sustainability

Review

Analysis of the Sustainability of Livestock Farms in the Area of the Southwest of Bihor County to Climate Change

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Abstract: The concepts of sustainability and vulnerability are complementary and closely linked; mitigating the vulnerability of the human environment/climate change can increase its resilience or sustainability. Climate change can increase existing vulnerabilities and deepen socioeconomic imbalances. Measures to reduce and adapt to the effects of climate change are needed in the livestock sector, as they can help reduce the damage caused by natural disasters and other effects of climate change. The future effects of climate change are a significant challenge for livestock managers, users of livestock products and other players, as they may face a number of problems, such as the qualitative and quantitative decline in cereals (feedstock), depletion of conventional sources of energy that provide the electricity and heat needed for animal husbandry, damage to animal shelters, changes in flood frequency and the effects of flooding on the process of spreading manure on land and unforeseen operating and maintenance costs. The adaptation of the intensive animal husbandry process to climate change is a complex process considering the variability of effects, physical vulnerability, degree of socioeconomic development of the entire analyzed area, natural adaptability, health services and disaster surveillance mechanisms. The purpose of this study is to help local authorities in the process of preparing for this transition in a way that takes into account not only socioeconomic factors but also the development constraints imposed by climate change. The studied area, Ciumeghiu–Avram Iancu, located in the southern part of Bihor County, Romania, has been designated as a disadvantaged area of socioeconomic development so that economic agents can apply for the financing of rural development projects with co-financing from European funds (up to 90%). The study presents an analysis of economic development (zootechnical activities) in the southern part of Bihor County, Romania in relation to the climatic vulnerability of the area. Knowing the changes induced in an area by climate change is still a challenge for any local community, and for a socioeconomically vulnerable area, such as the study area, it is important to have at hand studies that can indicate the directions and constraints of development in dictated by these changes. Through this study, we aimed to identify a correlation between the changes induced by climate change and the development capacity of livestock farms, as many economic agents have developed or are developing technical projects for the construction of animal farms in this area. This study is based on the requirements of European reference documents, standards and guidelines. Based on the data available at this time, the applied risk analysis methodology identified a moderate risk associated with increasing extreme temperatures, changes in average precipitation, increasing average temperature, availability of water/drought resources, floods, desertification and risks associated with soil erosion, and the risk of vegetation fires. The correlation of all these factors led us to the conclusion that the area allows for the strictly controlled development of new livestock farms based on plans for the development of territorial units in the area. These units must include desertified areas and define the areas for planting vegetal curtains that will both reduce the phenomenon of erosion and block the circulation of air masses with odor released from the activity of animal

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husbandry and manure management. The results of the analysis show that it is necessary to take into account the diverse nature of environmental evolution/climate change in different areas of economic development specific to a development area.

Keywords: adapting; change; climate variables; environmental pollution; exposure; livestock industry; risk; solutions; sustainability; vulnerability

1. Introduction

The concepts of sustainability and vulnerability are complementary and closely linked; mitigating the vulnerability of the human environment/climate change can increase its resilience or sustainability. First, sustainable development necessarily requires the integration of social, economic and environmental objectives. Integration begins with the recognition that the environment and society/economic development are closely linked.

Animal feed production has accelerated over the last 100 years in response to growing demand [1]. According to a report by the Food and Agriculture Organization (FAO), future consumption forecasts indicate that global meat production is expected to double from 229 million tons in 1999 to 465 million tons by 2050 [1]. Against the background of the increase of meat requirements on the market and the economic underdevelopment of the southern part of Bihor County, economic owners of zootechnical farms have developed, are developing and have approved projects.

However, the FAO report states that "The meat industry has a marked global impact on the disappearance of water, soil, plants and animals and the consumption of natural resources and has a strong impact on global warming" [1].

At the same time, climate change is occurring both globally and at the local level, inducing effects and constraints on animal husbandry activity. Climate change (rising temperatures, changes in rainfall, falling snow and ice) is taking place in Europe as well, and some of the changes observed have set records in recent years [2]. The observed climate change has already led to a wide range of effects on environmental systems and society (including economic activities), with important effects expected in the future. Climate change can increase existing vulnerabilities and deepen socioeconomic imbalances in Europe. Knowing the changes induced in an area by climate change is still a challenge for any local community, and in a socioeconomically vulnerable area, such as the study area, it is important to have at hand studies that can indicate the directions and constraints of development that will result from these changes.

The need to adapt to climate change is one of the major concerns of this period [3]. Romania is committed to preventing and combating climate change and aims to reduce carbon emissions. Along with other European countries, Romania is facilitating the economic transition to a sustainable, circular, energy-efficient economy based on renewable energy, climate-neutrality and resilience. In this context, this study focuses on issues related to climate change and its effect on the capacity of the southern part of Bihor County (villages Avram Iancu și Ciumeghiu) to support livestock activities.

The future effects of climate change pose a significant challenge for livestock managers and other stakeholders (road transport operators, utility operators), who may face a number of problems. These include the reduction in agricultural areas caused by natural disasters, unforeseen operating and maintenance costs, changes in crop quality and yield and changes in feed quality.

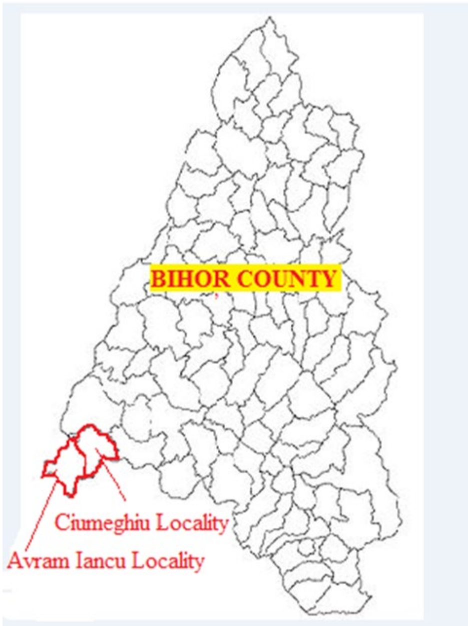
This study is based on the requirements contained in "ISO—14091:2021: Adaptation to climate change—Guidelines on vulnerability, impact and risk assessment" in line with the recommendations developed by the European Commission's Directorate-General for Climate Policy (DG Climate) included in the paper "Guidelines for project managers: making vulnerable investments resilient to climate", which were guided by "The Basics of Climate Change Adaptation Vulnerability and Risk Assessment".

We applied the requirements of these documents in the study to the entire complex of livestock farms in the south of Bihor County (villages Avram Iancu și Ciumeghiu).

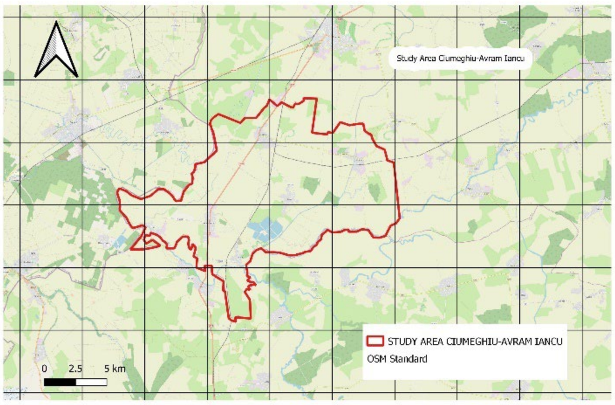
The study area is represented by the southern part of Bihor County, the communes of Avram Iancu and Ciumeghiu. The chosen study area, Ciumeghiu–Avram Iancu is a plain relief area located in the southern part of Bihor County, Romania.

The social problems in the area are due to the lack of jobs, which led to the classification of the area as disadvantaged. In these conditions, through the EU financial aid scheme in the financial years 2014–2020, development funds were accessed that contributed 90% of the investment needed to develop 15 high-capacity livestock farms (IPPC facilities).

These communes have great agricultural potential due to the plain relief that defines them. Figure 1a,b show the geographical area under study.



(**a**)



(**b**)

Figure 1. (**a**) Geographical area under study. (**b**) Geographical area under study.

The studied area belongs to the Pannonian biogeographical area in the Plain of Salon, a subunit of the Western Plain of Romania (Figure 2).

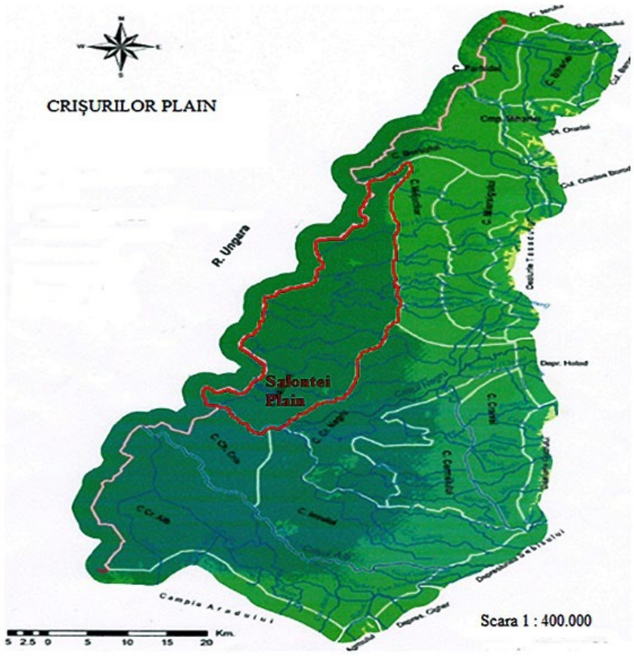


Figure 2. Salon Plain. Subunit of Crișurilor Plain.

The plain is of the alluvial-subsident type; it is very smooth, with altitudes of 98–100 m in the north and 90–95 m in the center and in the south, with heights of 89–90 m in the west of Salonta. The relief energy is mostly 0–1 m and rarely reaches 2–3 m. The fragmentation density is 0–0.2 km/kmp, but with drainage channels, it rises to 0.5–1.25 km/kmp. The higher parts rise 2–4 m above the lower ones and are highlighted in periods of excess moisture because they are more desolate. Their areas are sinuous, insular, sometimes more extensive, and often even have a thin layer of loessoids. The lower parts are dominated by a labyrinth of valleys, meanders and abandoned belciuge, which are drainage canals or ponds arranged on more extensive swamps.

The analyzed area includes the surface included in the territorial administrative units Avram Iancu and Ciumeghiu. According to data obtained from the National Institute of Statistics [4], the cumulative territory of the two communes was 19,245 ha in 2021. The distribution by type of land use is shown in Table 1.

Table 1. Distribution of the land by type of use in the studied area.

