [68–72]; then, (2) we processed the county and national statistical data; (3) we conducted the spatio-temporal representation of the main agricultural crops in the counties of Romania; and (4) we interpreted and investigated the data obtained in interdependence within the specialised literature.

In terms of the spatio-temporal distribution of the major agricultural crops in Romania using interactive GIS mapping, the following data sources were used: ref. [63]—general datasets about Romania (border limit, county limit, relief units, digital elevation model). The process and category of the data that were downloaded for the GIS database are described below.

The National Institute of Statistics [64] was used to collect statistical data by county of the main agricultural crops and the main indicator expressing the mechanisation of agriculture (number of tractors). The data were downloaded by checking the desired indicators, the regions of interest, and the years for which the analysis was carried out. For environmental data, we consulted the site in [65].

The data were downloaded in vector format from the ESRI Geodatabase from CLC [66], 2018 version. These data come in geodatabase format and contain a dbf and an Excel file, where the legend of the data is found; it is imported using the ArcMap Join and Relates—Join function.

The map with the physical–geographical location of Romania in a local and European context and the extension of arable land was made using the data source in [63,66]. Some other elements were added: European borders, weather stations, the Danube River, and the Black Sea border. The map was created in the ArcMap 10.7.2 program, and the classic steps were used for its creation.

The steps involved creating the layout and then inserting the data in vector and raster format. Clip type operations were carried out for the areas considered. It was necessary to use several data frames to locate Romania in a European context. The insertion of several data frames was performed. After this, the databases were inserted, and the chromaticity and specific symbols were chosen.

To create the maps of the area cultivated with corn, wheat, sunflower, and rape, we entered the statistical data downloaded from [64] into ArcMap using the Join Data Tool. Before joining the Excel table (NIS) that contains the statistical data, a shape with the counties of Romania was added. We slightly modified the Excel table by creating a separate Excel table for each crop, for each year, distributed by county. The county shapefile of Romania contains a common column with processed statistical data (the newly created Excel tables); the common column is represented by the name of the county (in ArcMap, it is found as COUNTY; in Excel it is also called COUNTY). Then, we right clicked on the layer with counties—Join and Relates—Join.

The data import for the counties of Romania was carried out using the tools Add Data—file location—selection and Add. After clicking on Join, the Join Data window appeared, and then we chose the files and the common field (JUDET) based on which union was made.

After joining the data, we could calculate the differences between the agricultural crops for different years. In the attribute table of the counties, which now contains the agricultural data, we entered the following fields using the Add Field Tool: dif_fl_soarelui, dif_maize, dif_rape, dif_wheat (all are in hectares).

Each column was populated with appropriate values using the Field Calculator. We used the following formulas to calculate the surface differences between 2018 and 1990 of agricultural crops: for sunflower: [Fl_Soarelui_18] and [Fl_Soarelui_90]; for wheat: [Wheat_18] and [Wheat_90]; for corn: [Corn_18] and [Corn_90]; for rape: [Rape_18] and [Rape_90].

To apply the differences in the areas of agricultural crops between 1990 and 2018, we used the column chart method. The following steps were followed to create the charts: we right-clicked on counties—Properties—Layer Properties—Symbology—Charts—Bar/Column; at Symbol, we imported the crop for generating the corresponding map (separately for sunflower, rapeseed, corn, and wheat).

To create a map with arable surfaces and the number of physical agricultural tractors per county, we used the Project Tool in order to transform the CLC 2018 data from ETRS89 to Stereo70. This tool can be found at Data Management Tools—Projections and

Transformations—Project. The Clip Tool was used to cut the shapefiles to the desired size and scale.

The number of physical agricultural tractors was represented using the cartogram method, and at Symbol, the column containing the data with the number of tractors (Tractors_18) was included. For all the maps, the legend, title, scale, north, and other necessary elements of the map were added through View—Layout View—Insert: Title, Legend, Scale Bar, Text (the resulting map was exported using File—Export Map; we chose the place where it would be saved, and the following formats are recommended: *tiff, *jpg, *bmp, *gif—*tiff). The chosen format was that of jpg.

4. Results

Agriculture is dependent on socio-economic and technical factors, mechanisation, or the selection of productive varieties, natural conditions (climatic zoning and altitudinal zoning, soil types), and land improvement works, which include combating soil erosion, drought through irrigation, and excess moisture through drainage and dams ([73], p. 173).

Globally, since ancient times, the primary activity sector—agriculture—and its sub-sectors [74] have represented one of the most important natural resources for balanced national development in the developed and developing counties of Romania. Cereals represent the most appreciable agricultural crops in Romania in terms of cultivated area; they are also the most important basic product in the food industry and for consumption by the population [75].

In 2018, cereals were recorded to take up the highest share of cultivated areas in Romania at 62.1%, which is a slight increase compared to 1990 (Figure 3).

