Relevance of Studies on Natural Risks in Urban Planning and Territorial Management Operations. Case Study - Municipality of Carei, Satu Mare County

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Abstract: *The study analyses the importance of integrating natural risks into urban planning and territorial management processes, with application to the municipality of Carei. The main categories of risks are highlighted: climatological (heatwaves, drought, hail), edaphic (soil degradation), hydrological (groundwater pollution), atmospheric (pollution), and seismic (low risk). The document emphasizes that the effects of climate change and the pressure of anthropogenic activities, necessitating prevention, adaptation, and protection measures affect the municipality of Carei. The study provides data from fieldwork and official sources (ANM, ANPM), also presenting strategic proposals for effective community response. The conclusion underlines the importance of risk-based spatial planning to support sustainable, safe, and responsible development.*

Keywords: *risks; urbanism; climate change; Carei*

1. Introduction

Studies on natural and anthropogenic risks are essential in urban planning and territorial development operations due to their direct impact on the safety, sustainability, and efficiency of spatial development. The relevance of these studies can be seen from several perspectives:

- *disaster prevention and reducing community vulnerability;*

Identifying risks such as earthquakes, floods, landslides, wildfires or industrial pollution helps avoid development in hazardous areas. Urban planning can include

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adaptation measures (e.g., levees, reinforcements, buffer zones) and strict building regulations in high-risk areas.

- *strategic and sustainable planning;*

Risk studies contribute to a coherent vision of spatial development: where construction is possible, what type of infrastructure is necessary, and which areas need to be preserved. They enable the creation of urban plans with increased resilience to climate change and hazards.

- *protection of life and property;*
- *fulfillment of legislative framework;*

In Romania and the EU, there are legal obligations to integrate risk assessments into urban planning documentation (PUZ, PUG, etc.). Urban documentation must include risk analyses as part of the environmental report or territorial impact assessment.

- *community awareness and responsibility;*

Risk studies help authorities and citizens understand the dangers present in the area. An informed community is better prepared to react and adapt in the event of a hazardous occurrence.

- *investment attraction and economic sustainability*

These types of studies fall under the category of analytical foundational studies, in accordance with the provisions of Order no. 233/2016 for the approval of the Methodological Norms for the application of Law no. 350/2001 regarding territorial planning and urbanism, as well as for the preparation and updating of urban planning documentation, amended by Order no. 3.494/2020. They must comply with the requirements of Article 20 para. 3, letter a (iv, v), and meet the structural criteria mentioned in Article 20 para. 4, letters a-e and para. 5 of the aforementioned Order 233/2016.

However, it should be emphasized that, unlike other foundational studies (e.g., topographic, historical, sociological, etc.), a study on landscapes, risks and environmental protection has a major particularity, namely a systemic approach based on a supra-local vision, often extending beyond strictly administrative boundaries, since environmental issues do not stop at administrative limits and do not consider borders or conventional delimitations. Therefore, such works rely on publicly available information (i.e.public reporting and information documents from the National Environmental Protection Agency (ANPM), strategic documents provided by interested municipalities, periodic reports from the National Water Agency, and the National Meteorological Agency (ANM). Based on these a synthesis of relevant information on the environment, risks, and climate change is made, as well as on a series of field observations and measurements.

The processing of information is also adapted and based on the requirements formulated in the relevant normative acts for environmental and climate change issues, including:

- European directives and regulations (Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ("European Climate Law");
- Law no. 265 of June 29, 2006 (updated) approving Government Emergency Ordinance no. 195/2005 on environmental protection;
- Law 117/2013 approving GEO 58/2012 on amending certain normative acts in the field of environmental and forest protection;
- Law no. 292 of December 3, 2018, on the environmental impact assessment of certain public and private projects;
- Annual reports on the state of the environment by ANPM;
- Risk Analysis and Coverage Plans (PAAR);
- County waste management plans;
- Flood Risk Management Plans at the level of Water Basin Administrations;
- Development strategies of the targeted counties;
- Information published on the websites of environmental protection agencies;
- Other relevant legislative acts.

This study constitutes an applied analytical and foundational exercise regarding natural risks in relation to the requirements imposed by the General Urban Plan of the municipality of Carei, Satu Mare County.

2. Location of the Studied Area

To determine the location of the studied area, three categories of positioning relevant for landscape analysis, risk assessment, and the impact of climate change were used:

mathematical positioning (latitude/longitude), physical-geographical location, and administrative position (fig. 1a). Each of these influences, to varying degrees, the state of the environment within the area of interest, contributing to the dynamics of environmental quality both on a local and regional scale.

From a mathematical positioning standpoint, the city of Carei is located at the intersection of 47°41′ north latitude and 22°28′ east longitude (according to Google Earth), which places it at relatively equal distances from the major European latitudinal climate zones. It is also situated between the influences of the western-Atlantic and Baltic-Nordic systems, as well as macro-continental topoclimates that play a role in the west-east circulation of air masses.

Physically and geographically, the city of Carei has an eccentric position in relation to the major natural units of the Romanian territory. It is located outside the Carpathian arc, in the north-west of the country, at the contact zone between two major subunits of the Western Plain: the Crişurilor Plain and, predominantly, the Someș Plain (via the Ecedea and Crasna plains) (fig. 1 b).

Its mathematical and geographical position explains most of the meteorological and climatic phenomena determined by the main baric centres of the European natural synoptic region (Azores High, Icelandic Low, Euro-Siberian Anticyclone, Mediterranean Lows), as well as the formation of the local topo-climate.

From an administrative standpoint, in relation to surrounding territorial units, Carei borders the following communes: Cămin and Căpleni to the north; Urziceni to the northwest; Foieni and Sanislău to the west; Petrești to the southwest; Tiream to the south; Căuaș to the southeast; and Moftin to the east (fig.1c).

Located at the intersection of national road DN 1F (Cluj–Urziceni) and European route E 671 (Timişoara–Livada), the city of Carei serves as an important and frequently traveled road junction.

Carei is situated approximately 35 kilometres from Satu Mare, the administrative centre of the county.

Although administrative position and distance from major cities or transportation axes may appear to be of limited direct relevance for environmental, risk, or climate change analysis, they can often provide key insights into the dynamics of certain environmental factors. This is closely linked to human activities and the economic characteristics of the neighbouring administrative-territorial units, given that natural dynamics do not recognize administrative boundaries or borders.