Land Use by Category	**Land Use by Subcategory**	**Territorial Administrative Unit**		**Total**
		Avram Iancu	**Ciumeghiu**	
ha		**ha**	**ha**	**ha**
Total area of agricultural land 16,732	Arable	6088	8596	14,684
	Pasture	728	1120	1848
	Finesse	37	145	182
	Vineyards	15	0	15
	Orchards	3	0	3
Total area of non-agricultural land 2513	Forests and other forest vegetation	80	284	364
	Land occupied with surface water	627	265	892
	Land occupied by construction	296	389	685
	Communications and railways	185	187	372
	Degraded and unproductive land	158	42	200
	Total	8217	11,028	19,245

According to the data in Table 1, a total of 14,684 ha of land can be used for spreading manure from livestock. Studies carried out by the Bihor Pedological Office on the entire surface of arable land in the studied area found that manure can be spread with a maximum load of 170 kgN/ha.

The 15 zootechnical farms listed in Table 2 operate or have approved development projects in the study area [5].

Table 2. Livestock farm.

Livestock Farm	Total Farm Capacity Heads/Series	Coordinates 70 STEREO		The Area of Agricultural Land Required for Manure Spreading
		lat.N	long.E	ha
Intensive poultry farm Nutripui	600,000	589,566	240,222	1059
Intensive poultry farm Nutripasăre	600,000	589,535	240,099	1059
Intensive pig farm Pedagro Ferme	12,000	585,419	244,431	911
Intensive cattle farm PFA Suciu Viorel	200	586,139	240,447	103
Pig breeding farm Star Repro	1200	586,011	241,759	189
Intensive sheep farm PFA Suciu Alina	400	586,139	240,559	39
Intensive poultry farm AviaFarm	58,000	586,491	240,031	102
Intensive poultry farm Multiagrofield	55,500	585,323	244,687	98
Intensive poultry farm Erdenor Fermagro	58,000	585,803	242,703	102
Intensive poultry farm Razvi-Farm	58,000	586,939	240,127	102
Breeding laying hens Grupul de producători carne pasăre Nutrientul	66.000	580,554	232,366	291
Laying hen farm Grupul de producători carne pasăre Nutrientul	84,000	584,219	237,022	311
Laying hen farm Grupul de producători carne pasăre Nutrientul	66,000	586,843	235,278	245
Laying hen farm Grupul de producători carne pasăre Nutrientul	360,000	587,563	235,358	1334
Total				5945

The plan to maintain air quality in the area does not highlight problems related to the quality of this environmental factor [6].

2. Materials and Methods

The following steps were taken in the study:

a. Identifying the sensitivity of animal husbandry activity from a climatic point of view;
b. Assessment of the exposure of livestock farms in the study area;
c. Vulnerability analysis of zootechnical activities;
d. Assessing the risk of animal husbandry to climate change.

a. Sensitivity analysis

Sensitivity analysis involves identifying the sensitivity of the area and the activities analyzed in relation to a number of climate variables and climate-related secondary effects/risks. The sensitivity of zootechnical activities to climate variables was assessed in terms of its components, namely: zootechnical production, road traffic, the benefits of using the zootechnical potential of the area and the demand for products on the market.

The following sensitivity classes have been proposed in accordance with the following general guidelines (Table 3):

- High sensitivity: climate variables have a significant impact on inputs, outputs, farm production processes and transport networks;
- Medium sensitivity: climate variables have a moderate impact on inputs, outputs, farm production processes and transport networks;
- Low sensitivity: climate variables have a minimal impact on inputs, outputs, farm production processes and transport networks;
- Without sensitivity: climate variables have no impact on inputs, outputs, farm production processes and transport networks.

Table 3. Sensitivity classes used to identify the sensitivity of livestock farms due to a climatic hazard.

Compound	No Sensitivity (0)	Small (1)	Medium (2)	High (3)
input—young animals, water, feeds, treatments	No impact on the analyzed activities	Minor disturbances of production processes	Moderate disturbances in the supply of young animals, feeds and water (not more than 15 min), without a significant decrease (by more than 5% of animal production)	Significant disruptions to the supply chain with a significant decrease in productivity of livestock farms by more than 10%
outings—animals for sale/slaughter/eggs/manure	No impact on the analyzed activities	Minor impact on farms—livestock production	Moderate impact on the productivity of livestock activities	Major impact on activity with a significant decrease in productivity of livestock farms by more than 10%
transport/infrastructure	No impact on the analyzed activities	Decommissioning of the transport infrastructure for a maximum of 24 h, with a minor impact on the farms in the area	Decommissioning of transport infrastructure for 1 day, with medium impact on livestock farms	Decommissioning of transport infrastructure for more than 1 day, with major impact on the activity of livestock farms

b. Assessment of exposure

The study assessed the exposure of livestock farms to the effects of climate change in terms of the geographical area in which they are located. The exposure assessment was performed for both current and future climatic conditions. The scale for assessing the exposure to current and future climatic conditions considered is presented in Table 4.

Table 4. Scale for assessing exposure to current and future climatic conditions.

	Exposure			
	No Exposure (0)	Low (1)	Average (2)	High (3)
Exposure to current conditions	Coincidence never manifested	Coincidence has occurred once in the last 25 years	Coincidence has occurred twice in the last 10 years	Coincidence has manifested itself every year for the past 5 years
Exposure to current conditions	The data collected so far do not suggest a negative trend (increase or decrease, as appropriate)	The data collected so far suggest a slight negative trend (increase or decrease, as appropriate)	The data collected so far suggest a negative trend (increase or decrease, as appropriate)	The data collected so far suggest a significant trend of negative evolution (increase or decrease, as the case may be)
Exposure to future conditions	The hazard will not occur in the future in the location (s) analyzed due to climate change	Coincidence is unlikely to occur more frequently in the future due to climate change	Coincidence may occur more frequently in the future due to climate change	Coincidence will occur more frequently in the future due to climate change

In order to evaluate the exposure in the study area for each of the selected climatic variables, public data on temperature, precipitation, wind speed, aridity, evapotranspiration, hazard maps and Landsat 9 satellite images were used. In Table 5, we present the indicators, methodologies and data sources used.

Table 5. Matrix used to classify vulnerabilities.

		Exposure			
		No Exposure (0)	**Low (1)**	**Average (2)**	**High (3)**
Sensitivity	No sensitivity (0)	0	0	0	0
	Small (1)	0	1	2	3
	Average (2)	0	2	4	6
	High (3)	0	3	6	9
The legend:					
	Vulnerability	no vulnerability (0)	reduced (1–2)	average (3–4)	high (6–9)

c. Vulnerability analysis of zootechnical activities;

A vulnerability analysis consists of identifying climate variables/hazards that may impact existing or proposed farms based on sensitivity and exposure for both current and future conditions. This was achieved with the help of the matrix presented in Table 5, in which Vulnerability = Sensitivity * Exposure.

d. Assessing the risk to animal husbandry posed by climate change.

The risk assessment was based on the analysis of vulnerabilities by identifying the risks associated with large and medium vulnerabilities. It consists of assessing the probability and magnitude of the consequences of the effects associated with the identified hazards, as well as assessing the importance of the risk for the success of the zootechnical activities in the study area. The matrix used for the risk assessment is presented in Table 6. The scale for assessing the probability of occurrence of the hazard is included in Table 7, and the scale for assessing the extent of the consequences is included in Table 8.

Table 6. Matrix used for risk assessment.

		Magnitude of Consequences (M)		
		1	**2**	**3**
Probability of occurrence (P)	1	1	2	3
	2	2	4	6
	3	3	6	9
The legend:				
Risk level		(1–3 Reduced)	(4–6) Moderate	(7–9) High

Table 7. Scale for assessing the probability of occurrence of hazard.

1	2	3
Unlikely	Probable	Almost certain
Low probability of occurrence	Coincidence has occurred and is likely to occur	The coincidence has appeared before, and it is almost certain that it will appear again

Table 8. Scale for assessing the magnitude of consequences.

1	2	3
Minority	Moderate	Catastrophic
Event with minor adverse effects on normal operation, which can be removed by routine maintenance or by changing operations	Event with moderate negative consequences on normal operation, which requires investment and may require adaptation measures	Disaster that can lead to the interruption of services and/or the destruction of some components of the systems with a major impact on local communities, which requires adaptation measures

Climate sensitivity of livestock farms was analyzed in relation to a set of key climate variables that were selected based on the specific requirements of livestock activities.

Climate variables include both the primary effects of climate change and directly dependent primary effects on climate change. In turn, the components of zootechnical activities are interdependent; affecting some of them can have consequences on others. Table 9 summarizes the indicators, methodologies and data sources used.

Table 9. Indicators, methodologies and data sources used.

Variable	Methodology
Temperature	GIS analysis: identification of areas with high temperatures and the highest estimated increases in summer and areas with low temperatures in winter and estimated changes [7,8].
	Profile literature analysis [9–11].
Rainfall	GIS analysis: the evolution of annual rainfall and extreme rainfall [7,12].
	Profile literature analysis [10,13].
Wind speed	GIS analysis: Identifying areas where high wind speeds are recorded [14].
	Profile literature analysis [11].
Availability of water resources	GIS analysis: identification of aridity index distribution and potential evapotranspiration [15].
Floods	GIS analysis: identification of areas at high risk of flood exposure [16].
	Data and information from the responsible authorities [17].
Risk of vegetation fires	Hybrid Fire Index Calculation [18,19].
Landslides	GIS analysis: identification of areas at high risk of landslide exposure [20].
Land erosion	GIS analysis: identification of areas at high risk of land erosion exposure [21].

In order to assess the exposure in the analyzed area, the following indicators were studied.

2.1. Temperature

IPCC Guide V shows that almost the entire surface of the Earth has risen in temperature, with the global average increasing by 0.85 °C between 1880 and 2012. In Europe, the average annual temperature was 1.5 °C higher in the period 2006–2015 compared to pre-industrial levels [10].

According to the Guide on Adaptation to the Effects of Climate Change by the Ministry of Environment and Sustainable Development, there was an increase in average annual temperatures in Romania over the period 1901–2006, but it was lower than the global increase.

Climate models predict that global average temperatures will rise in all greenhouse gas scenarios in the 21st century. The global average estimates are between 2.6–4.8 °C at the end of the century, and in Europe, the heating is accelerated, reaching 2.5–5.5 °C higher in the period 2071–2100 compared to 1971–2000 [10]. The evolution of temperatures in Romania will be similar to that in Europe more broadly.

Significant changes in extreme temperature trends have also been reported. Thus, the annual frequency of tropical days increased during the summer and the frequency of winter days decreased [22].

The analysis of extreme temperatures was performed based on Climate Wizard Output data with a spatial resolution of 1 km, which provided information on the current situation (temperatures measured between 1960 and 2010) and estimates of future temperatures. The CNRM-CM3 model was used to estimate the situation in 2065 in the event that greenhouse gas emissions will reach their maximum point in 2040. Representative data were used for the extremes—maximum temperatures (38.8 °C on 4 August 2017) and minimum temperatures (−18.9 °C on 10 February 2012). The average temperature of the area was 11.7 °C in the analyzed period (1 January 2001–31 December 2021). These data were recorded at the Oradea Meteorological Station to observe the changes in these climatic parameters in the studied area.