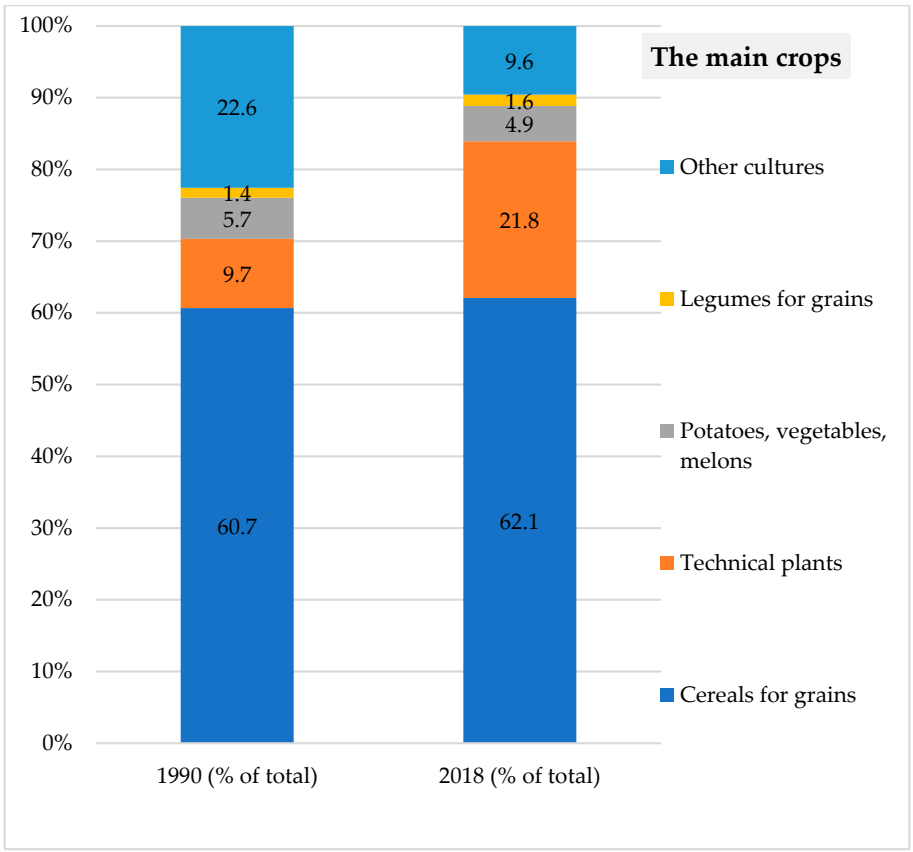

Figure 3. Structure of the areas covered with the main agricultural crops in Romania (1990–2018). Source: authors' processing of NIS data [64].

Among cereals, the most extensive cultivation areas are planted with corn and wheat (Figure 4), for which a significant increase has also been recorded between the two years previously mentioned.

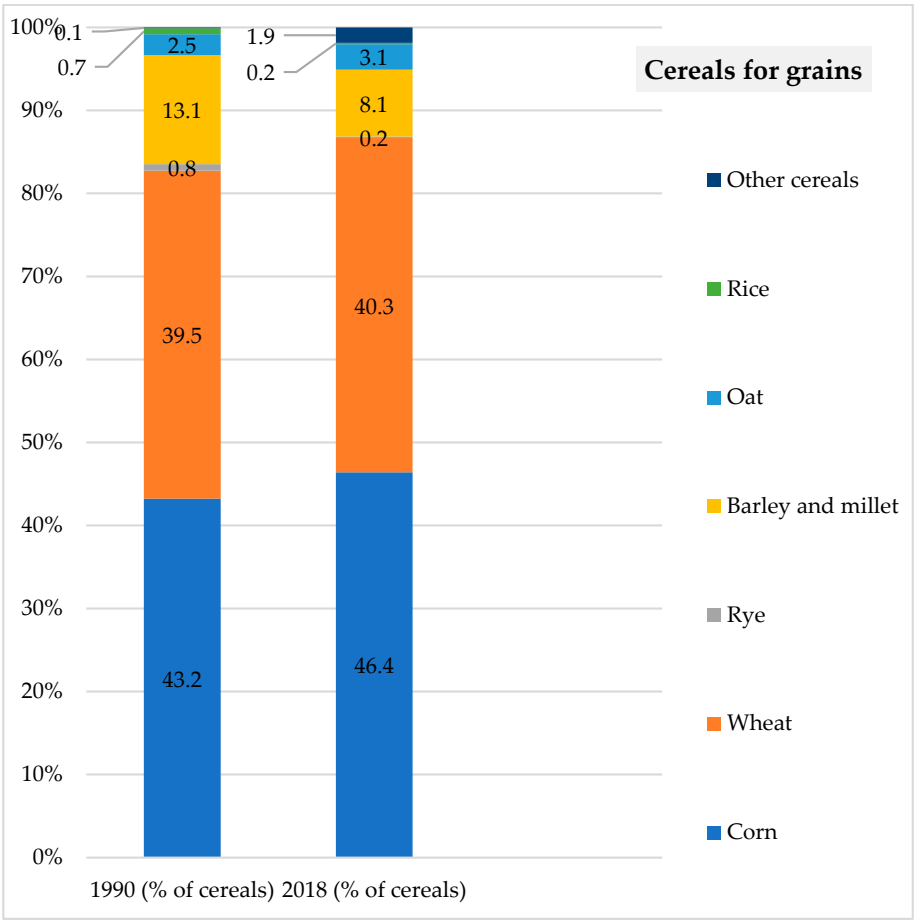

Figure 4. Structure of the areas planted with the main cereal crops in Romania (1990 and 2018). Source: authors' processing of NIS data [64].

4.1. Cereal Crop (Wheat and Corn)

Wheat fundamentally provides the basis of human nutrition either directly, through primary processing, or indirectly, through providing fodder for animal rearing. In Romania, the total production of cereals, especially wheat, recorded significant decreases after the 2000s. In recent years, an upward trend has been observed: wheat production increased from 7.3 million tons in 1990 to 10.1 million tons in 2018 (Figure 5). In contrast, the national area cultivated with wheat decreased from 2.3 million hectares in 1990 to 2.1 million hectares in 2008. The counties of Dolj, Constanța, Teleorman, Olt, Timiș, and Calarasi had 120,000 hectares cultivated with wheat in 2018.

According to the Food and Agriculture Organization (FAO) of the United Nations, in the year 2021, the most produced cereal in the world was corn, followed by rice and wheat [76]. The corn crop represents the basis for the food industry and fodder for livestock. It has a very high yield and a receptivity to reproduction and genetic modification [77]. Romania recorded spectacular growth after 1990; if a total production of 6.8 million tons of corn was obtained in 1990, from a cultivated area of 2.46 million hectares, in 2018, the total production reached 18.7 million tons, with the area cultivated in the aforementioned year being of 2.44 million hectares. The largest areas cultivated with corn in 2018 were in Timiș, Arad, Botoșani, Călărași, and Buzău counties (Figure 6), with 100,000 hectares each.