3. Critical Analysis of the Current Situation

The local diagnosis is the first step in any analytical approach. In line with the purpose of this study, it aims to identify the current state of affairs and any dysfunctions, based on which possible solutions for their elimination or reduction will be proposed, along with potential future development scenarios.

However, we must reiterate that a study focused on landscapes, risks, and environmental protection involves a major particularity—namely, a supra-local perspective that systematically transcends strictly administrative boundaries. This is because environmental issues, landscapes, risks, or climate change have a macro-spatial character; they do not stop at the borders of administrative-territorial units (ATUs) and do not consider conventional boundaries. Therefore, throughout this study, the analytical approach will oscillate between local examples and details and regional contextualization that enable a better understanding of large systemic mechanisms.

3.1. The State and Quality of Environmental Factors

Assessing the current state of environmental factors in the territory of the Carei ATU is an important stage in establishing the objectives and priorities of the General Urban Plan regarding environmental protection and conservation. Sustainable environmental management and the integration of environmental objectives into all strategies, plans, and projects targeting the complex development of the territory require an objective diagnosis of the dysfunctions related to environmental quality. The quality of environmental factors results from the interdependencies established between their components and human activity.

3.1.1. Air Quality

Various types of gases, droplets, and vapours that reduce air quality cause air pollution in the municipality of Carei. The most well known gaseous pollutants are CO, CO_2, and nitrogen oxides. These chemical compounds may originate from various reactions, with the main local cause being the combustion of fossil fuels and road vehicles. Carbon monoxide (CO) is an extremely toxic air pollutant—colourless, odourless, and tasteless—produced by the incomplete combustion of fossil fuels such as gasoline, natural gas, oil, coal, and wood. In Carei, the largest anthropogenic source of CO is vehicle emissions, specifically exhaust gases.

In addition to gaseous pollutants, the atmosphere may also be polluted by particles from various sources. These particles (in suspension, fluid, or solid state) vary in composition and size and are often referred to as "aerosols." They are most commonly known as "particulate matter" (abbreviated as PM).

This "floating dust" can be classified based on its aerodynamic diameter. Particulate matter such as PM10, PM2.5, PM1, and PM0 are defined as particles with aerodynamic diameters smaller than 10, 2.5, 1, and 0.1 µm, respectively. PM10 and PM2.5 often come from different emission sources and have different chemical compositions. Emissions from the burning of gasoline, oil, diesel, or wood produce much of the PM2.5 outdoor air pollution. PM10 also includes dust from construction sites, landfills, and agricultural activities, as well as particles resulting from fires, waste burning, industrial sources, wind-blown dust from open lands, pollen, or bacterial fragments.

To monitor air quality, current recordings from the automatic station SM 2 are analysed. This suburban/traffic-type station is located in Carei, on Someșului Street no. 15, at coordinates 47.6897278° N / 22.4584999° E, elevation 129.00 m. The station monitors values for 12 pollutant parameters: benzene, ethylbenzene, CO, m-xylene, NO, NO_2, NO_x, o-xylene, p-xylene, SO_2, toluene, and PM10, as well as seven meteorological and climatic parameters: pressure, solar radiation, temperature, precipitation, humidity, wind speed, and wind direction.

The analysis of the data recorded by the automatic air quality monitoring stations has revealed the following aspects:

➤ Sulphur Dioxide (SO_2)

Potential sources in Carei are:

- Natural sources: bacterial fermentation in marshy areas, oxidation of sulphur-containing gases resulting from biomass decomposition.
- Anthropogenic sources: heating systems that do not use natural gas, thermal power plants, and to a lesser extent, emissions from diesel engines.

In 2021, the automatic monitoring stations did not record any exceedance of the hourly limit value of 350 $\mu g/m^3$, according to Law 104/2011. At the SM2 station in Carei, the data capture rate was 100%, with an annual average of 8.68 $\mu g/m^3$ — very low values.

➤ Nitrogen Oxides NOx (NO / NO_2)

Potential sources in Carei are:

- Anthropogenic sources: Nitrogen oxides are formed during combustion when fuels are burned at high temperatures. Most commonly, they are the result of road traffic, industrial activities, and electricity production. Nitrogen oxides contribute to the formation of smog, acid rain, deterioration of water quality, greenhouse effect, and reduced visibility in urban areas. Nitrogen dioxide is known to be a highly toxic gas for both humans and animals (its toxicity level is four times higher than that of nitric oxide). Exposure to high concentrations can be fatal, while lower concentrations affect lung tissue. At station SM2, the annual average was 13.50 μg/m^3, with a data capture rate of 100%.

➤ Carbon Monoxide (CO)

Carbon monoxide is primarily formed by the incomplete combustion of fossil fuels. Other anthropogenic sources include road and railway traffic. CO can accumulate to dangerous levels, especially during atmospheric calm periods in winter and spring (as it is chemically more stable at low temperatures), when fossil fuel combustion is at its peak.

At SM2, data capture was 100%, with an annual average value of 0.77 μg/m^3.

➤ Benzene

90% of ambient air benzene originates from road traffic. The remaining 10% comes from fuel evaporation during storage and distribution.

Health effects: Benzene is a carcinogenic substance, classified as Group A1 (known human carcinogen). It has harmful effects on the central nervous system. In Carei, the SM2 station reported an annual average value of 2.37 μg/m^3 with a data capture of 93.15%. This is below the annual limit value of 5 μg/m^3 for human health protection.

➤ Particle Matter PM10 and PM2.5

These represent a complex mixture of very small solid particles and liquid droplets. Local natural sources: soil erosion, dust and sand storms, pollen dispersion. Anthropogenic sources: industrial activity, residential heating, thermal power plants. Road traffic also contributes to particulate pollution, both from tire abrasion and incomplete combustion.

Particle size is directly linked to their potential to cause harm. Particles with an aerodynamic diameter of less than 10 micrometres can pass through the nose and throat and reach the pulmonary alveoli, causing inflammation and poisoning. Especially vulnerable are individuals with cardiovascular and respiratory diseases, children, the elderly, and those with asthma.

In the city of Carei, SM2 reported:

- Nephelometry data capture: 98.63%, with an annual average of 18.58 μg/m³.
- Gravimetric analysis: 98.63% data capture, annual average of 23.10 μg/m³ (limit value: 50 μg/m³).