The following figures show the results of the increases in the maximum temperature in July and the minimum temperature in January.

In Bihor County, an increase in the maximum temperature in July of 3–4 °C is expected by 2065 (Figure 3). In the case of the minimum temperatures in January, an increase of 3–3.5 °C is expected (Figure 4) by 2065.

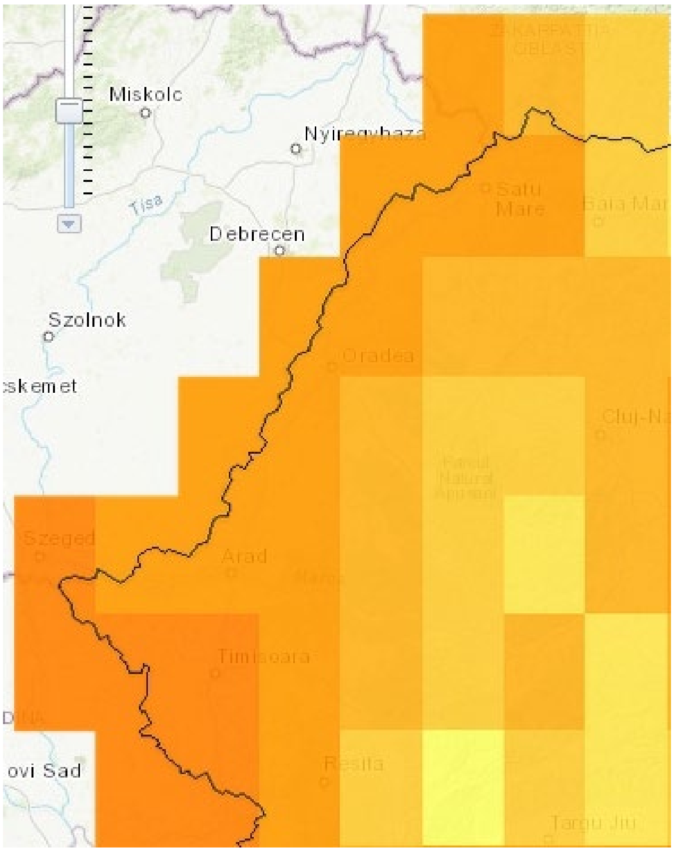


Figure 3. Estimated increase by 2065 of the maximum temperature in July.

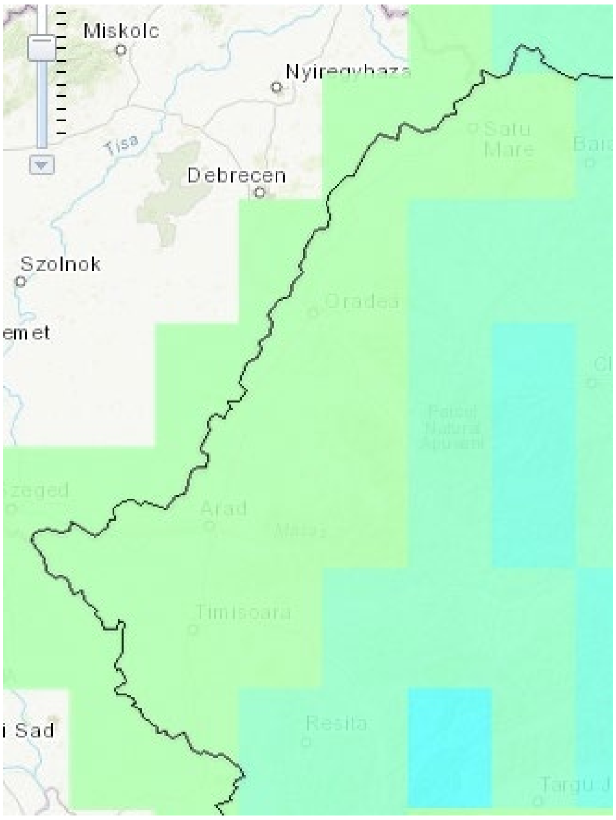


Figure 4. Estimated increase in 2065 of the minimum temperature in January.

The average maximum temperatures estimated in July 2065 in Bihor County are between 20 and 25 °C (Figure 5). The average minimum temperature in January 2065 will be in the range 0–9 °C (Figure 6).

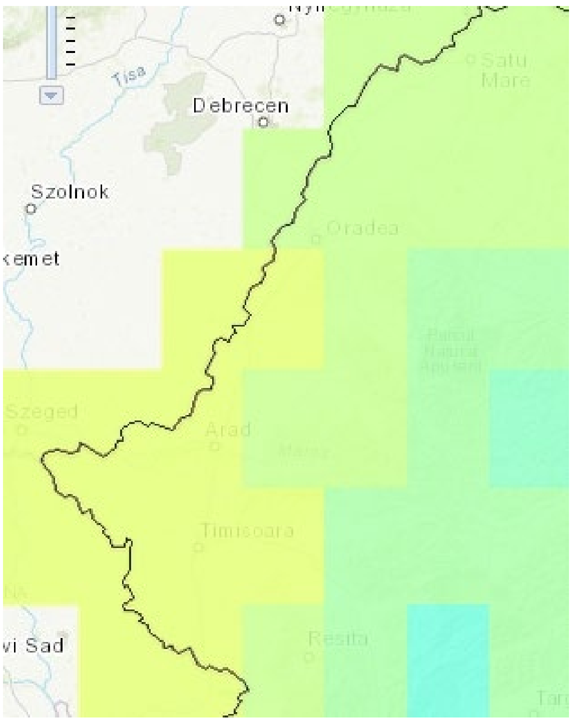


Figure 5. Estimated average maximum temperatures in July by 2065.

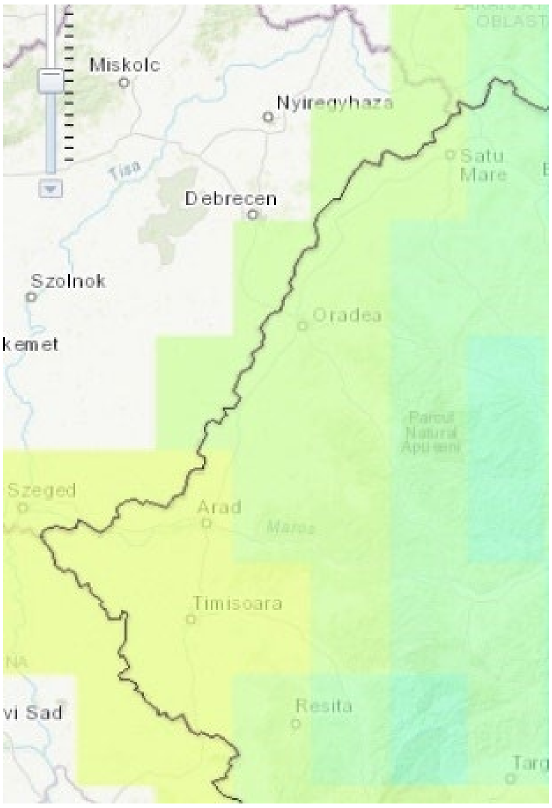


Figure 6. Estimated average minimum temperatures in January by 2065.

Heat waves are also of major interest in terms of rising temperatures. According to a report by the National Meteorological Administration in 2015, "Climate change—from physical bases to risks and adaptation" [11], in the case of Romania, a heat wave is defined in regulations that impose measures to combat their effects on the population as an interval of at least 2 days with maximum temperatures at least equal to or greater than 37 °C. Intense and persistent heat waves have become more frequent in recent decades compared to previous ones (for example, the 2007 and 2012 episodes). The implementation area of the project is in regions where clear trends of increasing the number of days with heat waves have been identified [11].

According to the IPCC's AR5 Synthesis Report: Climate Change 2014 [23], the frequency of heat waves has increased in large areas of Europe, with anthropogenic impact doubling the likelihood of this phenomenon occurring in some areas. It is also expected that heat waves will be more frequent, and their duration will be longer. In Romania, in the years 2003, 2007 and 2012, intense heat waves were registered. The regions with a significant tendency to increase in terms of the number of days with heat waves are those located in the south, east and west, outside the Carpathian arc, so Bihor County is likely to encounter this problem [11]. In the period 2021–2065, an average increase in the number of days with heat waves between 0 and 0.02 days/year is expected compared to the period 1971–2000 outside the Carpathian arc [14]. The analyzed area shows a significant tendency to increase the number of days with heat waves [11]. The index of tropical nights shows the number of nights with a temperature above 20 °C, in which thermal discomfort is accentuated. The index [11] showed an increasing trend over the period 1961–2013 and it is estimated that there will be up to six more tropical nights per year in the study area between 2021–2065 compared to 1971–2000. The duration of sunshine on the territory of Romania increased in the period 1961–2013, especially in the southern part of the country.

2.2. Precipitation

Most climate models indicate an increase in rainfall in northern Europe (especially in winter) and a decrease in southern Europe (especially in summer) [10]. According to the same models, an increase in the number of days with very high amounts of precipitation is expected. In Romania, a reduction in rainfall is expected during the summer at the end of the 21st century. From a pluviometric point of view, in the period 1901–2000, at the 14 stations with long observation lines in Romania, there was a general decrease in annual precipitation quantities.

From an analysis of the annual average atmospheric precipitation over the last 45 years in the Salonta Plain, the annual average was 800–996 mm. The minimum value of 364 mm was recorded at the Oradea meteorological station in 2000 (406 mm—1973 Chisinau Cris, 420 mm—1975 Săcuieni, 377 mm—1990 Holod). The maximum value of 996 mm was recorded in 2005 at the Chisinau Cris station (896 mm—1974 Holod, 805 mm—1974 Săcuieni, 884 mm—1996 Oradea).

To analyze trends in rainfall under climate change, Climate Wizard Output data were used to calculate the difference between the current situation and that estimated for 2065. The estimated future precipitation is based on the CNRM-CM3 model, in which the greenhouse effect peaks in 2040 (RCP6.0).

There are similar trends in Bihor County. There are increases in the annual rainfall between 0 and 10 mm/year throughout Bihor County. The study area is in an area with an estimated rainfall of 750–1000 mm/year in 2065, with only some areas in the county reaching 1000 mm/year (Figure 7).