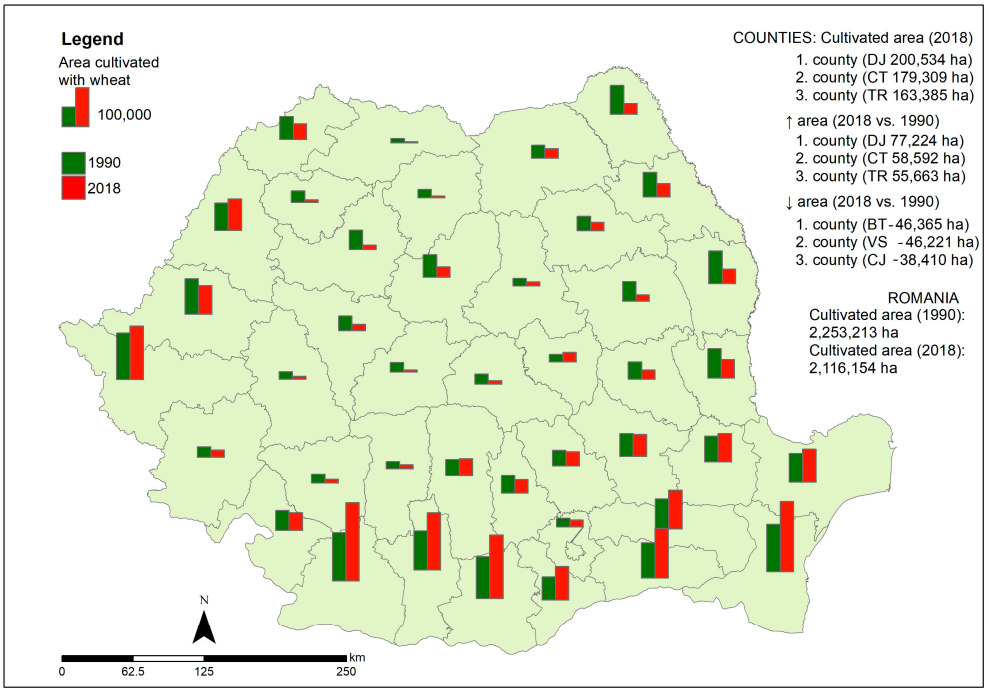

Figure 5. Dynamics and county distribution of the areas cultivated with wheat—in hectares (1990–2018). Source: authors' processing of NIS data [64].

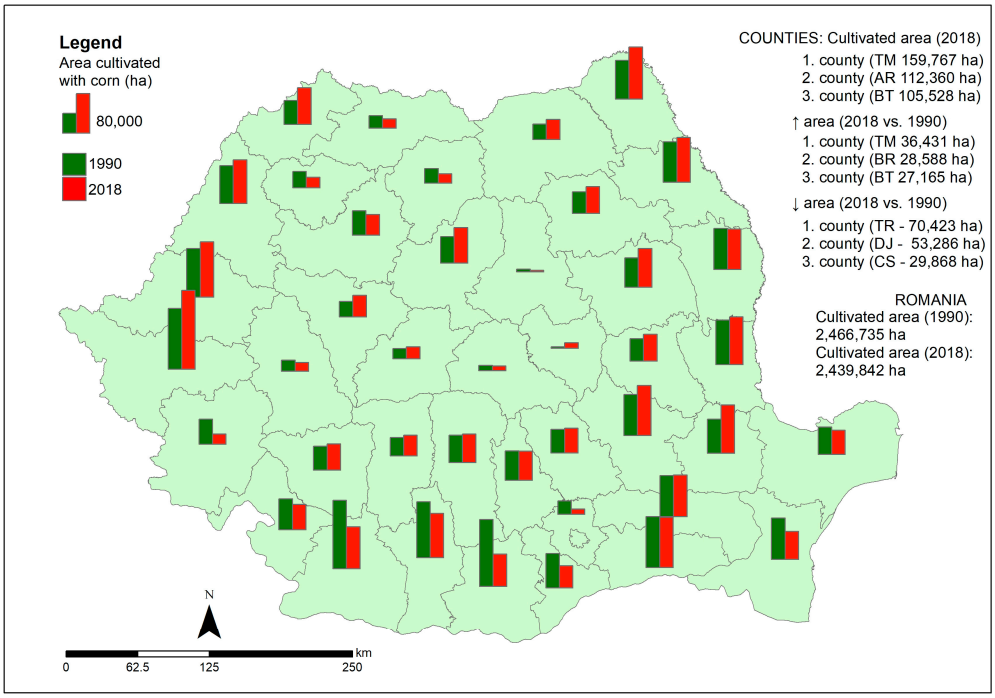

Figure 6. Dynamics and county distribution of the areas cultivated with corn—in hectares (1990–2018). Source: authors' processing of NIS data [64].

4.2. Cultivation of Oleaginous Plants (Sunflower and Rapeseed)

After the revolution in 1989 in Romania, the areas cultivated with technical plants doubled (Figure 7). The oleaginous plants recorded the highest share of the areas cultivated with technical plants in Romania during the analysis period (between 1990 and 2018). Among them, sunflower and rapeseed stand out, especially in Romania. Thus, we further investigated these plants in the form of interactive maps.