This limit exceeded in 2021. The exceedances were attributed to domestic heating, burning of plant waste from households, and meteorological conditions such as atmospheric inversion, which prevents smoke dispersion. Gravimetric analysis of PM10 particles recorded 24 exceedances of the daily limit values, with the maximum daily average reaching 83.9 μg/m³.

In the observation period between March 25 and April 25, 2025, none of the parameters recorded exceeded the maximum allowed values. General emission indices were consistently at level 1 ("good"), although valid data for PM10 was missing.

Summary of Air Quality Monitoring Data:

- Most parameters (SO_2 and NO_2) remained within permissible limits, posing no major health risk, with levels below regulatory thresholds.
- PM10 particles did exceed daily limit values at the SM2 suburban/traffic-type station. Despite the diminished industrial contribution, urban areas continue to face particulate issues, mainly due to:
  - Road traffic;
  - Domestic heating;
  - Inadequate plant waste management (open burning) These exceedances were especially frequent in autumn-winter, particularly in the Grădini neighborhood.
- A strong seasonal variation was observed, closely linked to weather conditions and the nature and intensity of human activities:
  - Lowest pollution levels in summer months (July);
  - Highest pollution levels during winter months.

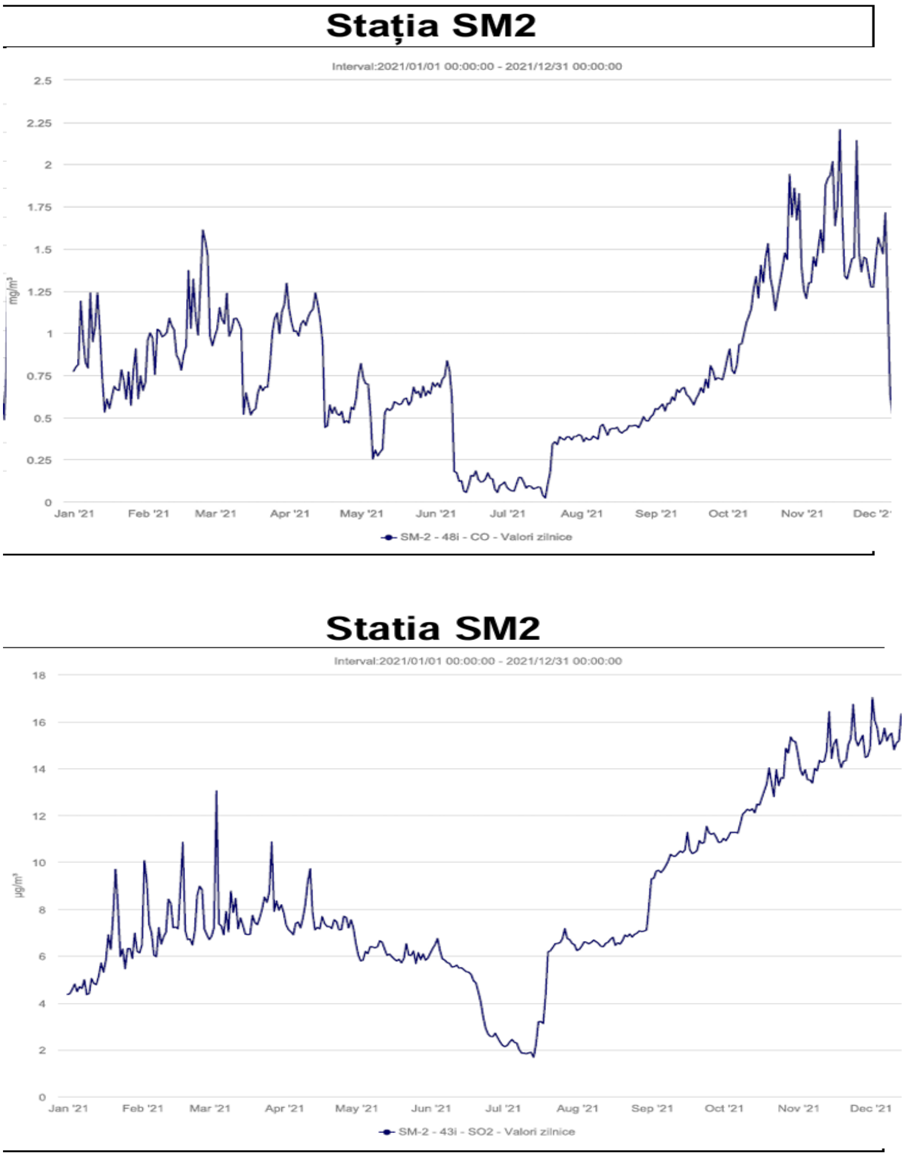


Figure 1. Seasonal variation chart of pollutant concentrations

On the other hand, another source of air quality information and monitoring is the AQI laboratory network. To easily communicate air pollution levels, governments and academic institutions use an indicator known as the Air Quality Index (AQI). The more polluted the air is, the higher the index value—meaning a larger portion of the population may be susceptible to experiencing negative effects from pollution, whether short-term or long-term health impacts.

Thus, the analysis of data recorded by the platform revealed that, overall, the city of Carei shows a relatively good annual average in terms of air quality.