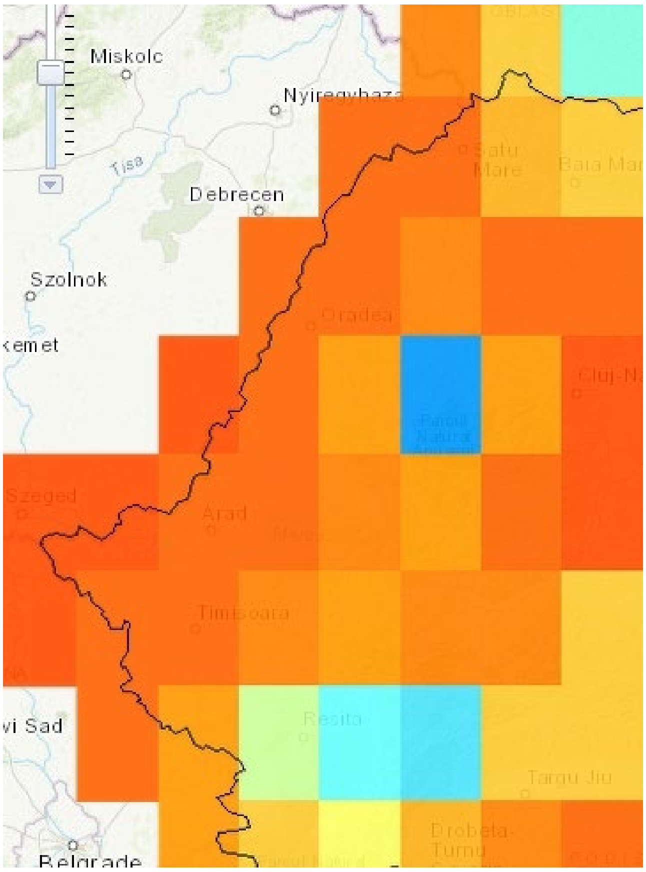


Figure 7. Estimated average annual rainfall in 2065.

Extreme rainfall was analyzed based on information from the European IMPACT2C [12] project. It was observed that most of Bihor County currently has extreme rainfall amounts of 10–15 mm/day (Figure 8). In 2065, it is estimated that extreme rainfall will not increase significantly in the county (Figure 9). According to the same source, the increase in extreme rainfall in Romania is between 0 and 2 mm/day over almost the entire territory of the country, except for the northeast and southeast, where the estimated increase is 2–4 mm/day. It should be noted that the data presented in the European IMPACT2C [12] project only include values of extreme precipitation below the 95th percentile.

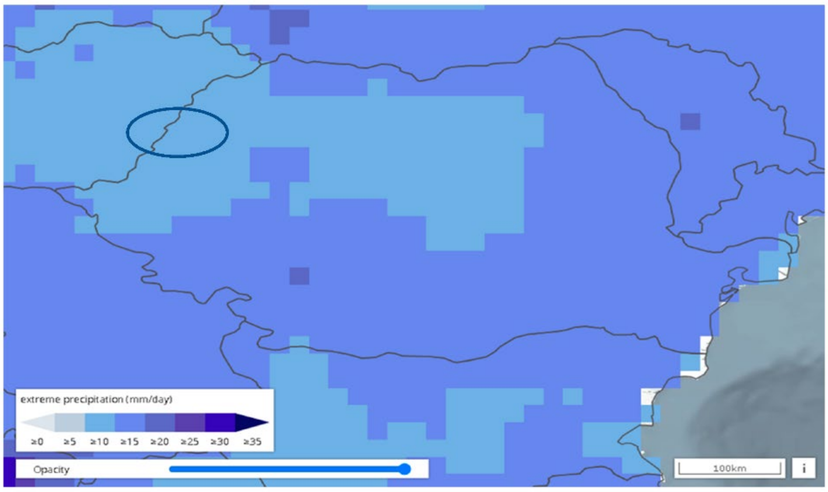


Figure 8. Extreme rainfall at present.

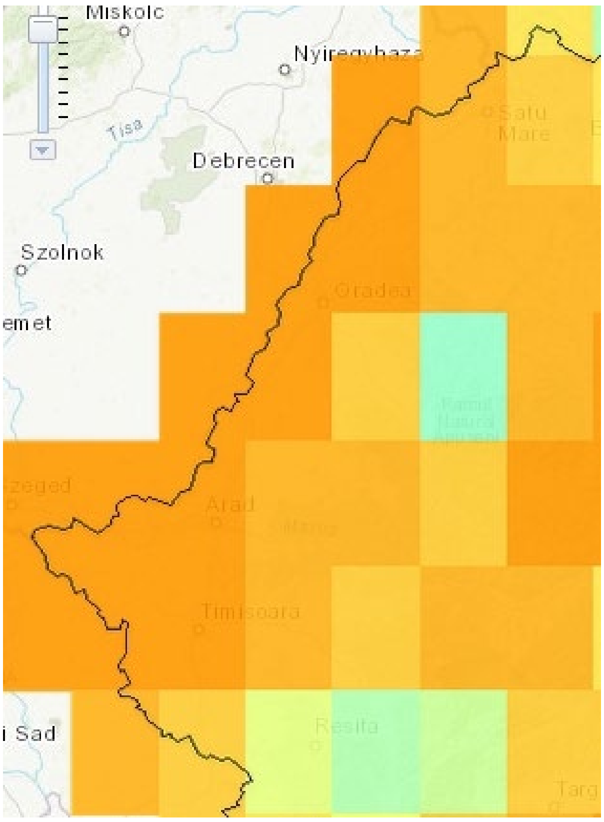


Figure 9. Estimated extreme rainfall in 2065.

Additionally, in terms of extreme rainfall, according to the report "Climate change—from the basics physical risks and adaptation", an index that illustrates the number of days per year with rainfall exceeding the amount of 20 L/mp/day (20 mm/day), an increase in the frequency of occurrences of episodes with precipitation exceeding 20 L/mp throughout the country within 24 h will occur in 2021–2050 compared with 1971–2000. In the case of the study area, the difference between the number of days with precipitation exceeding 20 L/mp in 2021–2065 compared to 1971–2000 is 1.5 days.

Drought is an extreme phenomenon characterized by a lack of precipitation. Droughts, although not sudden occurrences, such as rapid floods or storms, can have very significant negative socioeconomic effects due to their persistence. From a meteorological point of view, a dry interval is one in which there is a significant deficit in the precipitation regime. Meteorological drought sets in after 10 consecutive days without rainfall (in the warm season). The persistence of the meteorological drought is estimated according to the number of days without precipitation and the number of days with precipitation below the multiannual average of the period for which the analysis is made. Hydrological drought is associated with periods when rainfall is too light or short-lived that it has no effect on the direct water supply of the hydrological network. The result of hydrological droughts is felt in time and space in much larger areas. In this case, there are effects on the water supply and the production of hydroelectric energy and significant effects on the state of the ecosystems. Droughts are also influenced by temperature, with recent studies showing that the severity of drought is substantially influenced by rising temperatures. Based on the analysis of the Palmer Index for Drought Severity, the ANM report from 2020 [24] indicates a trend of aridization in southeastern Romania, with the Palmer index registering annual values of −1.5 to −3.3 in the period 1961–2010. The NMA report also indicates that future projections of the Palmer drought severity index calculated for Romania suggest that droughts will also be more intense due to global warming.

From a pluviometric point of view, over 90% of climate models predict pronounced droughts during the summer in Romania at the end of the 21st century (period 2090–2099), especially in the south and southeast (with negative deviations compared to the period 1980–1990 greater than 20%) [25].

2.3. Wind Speed

A study based on 20 climate models indicates increases in maximum wind speeds for northern and central Europe and decreases in southern Europe [26].

Wind speed shows major changes in long-term evolution. A total of 93% of the stations in Romania show decreasing trends in the average annual wind speed. The intra-Carpathian region is less affected than the other regions. Regional climate patterns indicate reduced changes in wind speed at the end of the century (2071–2100), showing an increase of 1 m/s [11].

In terms of cardinal directions, the most frequent winds are those from the southern sector in the Ciumeghiu–Avram Iancu area, with a high frequency in the winter months and a lower frequency in the summer months [14,27].

The average wind frequency in terms of cardinal directions for the period 1980–2020 is presented in Table 10.

Table 10. Average wind frequency in cardinal directions (m/s).

Weather Station	Cardinal Direction							
	N	NE	E	SE	S	SW	W	NW
Oradea	9,0	4,8	6,7	10,9	18,3	15,4	7,0	5,4
Chișineu Criș	12,9	4,5	5,2	6,6	12,2	9,0	6,4	4,1
Holod	13,3	12,6	12,4	2,2	5,0	12,5	8,9	3,9

From the analysis of the average frequency in different cardinal directions, the highest frequency was in the S (18.3 m/s) and SW (15.4 m/s) directions at Oradea station, S (12.2 m/s) and N (12.9 m/s) directions at Chisinau Cris, SW (12.5 m/s) and N (13.3 m/s) directions at Holod and NE (10 m/s) and SW (12.6 m/s) directions at Săcuieni.

The average wind speed in the studied area by cardinal direction (for the period 1980–2020) is shown in Table 11 [14,27].

Table 11. Average wind speed in different cardinal directions (m/s).

Weather Station	Month											
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Oradea	3	3,1	3,3	3,4	3	2,7	2,5	2,3	2,4	2,6	2,9	3,1
Chișineu Criș	2,1	2,3	2,4	2,7	2,5	2,1	1,9	1,6	1,7	1,8	1,9	2,2
Holod	1,8	2,3	2,7	2,7	2,4	2,2	2	2	1,9	2	2	1,9

Wind speed was analyzed using data from the Carpathian-Clim project [14] (Figure 10). The average annual wind speed in the study area is generally 2–3 m/s. Lower values are observed in small areas in Bihor County.

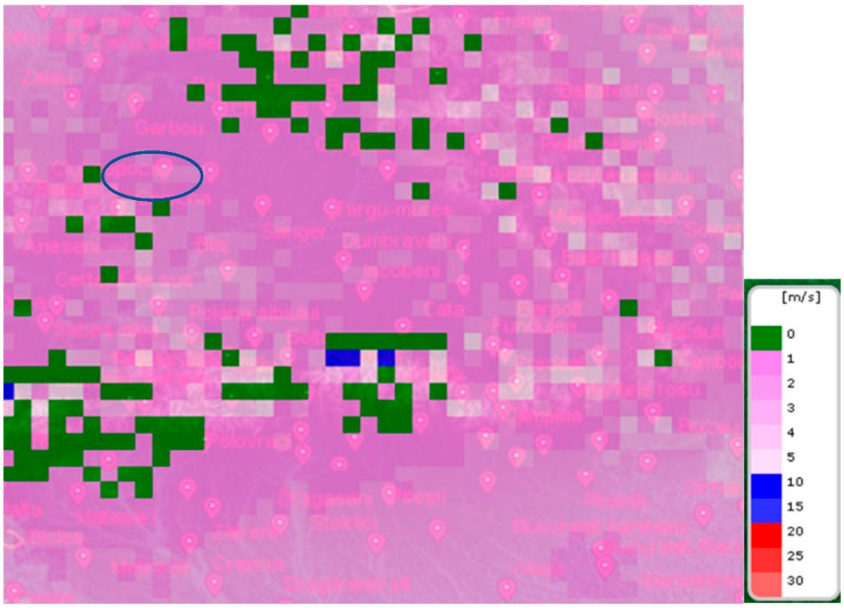


Figure 10. Predominant wind speed in the study area.