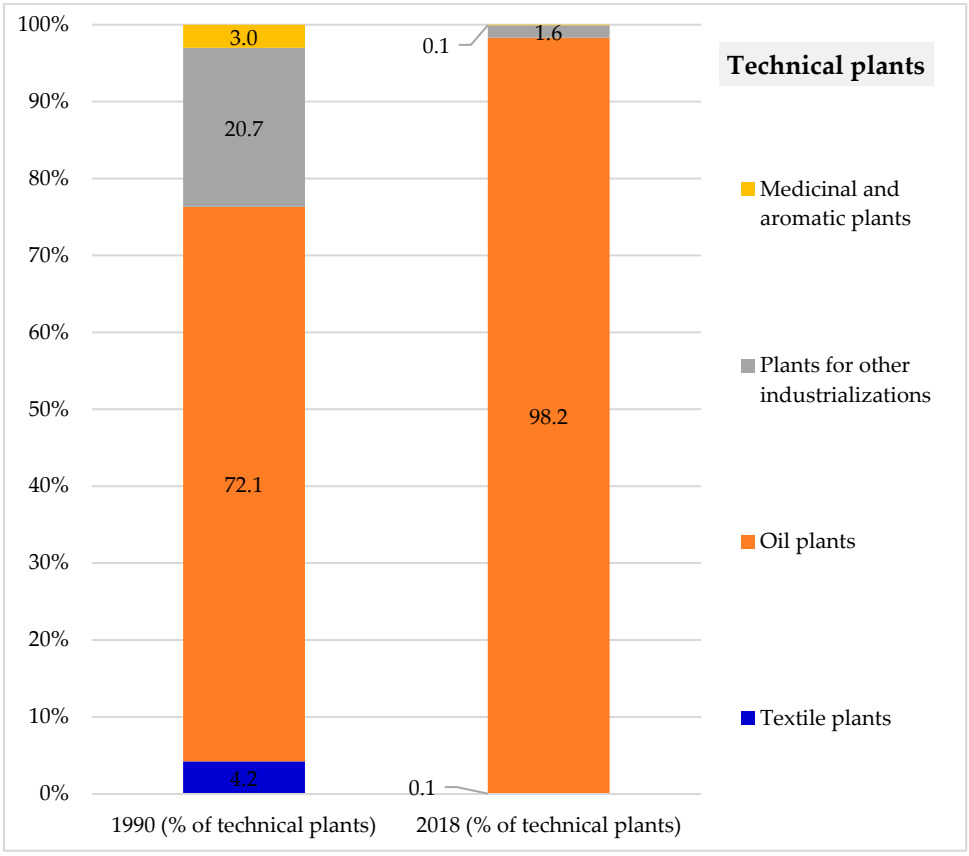

Figure 7. The share of the areas cultivated with the main categories of technical plants in Romania (1990 and 2018). Source: authors' processing of NIS data [64].

The sunflower can adapt to any climatic conditions; the most suitable natural conditions are in the regions where the temperatures during the flowering and ripening period are maintained at 22–25 °C, and the precipitation rate is about 500 mm/year. It is an oleaginous plant that is very resistant to drought, but on the other hand, it requires a lot of light and very fertile soils. Sunflower, on the other hand, responds very well to irrigation, with progressive yields of up to 200% on dry soils and in dry years [78].

Romania recorded an upward trend of the areas cultivated with sunflower during the 1990–2018 period (Figure 8). The cultivated areas are mainly in the Romanian Plain, Western Plain, and Moldavian Plateau. As a result of this positive dynamic, the counties with the most extensive areas cultivated with this oleaginous plant in 2018 were Brăila, Timiș, Constanța, and Dolj.

Rapeseed is one of the important sources of edible oil; therefore, it is important that its production is ensured globally [79]. The origin of rapeseed is still uncertain, as there are researchers who claim that it originates in Mediterranean Europe, whereas others believe that rapeseed originated in several other areas. Today, it is mainly cultivated in Canada, China, and Europe [80].

In Romanian counties, the areas cultivated with rapeseed between 1990 and 2018 recorded significant increases, with this plant occupying second place among the technical crops in Romania. The counties with the largest areas cultivated with this plant in 2018 were Ialomița, Teleorman, Constanța, Buzău, and Dolj (Figure 9).

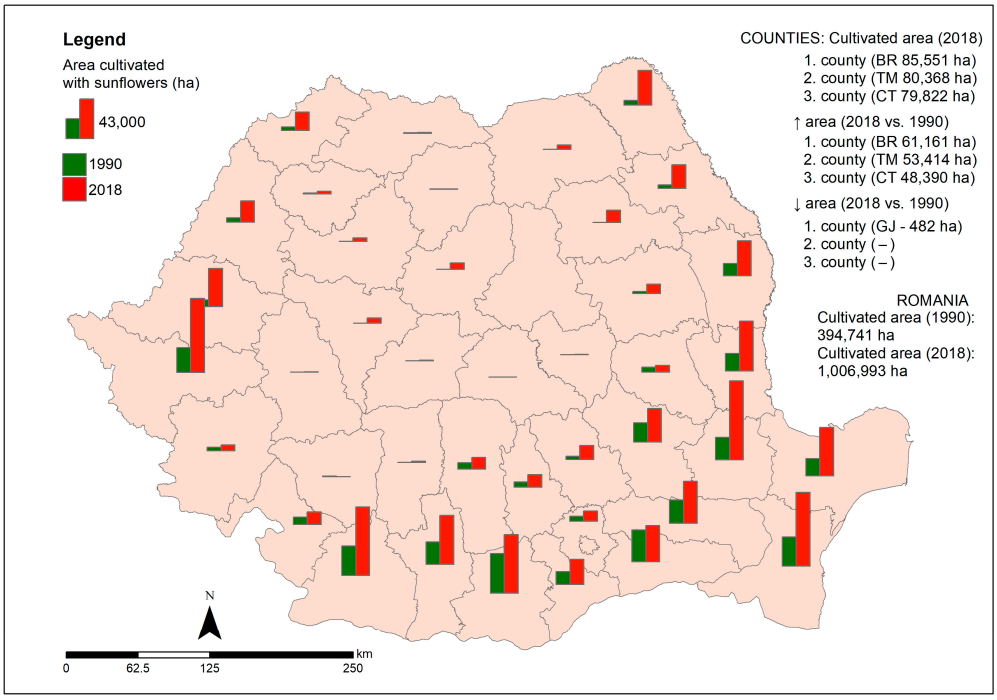

Figure 8. Dynamics and county distribution of sunflower cultivated in Romania—in hectares (1990–2018). Source: authors 'processing of NIS data [64].