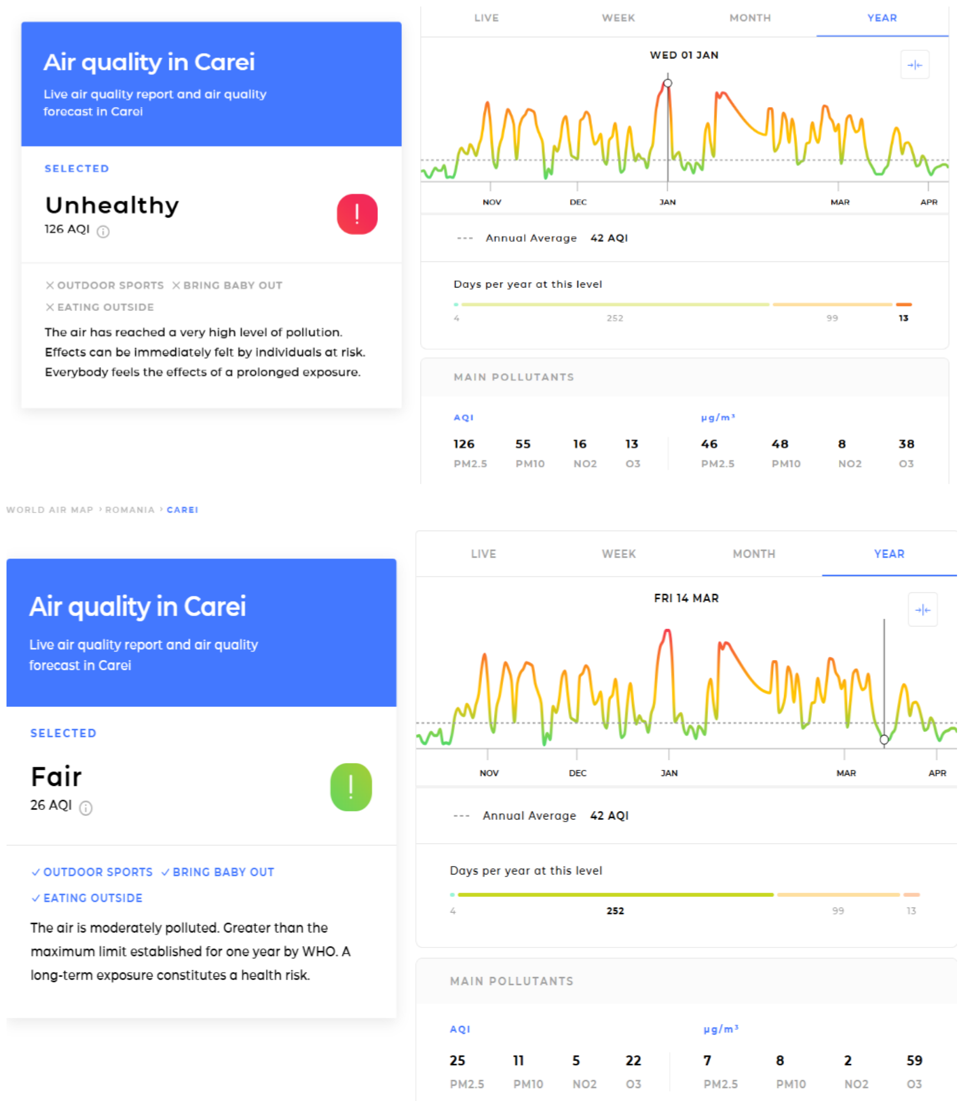


Figure 2. Comparative air quality situation in Carei on two different days (January 1, 2025, April 1, 2025)

Nevertheless, it has been observed that, although the air quality in the city of Carei remains within acceptable limits most of the time, there are periods when it shows significant variations that may pose a risk to vulnerable residents. For example, on January 1st, 2025, the pollution index was very high, with the monitoring platform issuing a warning by labelling the air quality as "unhealthy" for the general population.

3.1.2. Edaphic Factors. Current Quality of Soil and Subsoil

Edaphic factors refer to the soil layer, including its physical, chemical, and biological properties. Soil is generally more a product of climatic evolution than a factor in itself. However, under certain weather and climate conditions – such as extreme drought, dust storms, or excessive precipitation – it can amplify specific climatic characteristics.

In the administrative territory of Carei, over 94% of the land consists of soils classified as Class I and II in terms of agricultural suitability (such as cambic chernozems and argiluvial chernozems). Nevertheless, some areas feature soils with strong gleization, salinization, high permeability, and low humus content.

Soil plays a vital role in sustaining life and has the capacity to regenerate, filter, absorb, and transform pollutants. While air and water act as vectors for pollutant transmission, soil serves as the main medium of accumulation. Soil contamination may result from:

- the deposition of airborne dust and toxic gases brought down by precipitation;
- excessive use of herbicides, insecticides, fungicides, and chemical fertilizers;
- improper waste disposal practices.

These factors can lead to contaminated plants, which in turn may become a source of pollution for animals and humans. According to data from ANPM and OSPA Satu Mare, soil degradation processes have intensified over the last decades.

The main soil degradation processes observed in Carei include:

- surface erosion;
- degradation of organic matter;
- chemical contamination;
- salinization;
- compaction;
- loss of soil biodiversity;
- removal from agricultural use;
- flooding.

Although these processes are not currently at alarming levels, preventive measures are still necessary, particularly since some residents consider soil pollution to be the most serious and visible environmental issue in certain parts of the city.

3.1.3. Hydrological Factors

There are no major surface watercourses within the administrative boundaries of Carei. In the north, there are several tributaries of the Crasna River (Valea Mare, Valea Valadon, Valea Bobald), and in the south, tributaries of the Ier River (Valea Barnodului, Valea Vestigat). These are intermittent streams, which dry up in summer and display a torrential nature during heavy rainfall.

Given these characteristics, none of the watercourses are systematically monitored, and no data on water quality is mentioned in the AJPM environmental report for Satu Mare County.

On the other hand, groundwater sources face a higher risk of pollution, especially from agricultural point sources, including:

- semi-liquid and liquid animal waste;
- solid manure;
- silage effluent;
- untreated or poorly treated wastewater;
- various unregulated runoff.

Although phosphate pollution is typically limited due to the low mobility of phosphorus in soil, the risk increases when phosphate-based fertilizers are applied excessively over many years, particularly on sandy, highly permeable soils, which allow nutrients to seep through without being absorbed.

In addition, semi-independent housing developments (with private wells and septic tanks) contribute significantly to groundwater pollution and environmental imbalance. A high density of private wells and on-site sanitation systems can threaten aquifer quality, potentially causing ecological accidents affecting broader areas.

In terms of natural environmental factors, the city of Carei generally falls within acceptable parameters, with any exceedances being isolated and accidental. However, the persistence of certain local pollution sources, combined with seasonal climate variability, highlights the importance of constant monitoring and proactive environmental protection, especially regarding soil management and groundwater quality.

4. Categories of risks in the Municipality of Carei

The identification and description of risks within the territory of the municipality of Carei is part of the systemic diagnostic and forecasting process in both ecological and societal terms. Although risk analysis is a long-standing topic, it has only relatively recently become a focus in urban planning in Romania, primarily due to the increasing frequency of phenomena that can seriously disrupt the balance of a settlement at a given moment.