An analysis of the wind speed results of four numerical experiments [12] suggests that by end of the century (2071–2100) there will be a slight increase in the strong wind frequency (speeds higher than 10 m/s) compared to the reference period (1971–2000), but these changes are small. In Bihor County, the differences in the frequency of occurrence of wind episodes with speeds higher than 10 m/s are higher by up to 1–2% in the interval 2071–2100 compared to the interval 1971–2000.

With regard to extreme events (storms), existing observations on their location, frequency and intensity show considerable variability in Europe during the twentieth century [10]. The frequency of storms shows a general upward trend between 1960 and 1990, followed by a decrease. Available climate change forecasts do not indicate a clear consensus on either the direction of movement or the intensity of storm activity. This category includes tornadoes associated with severe convective storms. In the period 1822–2013, there are data on 129 tornadoes that occurred over 112 days. The spatial distribution of these data shows that they are more common in the eastern part of the country, with a hotspot in the southeast. Tornadoes are also more common in May–July, with a peak in May [27].

2.4. Soil Erosion

From a geological point of view, Ciumeghiu–Avram Iancu is located on the formations of the Pannonian depression, which arose from the slow sinking of a Hercynian massif consisting of crystalline schists. Above the crystal, located at a depth of about 1000 m, the sedimentary formations of the Pannonian and Quaternary are discordant and transgressive. The Quaternary has a thickness of about 250 m starting from the surface and is made up of locust and fluvial formations (Pleistocene and Holocene), presenting a cross-layered surface stratification typical of the formations of manure cones. The Quaternary consists of gravels and boulders in the mass of sands, with intercalations of clays and sandy dust [28] (Figure 11).

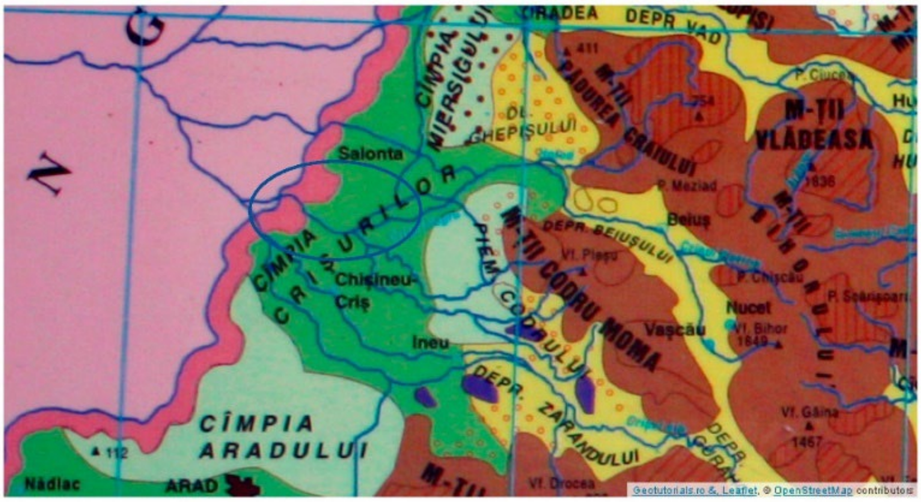


Figure 11. Geomorphology of the study area.

In the Salon Plain (low plain—Holocene, formed in the west), clay-sandy alluvial deposits of the Quaternary age predominate [29]. The most widespread are the Holocene alluvial deposits, but alluvial–proluvial deposits also appear at the contact point between the plain and the hills (Figure 12).

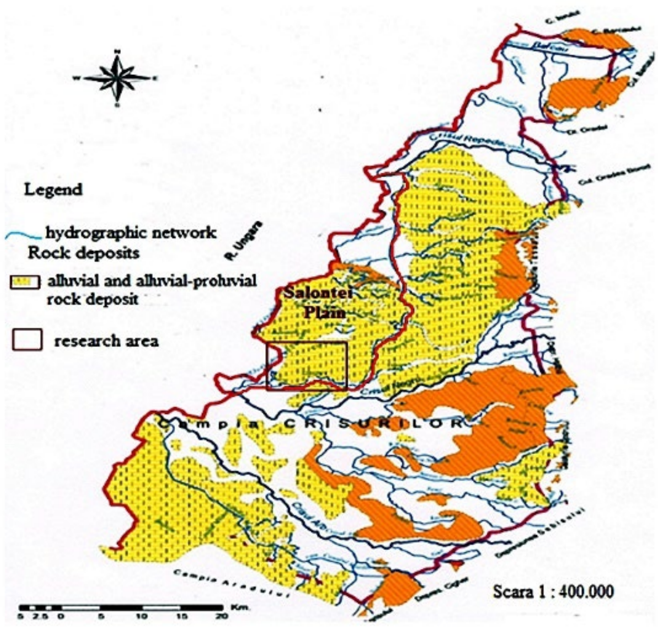


Figure 12. Rock deposits.

In some areas of the plain at depths of 2–6 m, calcosodic muds appear, which have given salic and alkaline properties to the soils. Drilling in the surface lithology has shown an alternation of clays and dust with pseudo-psammitic banks. In Batăr (a locality that borders the locality of Ciumeghiu), the drilling highlighted the composition of the Crişului Negru deposits, which are made of sands, gravel sands and boulders interspersed with clays [29].

The surface deposits of the studied area (Avram Iancu and Ciumeghiu) are represented by alluvial deposits and deluvial–proluvial deposits.

In the Salon Plain, the alluvial soils occupy the largest areas: 14,269.3 ha, followed by phaeoziomes 10,495.1 ha, solonets 7572.4 ha, eutricambosols 3848.5 ha, gleiosols 2284.8 ha, vertisols 701.2 ha and preluvosols 59.3 ha (Figure 13).

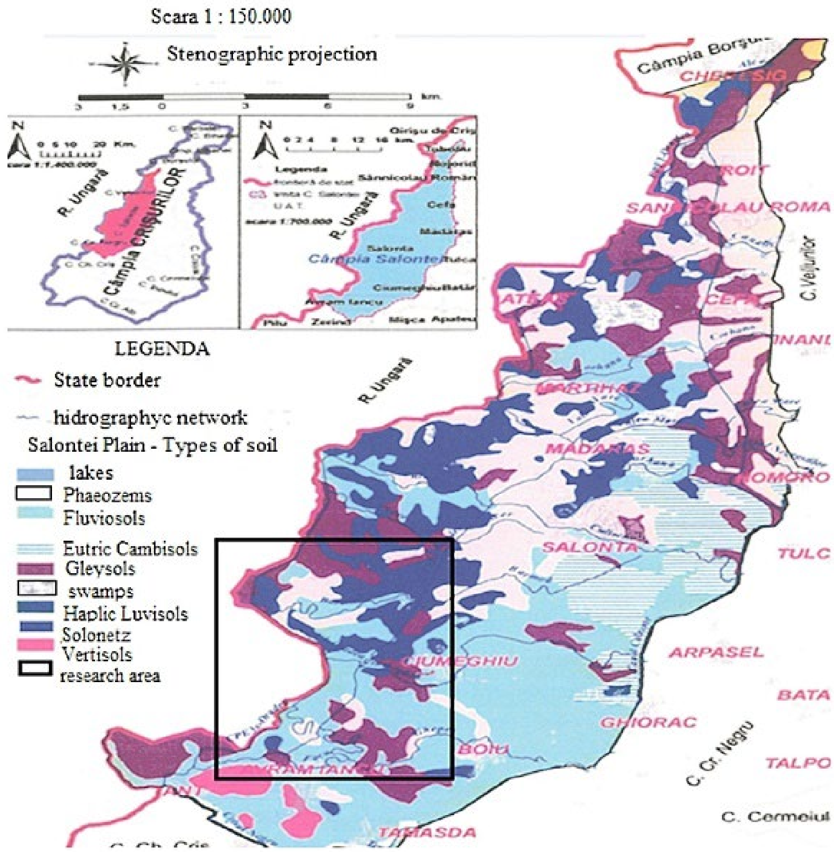


Figure 13. Map of the soils in the Salontei Plain (World Reference Base for Soil Resource—WRB—SR-1998).

The pedogenetic conditions of the studied area (Avram Iancu and Ciumeghiu) have led to the formation of the following soil types:

- Alluviosol, subtypes: typical, molic, gleic, batigleic, vertical.
- Faeoziom, subtypes: cambic, argic, cambic–gleic, cambic–batigleic, argic–gleic, argic–batigleic.
- Eutricambosol, subtypes: typical, molic, alluvial, batigleic.
- Preluvosol, subtypes: typical, molic, batigleic, vertical.
- Vertosol (small areas).
- Gleiosol, subtypes: typical, cambic, alluvial, molic, saline.
- Soloneț, subtypes: typical, batigleic, cambic, cambic–batigleic.

Due to the plain relief in the studied area, there are no special geomorphological problems that we need to consider.

2.5. Landslides

Risks associated with rainfall hazards, such as landslides, are also influenced by non-climatic factors such as population density, anthropogenic activity and land-use change.

The risk of landslides was analyzed using the European Map of Landslide Susceptibility (Figure 14). In the studied area, the risk is generally very low and low, with small portions of moderate.

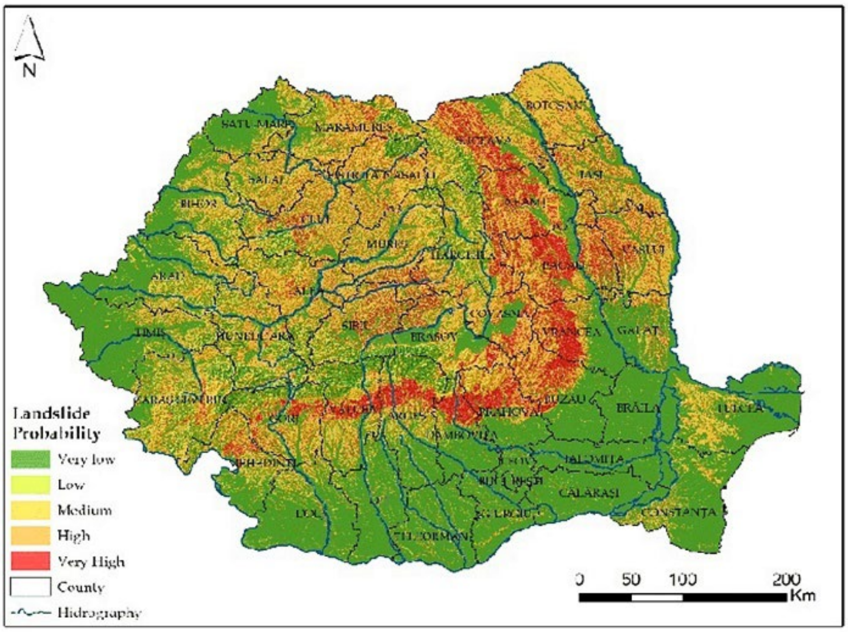


Figure 14. Risk of landslides.

2.6. Freeze—Defrost

Freezing is the most important winter climate phenomenon and is defined by a drop in air and soil temperature below 0 °C. Equally important is the frost regime.