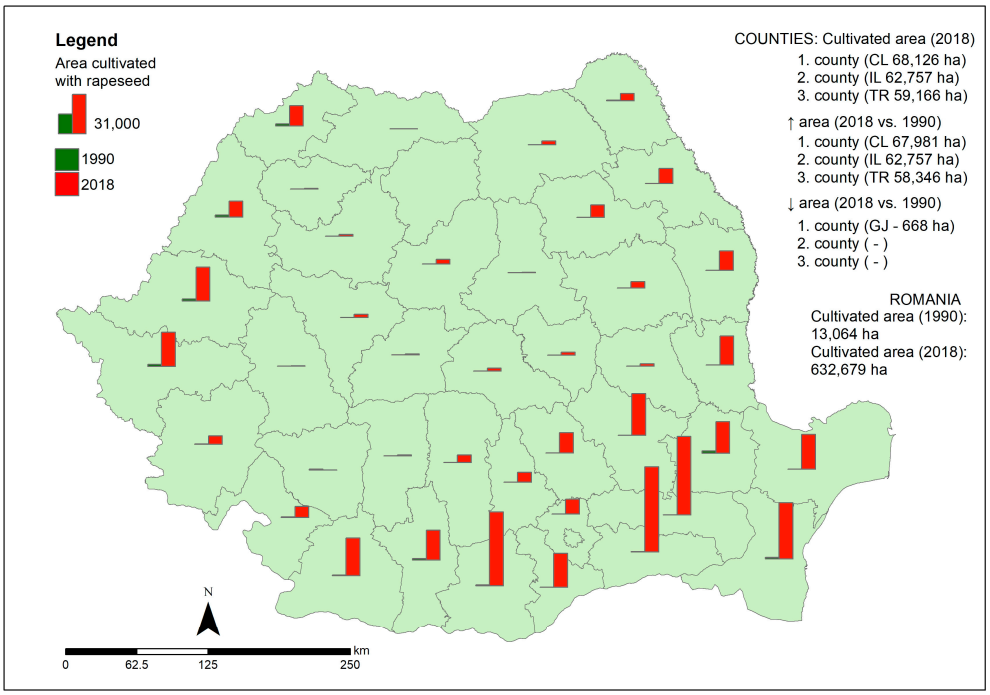

Figure 9. Dynamics and county distribution of areas cultivated with rapeseed in Romania—in hectares (1990–2018). Source: authors' processing of NIS data [64].

4.3. Dynamics and Distribution of Agricultural Land

Agricultural activity is based on several very important characteristics, namely: (1) the differentiated exploitation of the conditions of the edaphic factor (soil); (2) the amount of precipitation and average annual temperatures, in close correlation with the land features and altitude, which determines also specific vegetation; (3) the agricultural activity in Romania, which is strongly dependent on the labour force, and the means of the production

of agricultural crops; and (4) the volume and qualification of the specialised labour force, the size of the properties, the technical means, and the capital also constitute elements that are the basis of the development of agricultural production systems ([81], p. 54,58).

The land features of any city, county, region, or country represent a fundamental element in differentiating the natural agricultural use of geographical space and one of the important components of the natural environment, represented by major forms of relief, such as the Carpathian Mountains, the Subcarpathians, the Western Hills, the Moldavian Plateau, Mehedinți, Getic, and Dobrogei Plateaus, the Transylvanian Depression, the Western Plain and the Romanian Plain, and the Danube Delta, highlighted by altitude (Figure 10). The altitude ranges from 0 to 2544 m in the Carpathian Mountains; the altitudinal value imperatively imposes different agricultural uses in the mountain areas, as compared to the lowland area, which excels from an agricultural point of view. Also, due to the changes in the characteristics of soil with the increase in altitude, there is a vertical layering of cultivated plants. And thus, the so-called phenomenon of the mechanisation of agriculture is generated.

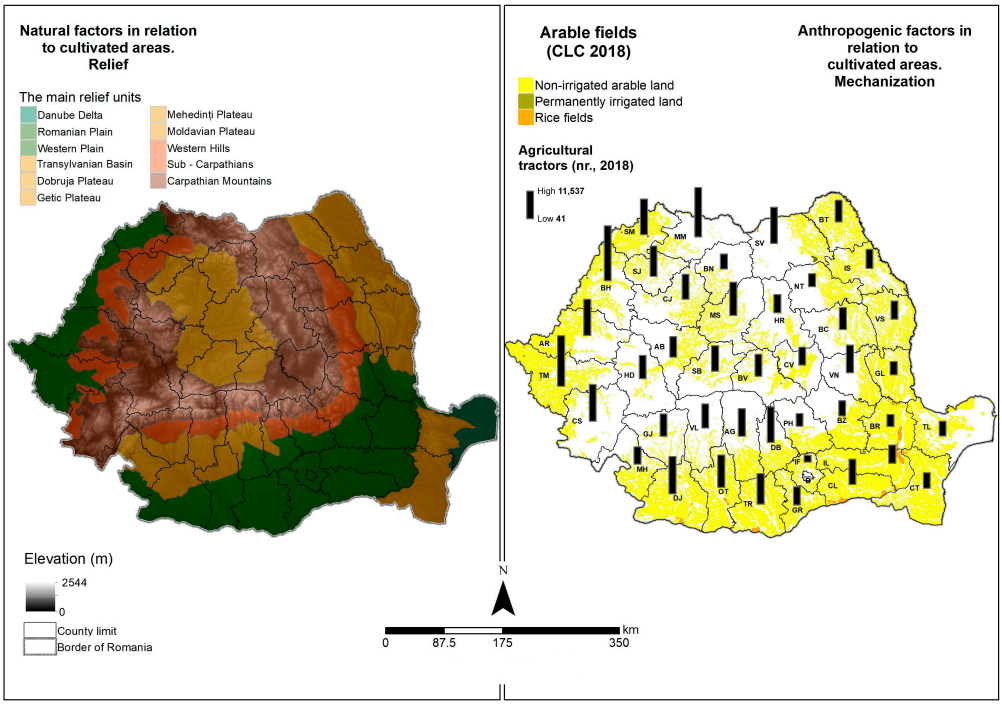

Figure 10. Landforms features, arable area, and number of tractors in Romania in 2018. Source: authors' processing of NIS data [63–66].