Risk is an abstract and sometimes ambiguous concept, with multiple meanings depending on the field in which it is used. In urban planning, three key concepts are directly associated with risk (Crichtob, 1999).

Although governed by laws, many natural phenomena and processes still maintain a random character — they occur unpredictably and thus fall within the scope of **hazards.** The characteristics of hazards include:

- they can occur over any surface area (large or small);
- they do not follow a specific duration;
- they cannot be prevented;
- they cannot be controlled;
- depending on the generating factor, hazards can be **natural** or **anthropogenic.**

It is important to emphasize that **a hazard is a threat**, not the event itself. It only becomes a **risk** when considered in relation to a human community that is **exposed and vulnerable** to a certain natural event.

Thus**, risk is inseparably tied to human presence**, as only humans are capable of understanding the causes and consequences of random phenomena. In the absence of human communities, only the hazard exists, regardless of the magnitude or consequences of extreme phenomena on the natural environment.

The second relevant element is **vulnerability**, defined as the degree to which a system (natural or human-made) can be affected when exposed to a specific hazard. Every system possesses a certain potential vulnerability, which depends on two factors: its **ability to adapt** to environmental changes and its **degree of exposure.** Notably, vulnerability is **the only variable that humanity can directly influence**, making it the key to reducing risk.

Risk in any inhabited area thus depends on both **hazard** and **vulnerability**, under the condition of **exposure**. Risk elements include people, buildings, land uses, infrastructure, services, and more.

In relation to risk, humans play a dual role — as both **amplifiers and triggers**, but also as **mitigators.** From this perspective arises the most common classification of risks: **natural** and **anthropogenic.** Their effects manifest as changes in the system, both in terms of **functionality** and **impact on human life**.

4.1. Natural Risks

According to the European Commission's working document on both **natural and human-induced risks**, twelve categories of risks have been identified across the EU: earthquakes, volcanic eruptions, landslides, drought, floods, heavy rainfall, storms and gales, technological risks, radiation, wildfires, waste, and accidental pollution[1].

Based on the **origin of occurrence**, these can be grouped into **natural, anthropogenic**, and **mixed.** Among natural risks, some — due to their interdependence — form a distinct group of **climatological risks**, also observed in the territory of Carei.

Climatological risks are natural processes resulting from variations or changes in the climate, which can have significant negative effects on the environment, human health, the economy, and infrastructure. These risks are often **gradual and cumulative**, but their **impact can be severe**, especially when interacting with **social or economic vulnerabilities**. They are closely tied to **climate change** and **global warming.**

Climate change has been under scrutiny in urban analyses worldwide for over two decades. It entails both visible and subtle modifications in weather and climate patterns — warming or cooling reflected in seasonal dynamics and changes in the frequency and intensity of extreme events.

The most significant change observed so far is **the general warming of the climate.** The **Copernicus Climate Change Service (C3S)** — the European service providing

[1] European Commission: Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO), *Overview of natural and man-made disaster risks the European Union may face – 2020 edition*, Publications Office of the European Union, 2021, https://data.europa.eu/doi/10.2795/1521

authoritative information on past, present, and future climate — reported in its 2024 annual bulletin that[1]:

- **2024 was the warmest year ever recorded in Europe**, with an average temperature of **10.69°C**, which is **0.28°C higher than the previous record (2020);**
- The 2024 average was **1.47°C above the 1991–2020 reference period**, and **2.92°C above** the 1850–1900 pre-industrial baseline;
- Spring (March–May) and summer (June–August) 2024 recorded the **highest average seasonal temperatures ever**, with deviations of **+1.50°C and +1.54°C**, respectively;
- Europe experienced **the fastest rate of warming** globally, with a marked climatic divide between **Eastern regions** (which endured extreme heat and drought) and **Western regions** (which were excessively warm and humid). It also saw **the most widespread flooding** since 2013;
- On **July 17, 2024,** a **record 20% of the European territory** experienced **at least "severe heat stress".** Southeastern Europe, including **Romania,** recorded a **historic number of days** with severe heat stress and **tropical nights;**
- **Solar radiation** also displayed a distinct East–West contrast. Western Europe was generally **cloudier than average**, resulting in negative solar radiation anomalies, while Eastern Europe recorded **above-average radiation levels,** which influenced several meteorological variables, triggering either **immediate adaptation efforts or long-term climate strategies.**

4.2. Climatological Risk Phenomena Identified in Carei

Given this context and Carei's geographical location, several phenomena and processes with climatological risk potential have been identified:

• Heatwaves and extreme heat – prolonged periods of extremely high temperatures that pose health risks.

[1] European Centre for Medium-Range Weather Forecasts. (2023). *Annual SMOS brightness temperature monitoring report – 2022/23* (ESA Contract Report No. 4000130567/20/I-BG). European Space Agency. https://www.ecmwf.int/sites/default/files/elibrary/022024/81549-annual-smos-brightness-temperature-monitoring-report.pdf

In the last century, summers in Carei were milder, with only brief episodes of heat. However, since the 2000s, the region has seen a **notable increase in both frequency and duration of heatwaves**. Over the last 10–15 years, heatwaves have become common, especially in **July and August.** Noteworthy examples include:

- **July 2007** – one of the hottest heatwaves in recent decades, with temperatures reaching or exceeding **38°C** in Carei;
- **August 2012 –** a 15-day heatwave with temperatures above **35°C**;
- **August 2015 and 2017** – persistent heatwaves with several consecutive days over **35°C**, affecting crops and public health;
- Summer 2022 – a nationwide heatwave, with temperatures exceeding 37°C in Carei, prompting orange-level heat alerts;
- August 2023 – a severe heatwave with temperatures up to 39°C, causing intense thermal discomfort and water use restrictions in Carei and surrounding villages;
- July 2024 – a heatwave that began on July 8 and lasted 15 days, with red-level heat alerts and national temperatures of 39–40°C, also severely impacting Carei.

These episodes reflect a **regional warming trend** and underline the need for **local adaptation strategies,** such as expanding green spaces, restoring urban shading systems, and equipping health infrastructure for extreme events.