Taking into account the available data, as well as the fact that the temperature generally shows an increasing trend, we consider that the current and future exposure of livestock farms to the freeze–thaw phenomenon is moderate, both under current and future conditions. In the studied area, the depth of frost is around 80 cm.

Figure 15 shows the frost depth zones in Romania.

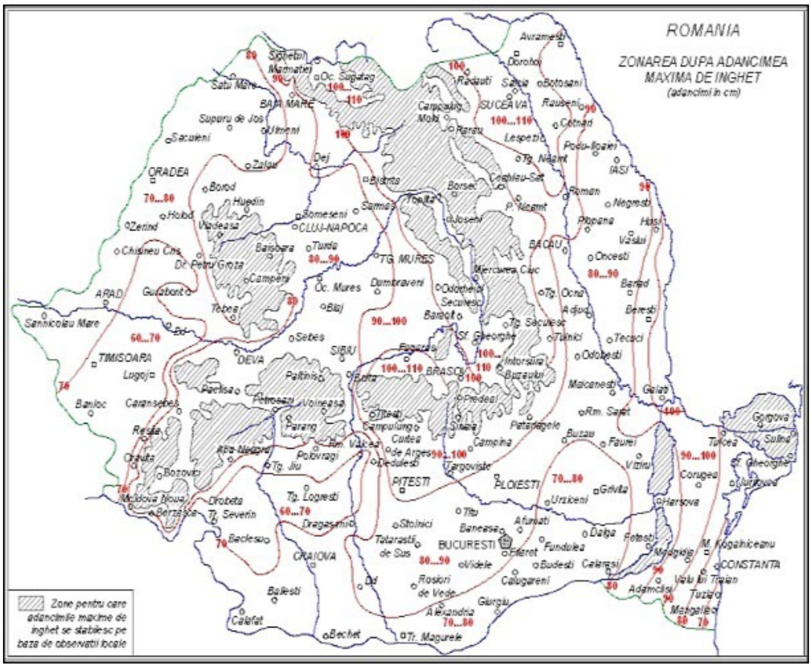


Figure 15. Frost depth zones.

2.7. Floods

Floods are a common natural disaster in Europe, and along with storms they are the most important natural hazard in Europe in terms of economic damage. Floods and floods caused by heavy rainfall with local manifestations are likely to become more frequent throughout Europe [10].

The current flood risk analysis was performed using the INHGA estimate. It is estimated that there is a high risk of flooding along the watercourses and the main tributaries of Crişul Negru.

The identified risk areas are largely confirmed by the hazard and flood risk maps available on the website of the National Administration of Romanian Waters and the extension of the flood zones identified in the Flood Risk Management Plan. No potentially significant flood risk areas were identified in the study area [17].

A flood hazard map of the study area for the scenarios with the three probabilities of occurrence (0.1%, 1%, 5%) is shown in Figure 16 [17]. The analysis of the flood risk map in the three occurrence scenarios indicates that the analyzed area becomes completely floodable in the 5% probability scenario.

Figure 16. Flood hazard map in the study area for the three production scenarios.

The risk of floods in Romania [10] will increase in the coming years. Future changes in flood risk for Europe's major rivers have been estimated using a hydrological model and a set of seven climate models. Figure 17 shows the projected changes for floods with a frequency of "one in a hundred years" between the reference period and three future time periods. Blue rivers show an increase in the magnitude of floods, and red rivers indicate a decrease. The study area is estimated to experience an increase in the magnitude of floods of between 20 and 30% by 2080.

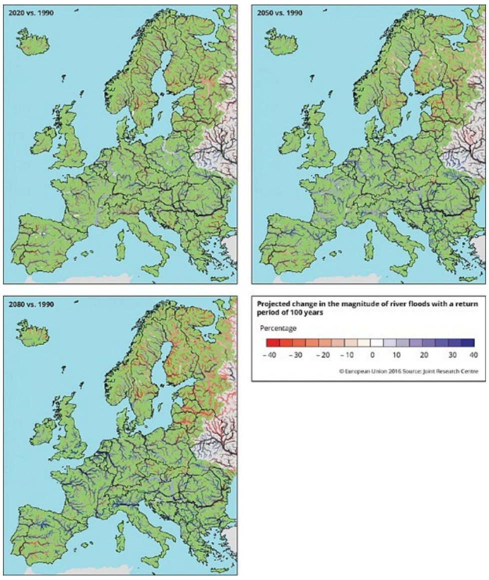


Figure 17. Forecasted changes in the magnitude of river floods over a 100-year recovery period.

2.8. Availability of Water Resources

Climate change introduces an additional element of uncertainty regarding the availability of water resources [10]. Romania's water resources are estimated at 127 billion cubic meters (MMC)/year, with river basins contributing 40 MMC and 87 MMC being available through the Danube basin. Groundwater potential is estimated at 10 MMC/year. The usable fraction of total water resources (surface and groundwater), as defined by the existing capacity to extract and use water, is 40 MMC/year. The total water requirement is 8 MMC/year.

The spatial distribution of groundwater bodies in the analyzed area is represented in Figure 18. The Crişuri hydrographic space has 788.4 million cubic meters of total water resources, of which 350.0 million cubic meters/year are usable resources [30].

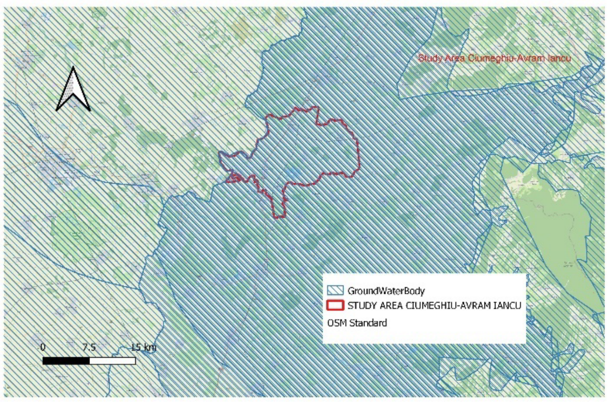


Figure 18. Groundwater bodies in the study area.

The Ciumeghiu–Avram Iancu area is located in the suburbs of Salonta and the alternation of permeable layers (sandy dust and gravel and boulder sands) allow for the rise of groundwater depending on variations in rainfall in the area. The groundwater was intercepted at a depth of 2.70 m and an ascending regime is provided to a depth of 1.60 m.

The Plain of Salon is a kind of "polder" surrounded on three sides by dams—in two directions by the Crişuri dam and to the east by the Collector Canal. The Collector Canal represents the hydrographic element specific to this plain, has a length of 61 km, starts from Crişul Repede (Tărian) where the potential flow is 6 mc/s and flows into Crişul Negru east of Tâmaşda, where it can reach 60 mc/s.

The streams coming from the east, especially Corhana and Culişer (which collect many others) are dammed over certain distances, while to the west their riverbeds have been deepened to drain the groundwater. The agricultural use of the land in the area determined the development of a network of drainage canals in the 1970s, which were tasked with draining the excess water.

The Crișuri basin is subject to an increasing frequency of extreme events, with rapid alternation between severe heatwave/severe drought and heavy rainfall/floods being more and more obvious. This phenomenon is predicted to continue in the future, based on climate scenarios for the time intervals 2011–2040 and 2021–2065 [30].

Global Aridity and PET databases were used to represent the aridity index (Figure 19) and potential evapotranspiration (Figure 20) in the study area [18]. The aridity index represents the ratio between the sum of the annual precipitation and the potential evapotranspiration. The values of the aridity index in the project area are between two ranges: 0.8–0.65 and 0.65–0.5, which puts it in an intermediate zone between the wet and semi-arid areas. Potential evapotranspiration is between 751–1000 mm/year in most of the study area.

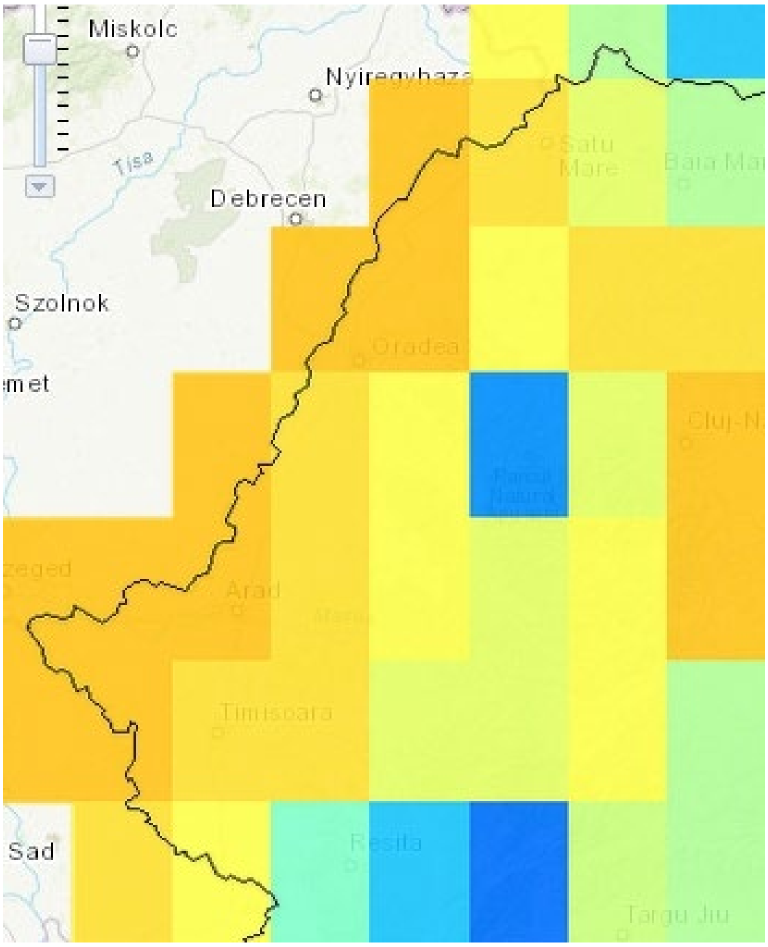


Figure 19. Aridity index in the project implementation area—estimated increases until 2065.