The mechanisation of agriculture represents a very essential aspect in the agrarian economic transformation and plays an important role in the intensification of labour productivity in the agricultural sector, consequently contributing to sustainable food security, promoting the sustainability of the natural environment, and reducing rural poverty [82,83].

The main indicator for Romania, which expresses the degree of mechanisation of agriculture, is the number of tractors (Figure 10). For the year 2018, the distribution of tractors was very even at the national level; most were in the counties of Bihor (11,537 tractors), followed by Timiș (10,625 tractors) and Maramureș (10,326 tractors). The fewest tractors, excluding the Municipality of Bucharest (41), were in Ilfov (1454) and Brăila (2477).

The total agricultural area of Romania in 1990, immediately after the 1989 revolution, was 14,769,028 hectares. From this surface, the largest part was allocated to the arable surface (64%) (Figure 11), followed by pastures (22%), and on the last two positions, there were vineyards and wine nurseries and orchards and fruit nurseries (2%).

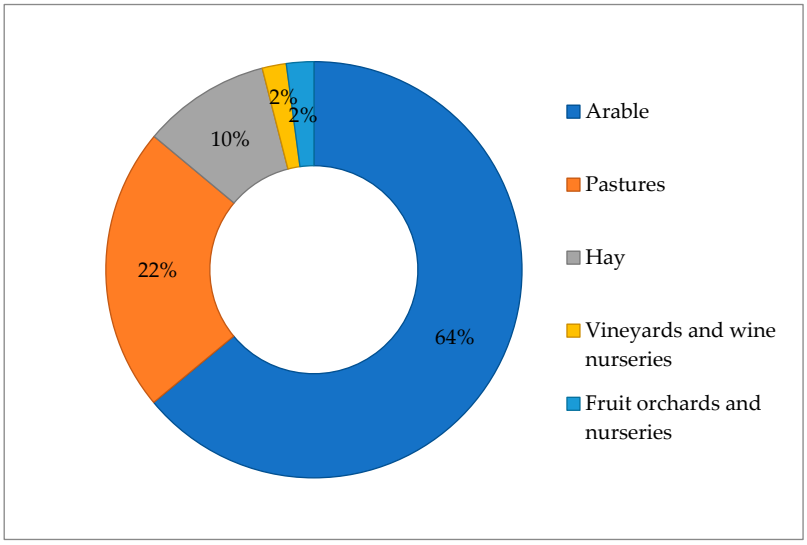

Figure 11. The agricultural area according to the way of the use of the land fund—in hectares (1990). Source: authors 'processing of NIS data [64].

In 2014, the total agricultural area of Romania was 14,630,072 hectares. Of this (Figure 12), the largest part was also represented by the arable surface (64%), followed by pastures (22%), and in last place was orchards and fruit nurseries (1%).

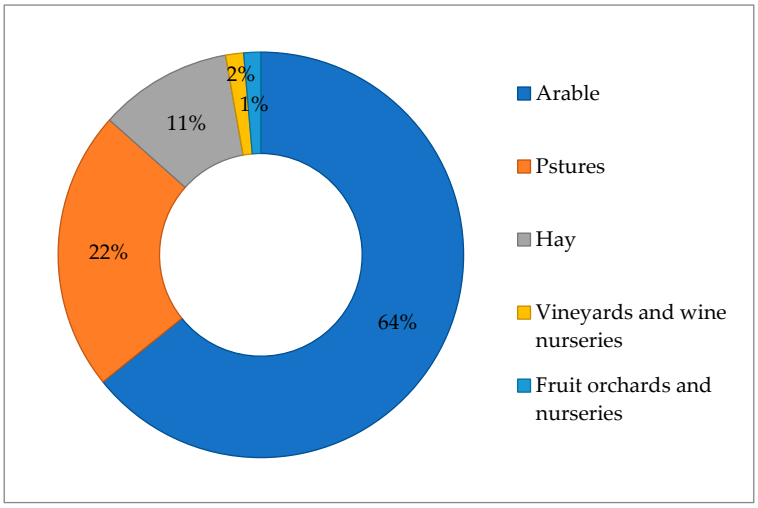

Figure 12. The agricultural area according to the way of use of the land fund—in hectares (2014). Source: authors' processing of INS data [64].

4.4. Urbanisation Index

The counties with an urbanisation index of <30% were Dâmbovița at 28.2% and Giurgiu at 29.1%. The highest values > 70% of the urbanisation index at the level of the counties of Romania in 2018 were recorded in Brașov at 70.6%, Hunedoara at 74.5%, and Bucharest—Ilfov Region—at 88.6% (Figure 13).

In the case of Brașov county, the county's urbanisation index is particularly influenced by the economic potential of Brașov Municipality; the rest of the towns in the homonymous counties are developed from a tourist point of view, such as Predeal, Bușteni, Sinaia, Sighișoara, etc.