Climatic analyses and maps from the Romanian National Meteorological Administration (ANM) further confirm the warming trend in Carei. According to these sources**, 2024 was the hottest year recorded in Romania**, based on data from 129 meteorological stations with complete records for 1961–2024[1].

- The national **average annual temperature was 11.6°C**, which is **2.0°C higher** than the 1991–2020 median.
- Thermally, **10 out of 12 months** showed positive anomalies. Monthly average temperatures exceeded the standard reference median by **0.6°C (October)** to **6.8°C (February).**

For **Carei**, the **annual average ranged between 12.1–14.0°C**, representing a **positive anomaly exceeding +2.5°C,** significantly higher than the national average increase.

[1] Caracterizare meteorologică anul 2024, Administrația Naținală de Meteorologie, - Anul/Meteorological characterization of the year 2024, National Meteorological Administration, - Year 2024.

This is further confirmed by the situation in **January 2025**, usually the coldest month of the year, which placed Carei in the **"extreme thermal severity" zone** (see Fig. 22 a & b). The deviation of the average air temperature in January 2024 from the 1991–2020 reference period was **entirely positive**, with most deviations exceeding **+2.0°C**.

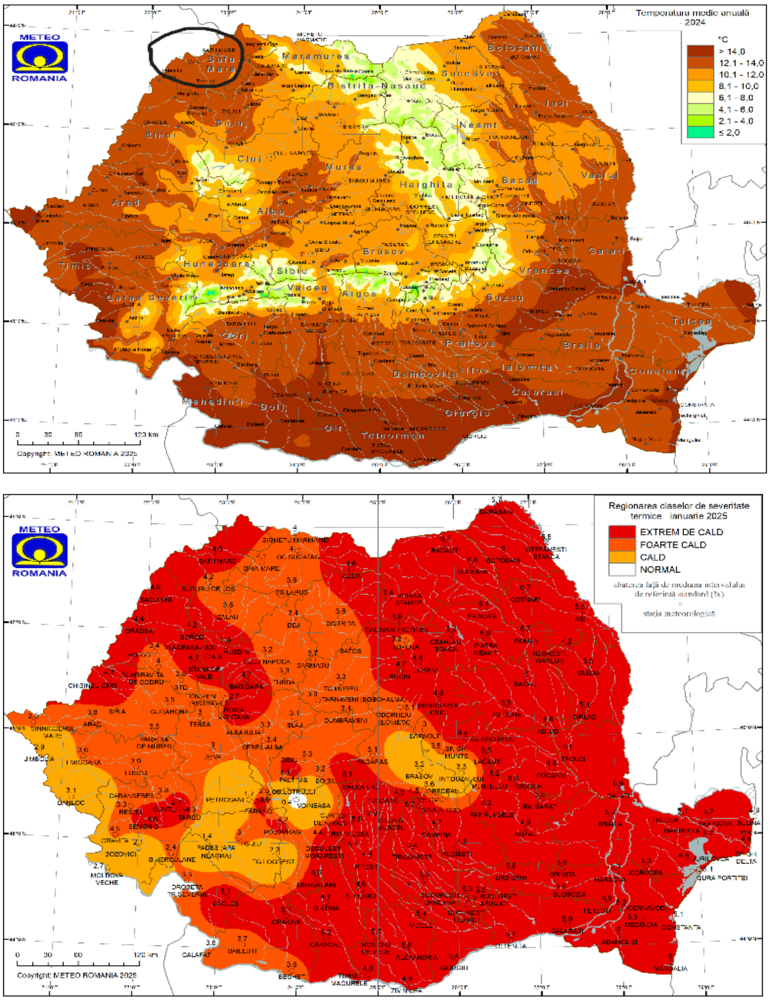


Figure 3. a&b. Average temperature in 2024 (a) and average temperature of January (b), *Source: ANM*

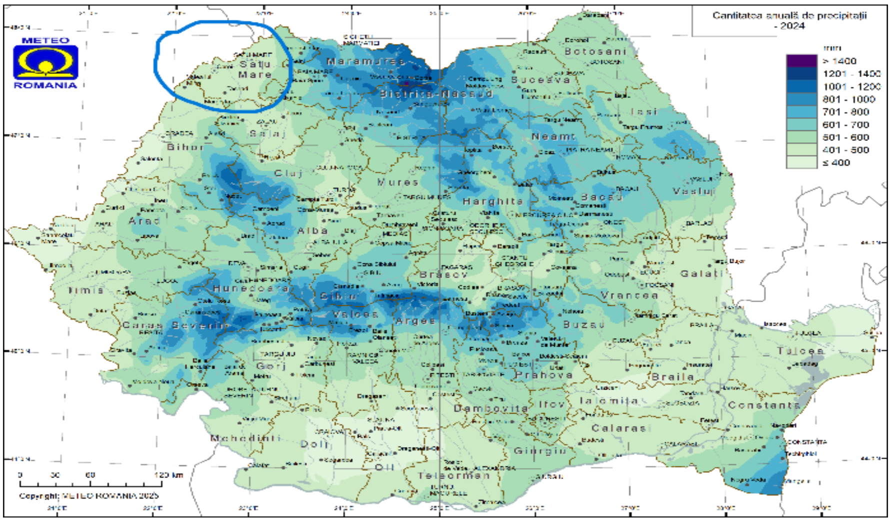
Drought – Prolonged Lack of Precipitation and Reduced Soil Moisture

Closely linked to the rise in seasonal and multiannual average temperatures, drought has increasingly taken hold in the agro-meteorological landscape of the municipality of Carei, representing the second major type of natural hazard, directly derived from climate-related risks.

This phenomenon must be viewed in the broader context of climate changes recorded at the national level, even though the severity of its impact can vary locally, depending on factors such as topography, vegetation, and soil types.

In 2024, the **average annual precipitation across Romania was 551.4 mm,** which is **17% lower** than the reference period average (1991–2020). From a pluviometric standpoint, **negative anomalies were recorded in six out of twelve months**—February, May, June, July, August, and October. During these months, monthly precipitation fell short of the reference average by **24% (in May)** up to **69% (in August).** In the remaining six months, precipitation exceeded the average, but only slightly, with surpluses ranging from **5% in November** to **21% in March,** insufficient to offset previous deficits.