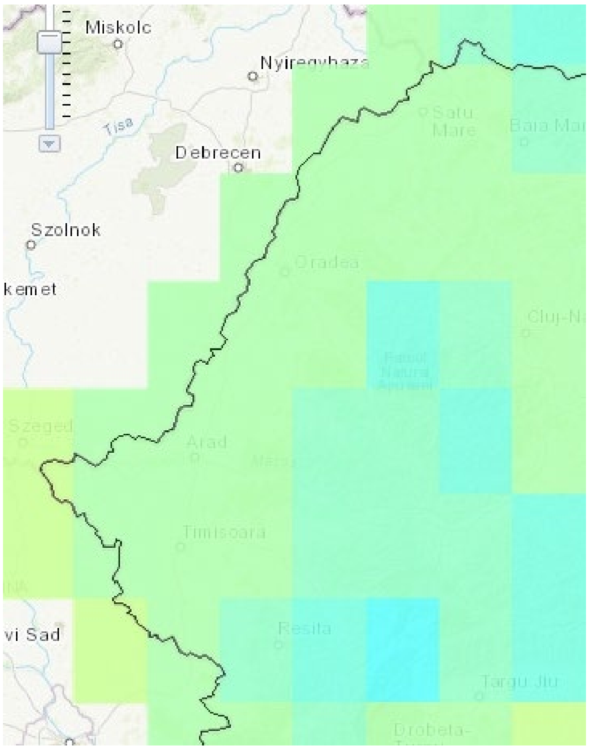


Figure 20. Potential annual evapotranspiration average in the project implementation area—estimated increases until 2065.

2.9. Desertification

Desertification is a complex phenomenon involving the gradual transformation of land with fertile soils into deserts, and it can be caused by climate change (severe and prolonged drought) or human activities (land overexploitation) [31].

Desertification is also a growing threat for Romania, as well as for the whole world. The trend of the evolution of average and maximum temperatures correlates with the evolution of the amount of precipitation, which indicates an increase in vulnerability to desertification in the studied area.

The predicted evolution of desertification risk and aridity index in the period 2071–2100 [32] compared to the period 1981–2010 [33,34] is shown in Figure 21.

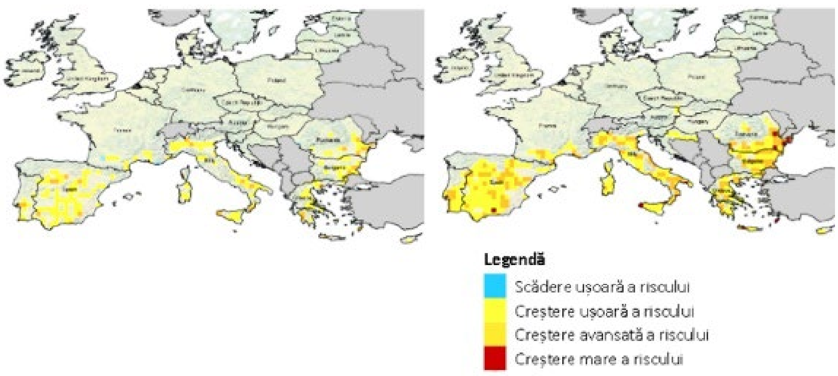


Figure 21. *Cont.*

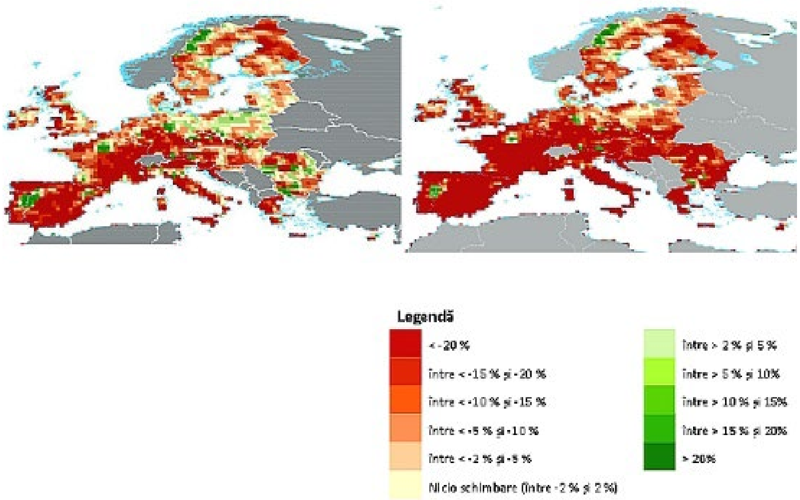


Figure 21. Predicted evolution of desertification risk based on the 2.4 °C scenario (CPR 4.5—(**left**)) and the 4.3 °C scenario (CPR 8.5—(**right**)) in the period 2071–2100 compared to the period 1981–2010.

The analysis of the desertification forecast in the two scenarios indicates that in both variants the agricultural surface of the analyzed area on which the mature manure from the activity of the zootechnical farms can be spread decreases. In the 2.4 °C scenario (CPR 4.5), the arable area in the studied area decreases by 5–10% to 13.216–13.950 ha. In the 4.3 °C scenario (CPR 8.5), it decreases by 10–15% to 12.481–13.216 ha.

2.10. Risk of Vegetation Fire

Climate patterns suggest warming, an increase in droughts, heat waves and dry spells in southern Europe [10]. From the point of view of the evolution of fire risk due to climate change, the factors that can determine its increase are the reduction of precipitation amounts and the increase in temperatures, as well as the presence of thunderstorms with electric discharges (natural cause of fires).

The species of trees found in the composition of the stands in the plain and hill areas do not have a high combustibility index, so under normal climatic and vegetation conditions, there is no risk of large fires. On the other hand, in mountainous areas, the composition of trees is dominated by coniferous species, which are characterized by high combustibility and even in normal climatic and vegetation conditions the risk of large fires is quite high, especially in the case of periods characterized by pedological and physiological drought [35]. Between 2021 and 2065, the risk of vegetation fires is estimated to be associated with increases in temperature and heat waves [24].

The HFI (Hybrid Forest Index) vegetation risk assessment is shown in Figure 22.

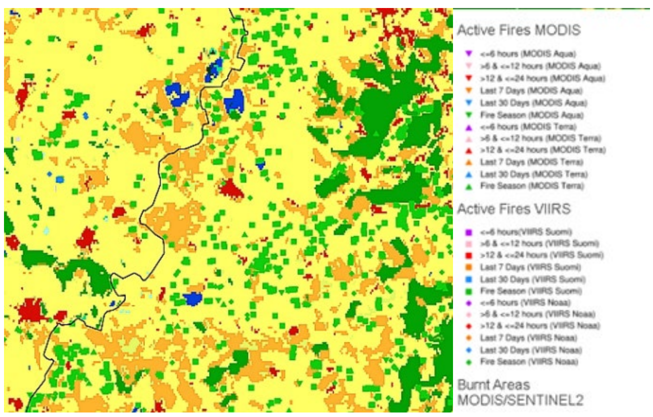


Figure 22. Potential fire hazard—HFI (Hybrid Fire Index).

Areas with a moderate risk of fire are associated with areas with a low water content of the plant mass. It can be seen that there is a low risk of present and future fire in the analyzed area.

3. Results

3.1. Sensitivity Analysis

Climate sensitivity has been identified for each of the components of livestock farms:

- Goods and processes: animals, fodder, water, halls, manure storage systems;
- Outings: sacrificial animals, eggs, young animals, manure;
- Transport networks: infrastructure elements (road superstructure, telecommunications systems, water distribution system, sewerage system, gas distribution system).

Each of these components has been included in the sensitivity classes presented in the previous section. The identification of the sensitivity of livestock farms in relation to climate variables is included in Table 12.

Table 12. Identifying the sensitivity of livestock farms in relation to climate variables.

Climate Variables	**Livestock Farms**		
	Goods and Processes	**Outings**	**Transport Networks**
	Primary effects		
Rising average temperature	3	2	1
Rising extreme temperatures	2	2	1
Changes in average rainfall	2	1	2
Changes in the amount of extreme rainfall	2	1	2
Average wind speed	1	1	1
Changes in maximum wind speed	1	1	1
Moisture	1	1	1
Solar radiation	1	1	1
	Secondary effects		
Hoses (including blizzard)	1	1	1
Floods	1	2	2
Desertification	2	2	1
Soil erosion	1	1	1
Vegetation fires	1	1	1
Landslides	1	1	1
Freeze–thaw	1	1	1
The legend:			
Climate sensitivity	Small (1)	Average (2)	High (3)

3.2. Exposure Assessment

Based on the analysis of the available information on climate change in the study area, an increasing trend of average annual temperatures, maximum temperatures and extreme rainfall, a differential trend of average annual decreasing trends and a decreasing trend of arable land for desertification precipitation were identified (Table 13).

Table 13. Summary of trends in major climate variables.

Climate Variable	Trend
Average annual temperature	
Extreme temperatures	
Average annual rainfall	
Extreme rainfall	
Wind speed	
Desertification	

Table 14 presents the results of the exposure assessment in the study area for both current and future climatic conditions.

Table 14. Assessment of the study area exposure in relation to climate variables.

Climate Variables	Exposure to Current Conditions		Exposure to Future Conditions	
		Primary effects		
Rising average temperature	1	In the period 1906–2005 in Romania, there was an increase in the average air temperature of 0.5 °C.	2	In the study area, it is possible that the air temperature in the period 2071–2100 will increase by 3–4 °C compared to the reference period of 1971–2000.
Rising extreme temperatures	2	Reducing the frequency of very low temperatures and increasing the frequency of very high temperatures. Significant trend of increasing the number of days with heat waves.	2	An increase in the maximum temperature of July by 4–5 °C for Bihor County. An increase in the January minimum temperature by 4–4.5 °C. Decreasing the duration and frequency of heat waves. The average annual number of days with episodes of heat waves in the period 2021–2065 compared to the period 1971–2000 will be lower by 0–0.02 days/year. Increase in the number of tropical nights by up to 6 nights/year in the interval 2021–2065 compared to the reference interval of 1971–2000.
Changes in average rainfall	1	General tendency of decreasing annual precipitation quantities in Romania in the period 1901–2000.	2	An increase in the annual precipitation quantities compared to the current level by 0–10 mm/year in Bihor County.
Changes in the amount of extreme rainfall	2	Extreme rainfall with values of 15–20 mm/day.	2	Stagnation of extreme precipitation in Bihor County. Increasing the number of days with rainfall exceeding 20 l/mp in 2021–2065 by 1.5 days.
Average wind speed	1	The average annual wind speed in the study area is generally 2–4 m/s. No clear trends were identified.	1	Reduced increase in average annual wind speed of 1 m/s.
Changes in maximum wind speed	0	No clear trends were identified.	1	Slight increase in the frequency of strong winds (with speeds greater than 10 m/s)—1–2% compared to the current situation.

Table 14. *Cont.*

Climate Variables	Exposure to Current Conditions		Exposure to Future Conditions	
		Secondary effects		
Availability of Water Resources/Drought	1	Crisuri River Basin is subject to the phenomenon of hydrological drought.	2	The intensification of extreme phenomena (extreme temperatures, heat waves, extreme rainfall, periods of drought) can lead to seasonal variations in water resources and an increase in pressure on them
Soil Erosion	0	Natural erosion phenomena are not present in the analyzed area. There are only areas marked by weak erosion processes that are influenced by water regimes, crop structures, soil processing technology, other human activities (e.g., overgrazing), etc.	1	Increasing variation in the structure and intensity of precipitation can make soils more susceptible to water erosion and increasing aridity can make finely textured soils more vulnerable to wind erosion. However, quantitative estimates are not available.
Landslides	0	Low risk of landslides in the analyzed area.	1	Possible intensification of this phenomenon.
Extreme storms/tornadoes	0	No clear trends were identified.	0	No clear trends were identified.
Floods	1	An analysis of the current flood risk map in the 3 occurrence scenarios indicates that the analyzed area will become completely floodable in the 5% scenario.	2	The study area estimates an increase in the magnitude of floods with values between 20 and 30% by 2080.
Desertification	0	No clear elements have been reported so far to highlight desertified areas.	2	The analysis of the desertification forecast in the two scenarios indicates that in both variants the agricultural surface of the analyzed area on which the mature manure from the activity of the zootechnical farms can be spread decreases.
Risk of Vegetation Fire	0	The territory of the analyzed area is characterized by a low risk of present fire.	1	The territory of the analyzed area is characterized by a low risk of fire in the future.