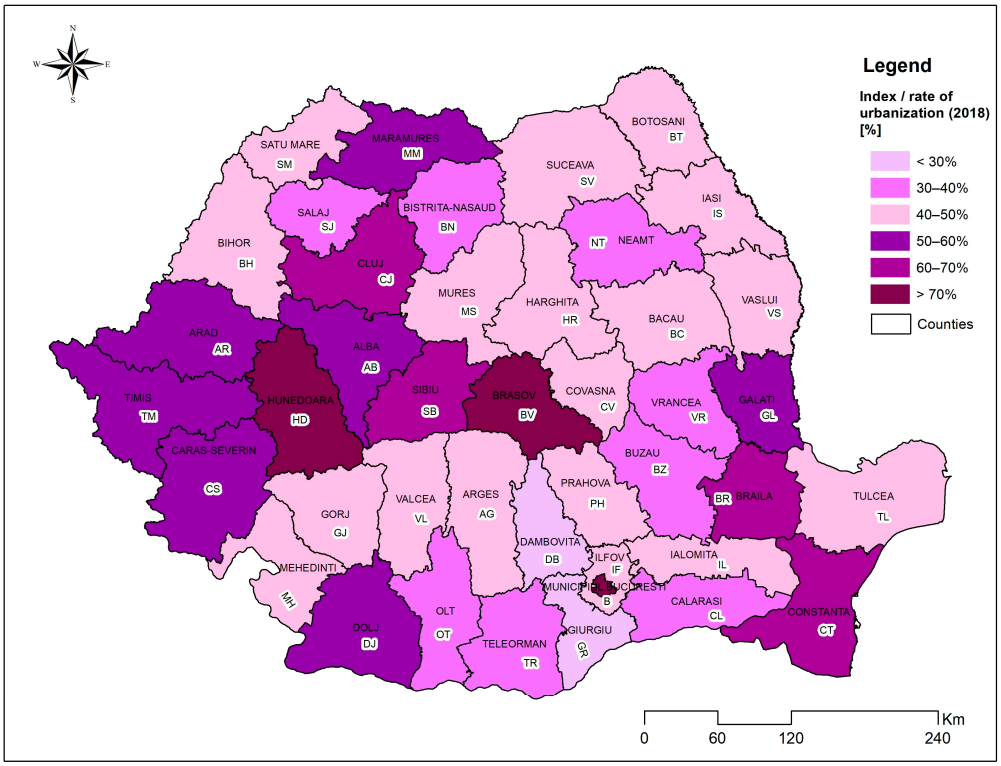

Figure 13. Urbanisation index in Romanian counties in 2018. Source: authors' data processing in ArcGIS 10.7.2.

An important factor of the urbanisation of a county/city is its climate and land features. In mountainous areas, the land features and climate make it very difficult to cultivate plants due to very low temperatures, very high precipitation, and very fragmented slopes. A plain area is favoured as the climate is very mild and relief very accessible for constructions and agriculture.

5. Discussion

Romania has the sixth largest agricultural area among the countries within the European Union, meaning that it should have an increased level of efficiency and the productivity of major agricultural crops (corn, wheat, sunflower, and rapeseed). However, Romania is one of the top ten exporters of wheat and corn worldwide. It recorded a low efficiency rate due to the fragmentation of agricultural land, weak land reclamation systems, unsatisfactory, or reduced mechanisation [84], to which can be added low technological and informational development, aging farmers, and sometimes inefficient production due to climate change (floods, natural calamities, agricultural and meteorological droughts, landslides). Drought, as an extreme climatic phenomenon, can have negative effects on Romania due to the very low productivity of the major agricultural crops of corn, wheat, and sunflower.

Consequently, the production capacity of wheat grain is more sustainable and ecological in less eroded soils than in more eroded soils [85].

Management technologies to increase total cereal production in a sustainable way in correlation with the implementation of the 2030 Agenda of the eight Sustainable Development Goals (SDGs) as the most significant for organic agriculture, and at the same time providing in parallel a variety of nutrient-dense foods, are urgently needed to be implemented in food industries based on corn, wheat, sunflower, and rape. This is necessary to meet the needs of an increasing global population in terms of the number of inhabitants in specific areas [86].

Wheat has been one of the grains most affected by the SARS-CoV-2 outbreak, as field harvesting and crop closures have severely disrupted the supply chain and, at the same time, prices have increased [87]. Therefore, wheat grain culture is characterised in the specialised literature as playing a significant role in the sustainability of the wheat supply chain [88]. As a result of its performance, it is necessary that the supply chain is concerned with sustainable collective innovations [89].

Sustainability, as a desire for the development and prosperity of the natural environment, should be applied uniformly to all farms around the world, showing the need for collaboration, dialogue, and debates regarding the economic, social, and environmental dimensions of sustainability in agriculture [90]. Correlating the previously presented information with the 17 Sustainable Development Goals, sustainable agriculture represents one of the key goals of the 2030 Agenda for Sustainable Development [91], which is that of a geographic space. According to the most recent studies that conceptually approached "sustainable agriculture", many authors expressed the need to protect this stability and balance, and on the other hand, they investigated how this objective could be achieved in the medium and long term [92–94].

According to Borychowski et al., in 2020, family farming with a small utilised area and a small scale of production constitutes a foundational basis for the agricultural sector of the economies of Central and Eastern Europe (CEE), in particular in Lithuania, Moldova, Poland, Romania, and Serbia [95].

Overall, agriculture as an economic branch, which provides the population with agro-food products and at the same time raw materials for numerous branches of industry, employs a relatively large number of people (workforce) worldwide (Table 1). However, the specific values vary from one continent to another, with Sub-Saharan Africa registering the highest share of the labour force at 54.9% in the agricultural sector, and at the opposite pole being North America with only a 1.6% share of the workforce at the level of agriculture.

Table 1. Workforce share by economic sectors worldwide in 2017.

	Region/Territory	Workforce Share by Sectors of Economy (% 2017)			Total Workforce (mil pers).
		Agriculture	Industry	Services	
1.	East Asia and Pacific	26.6	23.2	50.3	1258.64
2.	Europe and Central Asia	9.2	24.4	66.4	438.14
3.	Latin America and Caribbean	15.6	21.4	62.9	309.82
4.	Middle East and North Africa	17.2	26.8	56.1	150.10
5.	North America	1.6	17.4	81.0	183.41
6.	South Asia	44.4	22.9	32.6	694.07
7.	Sub-Saharan Africa	54.9	11.0	34.1	415.27

Source: data processed from World Bank, 2022 [96].

GIS software can manage, store, edit, analyse, and visualise various datasets in relation to the geographical location specific to the studied areas [97], as can be seen in the present study, and it has also been used in several agricultural research studies. To create interactive maps based on GIS software, for the distribution of agricultural crops in Romania, it is necessary to closely investigate all the available data and analyse different ways of processing and visualising them. This desideratum is extremely important to ensure the completeness, accuracy, sharing, correctness, and credibility of maps made with data processing in GIS software [98]. One of the particularly important aspects for ensuring sustainable and ecological agriculture is the appropriate research of agricultural land for

the production or distribution of different crops [99] with the help of GIS software, resulting in interactive maps.