Against this background, the **municipality of Carei recorded a precipitation deficit of 28.7% compared to the norm**, placing it—according to specialist analyses—within the category of **high pluviometric severity**. This situation affected the entire northwestern part of the country, particularly the **Satu Mare–Baia Mare region**, and had noticeable consequences on agriculture, water resources, and urban comfort.



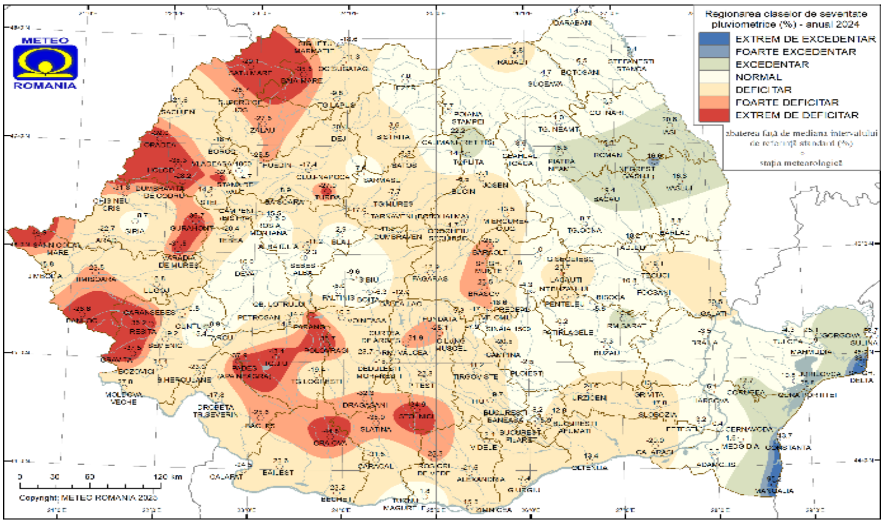


Figure 4. a&b. Average precipitation in 2024 (a) and rainfall severity classes (b)

Source: ANM

Drought is directly related to the third climate risk factor, namely changes in precipitation patterns.

Changes in Precipitation Patterns

As a consequence of climate change, there have been frequent deviations from precipitation patterns, not only in terms of quantity but also in the forms of precipitation. Thus, in the Carei-Satu Mare area, recent years have seen frequent hailstorms with hailstones ranging from 2.1–4 cm and 4.1–6 cm in diameter. These events are usually accompanied by strong winds with gusts exceeding 90 km/h, frequent lightning strikes, and torrential downpours that can accumulate and even exceed 25–35 liters per square meter. The most recent such event occurred in 2024 when a red alert for large hailstones was issued for the Carei, Tăşnad, Ardud, Moftin, Sanislău, Beltiug, Pişcolt, Acâş, Andrid, Căuaş, Santău, Tiream, Petreşti, Terebeşti, and Craidorolț area. The largest reported hailstone diameter was 7 cm in several localities in Satu Mare County (Ghenci, Marna Nouă-Sanislău). This caused significant material damage to agricultural crops, households, vehicles, and green spaces. Hailstorms tend to occur mainly during spring and summer months (May–July), when atmospheric instability is higher.

Variations in Piezometric Levels

Changes in precipitation patterns also affect soil water reserves, leading to a derived risk: significant fluctuations in piezometric levels. Soil moisture reserves fluctuate, as demonstrated by systematic hydrogeological measurements from the National Institute of Hydrology and Water Management (INHGA). According to hydrogeological bulletins published by INHGA for 2023–2024, groundwater levels in the Someș Plain experienced frequent and significant drops in several months, with April and May nearing historical lows due to reduced precipitation diminishing the natural recharge of aquifers. The forecast for June 2023 predicted a drop of over 100 cm below the historical minimum. This indicates a severe decrease in groundwater levels, surpassing the lowest values previously recorded by more than 1 meter.

This is a clear sign of a severe hydrological drought, with potential impacts on shallow wells, agriculture, and ecosystems dependent on groundwater. Although slightly different, the situation in January 2025 also showed low groundwater levels, up to half a meter below normal. This signals a significant reduction in risks of waterlogging, stagnation, and eutrophication in the Carei area over the past decade.

Floods

Considering Carei's geographical position and the absence of any permanent significant watercourses within the city, there is no imminent flood risk due to river overflow. However, over the years, the city has been affected by some floods caused by heavy rainfall and insufficient drainage capacity of the sewer system. A notable example is the event in December 2020, when several streets in Carei were flooded following torrential rains. Residents reported major difficulties with the stormwater collection system, which failed to handle the large volume of water, resulting in significant accumulation on roads and residential areas. Local media published images and reports highlighting the community impact. The substantial rainfall tested the drainage system, especially where storm drains were clogged. Outside the city, another potential flood risk area is near the Ianculești dam on the Sânmiclăuș valley, south of Carei. The dam was built for irrigation purposes and is owned and managed by the Carei municipality. Technical characteristics indicate a 3-meter-high earth dam sealed with an upstream mask or wall. The normal retention level (NNR) is 0.170 million cubic meters, while the maximum exploitation level (NME) is 0.065 million cubic meters.

Risk of aridification

Aridification is a medium- to long-term effect resulting from increasingly frequent drought periods. It may seem unlikely that an area that struggled with excess moisture in the 19th century and where embankment and drainage works were undertaken in the last century would now face the opposite challenge. However, this scenario is possible due to climate change, with models from Central Europe highlighting this trend clearly.

Since 2000, drought periods, although short, have become more frequent, gradually leading to the aridification of the area. The main phenomena illustrating this trend are:

- gradual alteration and destruction of the vegetation cover, with replacement of perennial plant associations by less valuable annuals, gradual reduction of their distribution areas, and drastic decrease in vegetation cover. Sparse vegetation fails to protect soils adequately, which start to degrade.
- soil degradation through surface erosion, deflation, crust formation, aridification, salinization, and alkalinisation. Under these conditions, the amount of water infiltrating the soil decreases, increasing the risk of expanding unproductive land areas.
- reduction of soil and groundwater reserves.

This scenario is also indicated by projections from the European Drought Observatory. For example, in the last decade of April 2025, Carei was located immediately adjacent to the drought-warning zone.

In conclusion, the main risk categories in the Carei area are climate change and general warming, manifested concretely as heatwaves, drought and aridness risk, torrential rains, hail, and only occasionally floods.