3.3. Vulnerability Analysis

The vulnerability analysis was performed using the matrix presented in Section 2 as a result of the correlation between sensitivity and exposure. The results of the analysis of the vulnerability of the project to climate change, both under current and future conditions, are presented below. Table 15 shows the current vulnerability of zones in relation to climate variables.

Table 16 identifies the vulnerability under future conditions in relation to climate variables.

Table 15. Current vulnerabilities of animal husbandry activity in relation to climate variables.

Climate Variable	Sensitivity			Exposure to Current Conditions	Vulnerability to Current Conditions		
	Input	Outputs	Transport/ Infrastructure		Input	Outputs	Transport/ Infrastructure
				Primary effects			
Rising average temperature	2	2	1	1	2	2	1
Rising extreme temperatures	1	1	1	1	1	1	1

Table 15. *Cont.*

Climate Variable	**Sensitivity**			**Exposure to Current Conditions**	**Vulnerability to Current Conditions**		
	Input	**Outputs**	**Transport/ Infrastructure**		**Input**	**Outputs**	**Transport/ Infrastructure**
Changes in average rainfall	2	2	1	1	2	2	1
Changes in the amount of extreme rainfall		1	1	1	1	1	1
Average wind speed		1	1			1	1
Changes in maximum wind speed			1			1	1
Secondary effects							
Availability of Water Resources/Drought	2	2	2	1	2	2	2
Soil Erosion		1	1			1	1
Extreme storms/tornadoes			1				1
Floods	1	2	1	1	1	2	1
Desertification	2	2	1	1	1	1	1
Risk of Vegetation Fire		1	1			1	1
The Legend:							
Sensitivity	without sensitivity (0)			small (1)	medium (2)	high (3)	
Exposure	no exposure (0)			small (1)	medium (2)	high (3)	
Vulnerability	no vulnerability (0)			small (1)	medium (2)	high (3)	

Table 16. Identifying vulnerability to future project conditions in relation to climate variables.

Climate Variable	**Sensitivity**			**Exposure to Current Conditions**	**Vulnerability to Future Conditions**		
	Input	**Outputs**	**Transport/ Infrastructure**		**Input**	**Outputs**	**Transport/ Infrastructure**
Primary effects							
Rising average temperature	2	2	1	3	3	3	3
Rising extreme temperatures	1	1	1	2	2	2	2
Changes in average rainfall	2	2	1	2	2	2	2
Changes in the amount of extreme rainfall		1	1	1	1	1	1
Average wind speed		1	1	1	1	1	1
Changes in maximum wind speed		1	1	1	1	1	1
Secondary effects							
Availability of Water Resources/Drought	2	2	2	3	3	3	2
Soil Erosion		1	1	2	1	2	2
Extreme storms/tornadoes			1	1	1	1	1
Floods	1	2	1	3	2	3	2
Desertification	2	2	1	3		3	2
Risk of Vegetation Fire		1	1	2	1	1	2
The Legend							
Sensitivity	without sensitivity (0)		small (1)		medium (2)		high (3)
Exposure	no exposure (0)		small (1)		medium (2)		high (3)
Vulnerability	no vulnerability (0)		small (1)		medium (2)		high (3)

Climate variables that could generate a moderate vulnerability include changes in average temperature, changes in extreme temperatures, changes in average rainfall, changes in extreme rainfall, floods, desertification and availability of water resources/drought.

3.4. Risk Assessment

The main climatic variables that can influence the activity of raising animals are temperature and precipitation, along with their secondary effects, including increases in average temperature, increases in extreme temperatures, changes in average rainfall, changes in extreme rainfall, floods, availability of water resources, drought and desertification. The main impacts on livestock activity generated by the identified trends of these climate variables are presented in Table 17.

Table 17. Possible impacts on livestock farms caused by climate change trends.

Climate Variable	Trends in Climate Variable	Possible Impacts/Consequences on Livestock Farms
Temperature	Temperature change (annual average, extreme), availability of water resources, drought and desertification	Increased operating costs; Decreasing the usable land area for manure spreading; Changing the conditions of emission and dispersion in the atmosphere of air pollutants resulting from the activity of increasing manure (NH_3, NO_2, NMVOC, TSP, PM_{10}, $PM_{2.5}$);
Rainfall	Changing average annual rainfall and extreme rainfall, floods, availability of water resources, drought	Exceeding the designed capacity of the infrastructure for rainwater collection and pre-treatment; Exceeding the designed capacity of the manure storage infrastructure; Flooding of certain parts of the road with consequences on the supply/delivery chain; Reducing the lifespan of animal husbandry farms; Increasing operating costs (repair costs, emergency services).

The risk assessment for the identified livestock farms with high and medium vulnerability is presented in Table 18. Table 19 includes the risk assessment matrix for the components that cause medium and high vulnerability of livestock farms.

Table 18. Risk assessment matrix for high and medium vulnerability animal husbandry components.

Compound	Risk	Risk Score		
		Probability (P)	Magnitude (M)	P × M
High vulnerability for livestock farms	Rising average temperature	3 The data show a clear trend of increasing temperatures and periods of drought in the study area	2 The consequences may be negative and adaptation measures may be envisaged	6
	Availability of Water Resources/Drought	3 The data indicate a clear trend of intensification of extreme phenomena (extreme temperatures, heat waves, extreme rainfall, periods of drought) leading to seasonal variations in water resources and increasing pressure on them	2 The consequences may be negative and adaptation measures may be envisaged	6
	Floods	3 An increase in the intensity and frequency of floods is possible due to the increase in the frequency of episodes with extreme rainfall	2 The consequences may be negative and adaptation measures may be envisaged	6
	Desertification	3 The data show a declining trend in agricultural area in the area	2 The consequences can be negative and adaptation measures can be considered by identifying new waste management techniques	6

Table 18. *Cont.*

Compound	Risk	Risk Score		
		Probability (P)	**Magnitude (M)**	**P × M**
Medium vulnerability for livestock farms	Rising extreme temperatures	2 The data show a clear trend of increasing temperatures and the number of dry days in the analyzed area	2 The consequences may be negative and adaptation measures may be envisaged	4
	Changes in average rainfall	2 The data estimate a trend of increasing extreme rainfall and decreasing average rainfall	2 The consequences may be negative and adaptation measures may be envisaged	4
	Soil Erosion	2 Increased variation in precipitation structure and intensity may make soils more susceptible to water erosion, and increased aridity may make finely textured soils more vulnerable to wind erosion	1 Event with minor negative consequences on normal operations	2
	Risk of Vegetation Fire	2 The data do not show a clear trend, but an increase in the risk of vegetation fires is possible due to rising temperatures and heat waves	1 Event with minor negative consequences on normal operations	2

Table 19. Risk assessment matrix according to the components that can cause medium and high vulnerability of livestock farms.

		Magnitude of Consequences (M)		
		1	**2**	**3**
Probability of occurrence (P)	1	1	1	1
	2	Soil Erosion Risk of Vegetation Fire	Rising extreme temperatures Changes in average rainfall	2
	3	1	Rising average temperature Availability of water resources/drought Floods Desertification	3

4. Discussion

An analysis of the existing data on climate change shows that at the level of the studied area there is a tendency to increase average annual temperatures, increase maximum temperatures and extreme rainfall, decrease average annual rainfall and increase/reduce wind speed. The area is at risk of flooding in the 1% insurance scenario and is at risk of desertification. The analysis of the desertification forecast indicated in both analyzed scenarios the fact that the agricultural area of the analyzed area is reduced by a maximum of 15%. Under these conditions, the agricultural area of the territorial administrative units that can be used for manure spreading (the method used by all farmers in the area for manure management) decreases to 12,481 ha.

The vulnerability analysis indicated that the climate variables that could generate a high vulnerability of zootechnical activities in the future include changes in average temperature, changes in extreme temperatures, changes in average rainfall, changes in extreme rainfall, floods, desertification and availability of water resources/drought. The analysis of the vulnerability of the animal breeding activity in the described perimeter leads to the vulnerability of the zootechnical activity in the area and consequently, to the economic vulnerability of the Ciumeghiu and Avram Iancu territorial administrative units, which are already economically disadvantaged areas.

Based on the data available at this time and the risk analysis methodology applied, the following were identified: moderate risks associated with rising extreme temperatures, changes in average rainfall, rising average temperature, availability of water resources/drought, floods and desertification, and low risks associated with soil erosion and the risk of vegetation fire. The identified risks related to animal husbandry under the influence of climate change indicate the need for the strategies and development plans of the two administrative-territorial units to take into account the constraints imposed by climate change. It is recommended that the analysis of opportunities for the development of economic activities in general, and zootechnical activities in particular, be carried out in accordance with these constraints and that local authorities stimulate or even support existing or future farms in the process of optimizing their methods, including manure management and the implementation of technological changes that reduce the impact of the zootechnical activity on climate change. It would be appropriate for economic operators managing livestock activities to be financially supported to create energy sources that use manure as fuel and to build an anaerobic digester in the area to reduce the land area required for manure spreading.

5. Conclusions

An analysis of the existing data on climate change looked at the effects induced by climate change in accordance with the official forecasts analyzed in two scenarios of the climatic evolution of the area. The analysis of the desertification forecast indicated in both analyzed scenarios that the agricultural area of the analyzed area will be reduced by a maximum of 15% so that the area usable by farmers for spreading manure will decrease to as low as 12.481 ha.

Under these conditions, the local public administrations can no longer practically grant construction permits for any more animals than for which they have granted permits so far. However, it must be kept in mind that the zootechnical development of the area must be carried out while taking into account the impact of atmospheric emissions resulting from animal husbandry and the level of odors generated by zootechnical activities.

Climate change will affect animal production and, consequently, food security. In these conditions, it is important that public authorities take into account in their development strategies the conclusions of specialized studies. At the same time, it would be useful to develop a comprehensive view at the local level of the costs, time and effort required for producers to optimize their animal husbandry technologies, conserve the environment and possibly acquire support from local communities to ensure the sustainability of their activities.

We note that the interactions between climate change and animal production are not yet well understood, despite the large volume of existing research, so we aim to develop our research by increasing the number of factors taken into account in the evaluation.

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