Nowadays, the agricultural sector in Romania's counties is very diversified, but with an accelerated pace of transformation. Currently, industrial agriculture with modern agricultural means it is in permanent development. Farmers in recent times have started to use increased amounts of mechanised agricultural machinery, chemical fertilisers and pesticides, and food products resulting from harvests which are sold on the commercial market, where, most of the time, a large part of it is exported [100].

Throughout the 21st century, agricultural land at national and international levels has faced a boundless recession as a result of environmental changes throughout the Earth, in particular climate change [101], the sharp deterioration of land, and extremely rapid urbanisation [102], including alarming population growth [103,104].

The sustainable development of agriculture in Romania can also be supported by "family farms", which, according to Micu et al., 2022 [105], addresses three dimensions for sustainability, namely economic, social, and environmental, which are discussed and analysed simultaneously.

The economic perspective of farms refers to upward development, yield, and stability [106], while the social manner addresses the fairness, empowerment, power, and insertion of family farms in such a way as to preserve rural traditions in the rural space and, more than that, to limit the exodus of the population from rural areas to urban areas [107]. And the dimension of environmental viability mainly addresses natural resources in the geographical space of farms, environmental pollution, and the biodiversity of family farm landscapes [106].

According to the United Nations Food and Agriculture Organization (FAO), the family farm is the key to a sustainable future in Europe and Central Asia [108], and, from our perspective, also the key to the socio-economic development of the primary sector of economic activity—organic agriculture—by acting as a nucleus of the ecosystem [109]. Presently, the ecological sector of agriculture is one of the fastest growing economic activity sectors of the food industry in several European countries [110]. On the European continent, the market for organic products has recorded an upward trend in the last 10 years; however, it is a very small market in parallel with the market for artificial or non-conventional products [111,112].

The socio-economic changes in Romania have direct, unfavourable consequences on the functioning of the basic agriculture, where sustainable and traditional mountain agriculture is abandoned and forgotten at the expense of an economy based on services, more specifically, tourism-related activities. Traditional Romanian land use practices are gradually being replaced by increasing amounts of investment, resulting in expansion and development in a very short space of time, without an essential and honest convention of environmental factors on the local, county, regional, and national scales. Environmental problems or difficulties arise from the moment when the traditional agricultural economy is abandoned in association with the expansion of new tourist facilities, for example, guesthouses, hotels, access roads, and other related facilities, constituting new agents of constraint on biodiversity [113].

6. Conclusions

The results obtained after generating interactive maps using GIS software for the distribution of the main agricultural crops in Romania cannot be generalised to all cities, counties, or regions in Romania. On the other hand, the obtained research results refer to the fact that the ecological development of agriculture presents some limitations in terms of sustainability due to production costs, small farm sizes, the need to build new food markets, reduction in production income, reduction in prices for chemical fertilisers, and the qualification of farmers to specialise in sustainable agricultural practice.

The limitations in Romania's agricultural data present substantial challenges for the sector's development and sustainability. Addressing these challenges is essential

for informed decision making, policy formulation, and effective resource allocation. By implementing standardised data collection methods, embracing technology, and fostering collaboration, Romania can better capitalise its agricultural potential and secure a more prosperous future for its agricultural sector. Thus, the analysis should be continued when new data on agriculture become available. The changes within and trends of the sector will be better underlined by applying the same set of methods of interactive maps on the new data.

Even so, considering the limitations in data supply and accuracy, the GIS software should be seen as a mechanism to support and strengthen the decisions of farmers in Romania. The validation of the areas for practicing sustainable, ecological agriculture is achieved through a monitoring system and supervision of the farm. Another limitation of this investigation is the inability to expand it globally because the volume of the data would be extremely large and there would be a possibility of accuracy errors.

In future research directions, the Landsat Program will be used, which provides researchers with calibrated and at the same time high-resolution spatial data for the land surface of cities and regions worldwide. Landsat-8, which was launched in February 2013, represents one of the most recent terrestrial remote sensing satellites [114–116]. The provided data cover a wide spectrum of research areas, for example, land use, agriculture, geology, environmental pollution, etc.

Also, the future interactive maps regarding agricultural crops in Romania, generated using the Landsat-8 model, can represent a viable solution to help decision makers (local and county councils and administrations, the local population) manage agriculture properly and at the same time [117] organise new policies and strategies meant to improve and adapt crops to climate change.

The second direction of research refers to the more exhaustive and rigorously detailed review of land cover assessment and monitoring by studying other variables for spatial statistical analysis and interpretation, such as the Normalised Difference Vegetation Index (NDVI), Land Surface Temperature Index (LST) [118–127], and the Normalised Difference Water Index (NDWI) [128].

The main advantage of the Corine Land Cover (CLC) is its periodic update in the countries of the European continent, although the degree of particularity of the data source is presented in the specialised literature as a limitation [129,130]. The mapping of vegetation and land cover (CL) through the creation of interactive maps in Romania is extremely important for research, and at the same time for the development of new public policies [131] and customised strategies based on the best-performing variables of landscape [132]. Analysis and interpretation in the GIS of land use evolution can be easily conducted using remote sensing data for long time intervals [133].

The third research direction will continue to focus on the development of ecological agriculture, the distribution and evolution in time and space of the land, and the prediction of the characteristics of the vegetation in Romania according to the altitude using the Hyperion Sensor [134].

In conclusion, this research study will provide effective support for the decision-making process in terms of the ecological and sustainable agricultural production of Romania's counties, offering farmers tools to constantly improve agricultural planning and evaluation, using the GIS software.

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Abbreviations

The following abbreviations were used in this paper:

GIS	Geographic Information System (Software)
QGIS	Open-source desktop GIS application
NIS	National Institute of Statistics
CLC	Corine Land Cover
R_u	Rate/urbanisation index
PU	Urban population
PT	Total population
FAO	Food and Agriculture Organization of the United Nations
NDVI	Normalised Difference Vegetation Index
LST	Land Surface Temperature Index
CL	Land Cover
CEE	Central and Eastern Europe
SDGs	Sustainable Development Goals

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