4.3. Seismic Risks

Satu Mare County has two seismic risk zones — the first is the Carei area, and the second is along the Halmeu-Livada alignment, where multiple epicenters exist. Being a plain region, surface earthquakes can be dangerous, although according to the National Institute of Earth Physics statistics, northwestern Romania is among the least affected regions. On the seismic hazard map, the Carei zone is classified with a PGA (Peak Ground Acceleration) value of 0.20–0.25g, which is much lower than the 0.40g value in the Vrancea zone. PGA measures the maximum ground acceleration during an earthquake expressed as a fraction of gravity (g), useful for seismic-resistant building design. In Carei, the risk of structural damage is low compared to high seismic hazard zones, and construction regulations are less strict. In conclusion, although the possibility of an earthquake cannot be completely excluded, seismic risk in Carei is considered low, and significant seismic events are very rare.

5. Conclusion

Environmental issues facing Carei can be better understood in the broader context of climate change and its associated impacts on biodiversity, agriculture, and energy strategies. Carei, located in north-western Romania, belongs to a region characterized by rich biodiversity increasingly threatened by various pressures linked to climate change and human activities. In brief, Carei, like many regions in Romania, faces environmental challenges that, while not always obvious, are deeply connected to climate change. These include pressures on agricultural productivity, biodiversity loss, and significant socio-economic challenges stemming from climate perception and public awareness. Future policies must adopt integrative approaches prioritizing sustainability, biodiversity conservation, and community engagement to effectively address these urgent environmental challenges.

6. References

*** (2022*). Classification and quantification of landscape features in agricultural land across the EU*, JRC Technical Report, European Comission.

*** (1966). *Clima Republicii Socialiste România/ Climate of the Socialist Republic of Romania*, Vol. II. Date climatologice/ Climatological data.

*** (1983). *Geografia României, vol I, Geografia fizică/Geography of Romania, vol. I, Physical Geography*. Bucharest: Ed. Academiei RSR.

*** (2014). Ghid de bune practici agricole pentru atenuarea efectelor schimbărilor climatice asupra agriculturii/ Guide to good agricultural practices for mitigating the effects of climate change on agriculture, realizat de Institutul Naţional pentru Cercetare-Dezvoltare pentru Pedologie, Agrochimie şi Protecţia Mediului – ICPA Bucureşti, Administraţia Naţională de Meteorologie şi Universitatea de Ştiinţe Agronomice şi Medicină Veterinară Bucureşti.

*** (2016). *Studiu regional. Impactul schimbărilor climatice asupra comunităților din Regiunea Centru/ Regional study. The impact of climate change on communities in the Central Region*. ADR Centru.

Armaş, Iuliana (2014). *Riscuri naturale – Sinteze pentru pregătirea examenului/ Natural hazards – Exam preparation summaries*. Bucharest: Universitatea Bucureşti.

Bălteanu, D., Șerban M. (2005). *Modificările globale ale mediului. O evaluare interdisciplinară a incertitudinilor/ Global environmental changes. An interdisciplinary assessment of uncertainties*. Ed. CNI Coresi

Bogdan, Octavia & Niculescu, Elena (1999). *Riscurile climatice din România/ Climate risks in Romania*. Bucharest: Academia Română, Instit. de Geografie.

Bojariu, R., Bîrsan, M-V., Cică, R., Velea, L., Burcea, S., Dumitrescu, A., Dascălu, S.I., Gothard, M., Dobrinescu, A., Cărbunaru, F., Marin, L. (2015). *Schimbări climatice – de la bazele fizicii la riscuri şi adaptare/ Climate change – from basic physics to risks and adaptation*. Bucharest: Printech.

Busuioc, A., Caian, M., Bojariu, R., Boroneanţ, C., Cheval, S., Baciu, M., Dumitrescu, A. (2013). *Scenarii de schimbare a regimului climatic în România pe perioada 2001-2030/ Climate change scenarios in Romania for the period 2001-2030*. Administraţia Naţională de Meteorologie.

Cheval, S., Bulai, A., Croitoru, A., Dorondel, Ş., Micu, D., Mihăilă, D., … & Tişcovschi, A. (2022). Percepţia schimbărilor climatice în România/ Perception of climate change in Romania. *Climatologie teoretică şi aplicată/Theoretical and applied climatology*, 149(1-2), 253-272. https://doi.org/10.1007/s00704-022-04041-4

Cicort-Lucaciu, A. (2020). Gândacii de pământ ucişi de drum dovedesc prezenţa carabus hungaricus (coleoptere: carabidae) în nord-vestul României/ Road-killed ground beetles prove the presence of Carabus hungaricus (Coleoptera: Carabidae) in northwestern Romania. *Cercetarea pentru conservarea naturii/ Research for nature conservation*, 5(3). https://doi.org/10.24189/ncr.2020.035

Czúcz, B., Baruth, B., Terres, J. M., Gallego, J. et al., (2022). *Classification and quantification of landscape features in agricultural land across the EU – A brief review of existing definitions, typologies, and data sources for quantification, Publications Office of the European Union*, https://data.europa.eu/doi/10.2760/59418

Ielenicz, M., Popescu, N. (2003). Relieful Podişul Dobrogei – caracteristici şi evoluție/ The relief of the Dobrogea Plateau – characteristics and evolution. *Analele Universităţii/ Annals of the University*, Bucharest.

Jurchescu, M., Micu, D., Sima, M., Bălteanu, D., Dragotă, C., Micu, M. (2017). An approach to investigate the effects of climate change on landslide hazard at a national scale (Romania). *Proceedings of the Romanian Geomorphology Symposium*, 33 edition, 11-14.

Măhăra, G. (2006). *Variabilităţi şi schimbări climatice/Climate variability and change*. Editura Universităţii din Oradea.

Mureşan, G. & Drăgan, M. (2024). Educaţia pentru mediu şi schimbări climatice în România din perspectiva strategiilor internaţionale şi naţionale în domeniu/ Environmental education and climate change in Romania from the perspective of international and national strategies in the field. *Studia Universitatis Babeş-Bolyai Geographia*, 69(2), 43-54. https://doi.org/10.24193/subbgeogr.2024.2.03

Mănescu, C., Mateoc-Sîrb, N., Sicoe-Murg, O., Manescu, A., & Vass, H. (2023). *Studii privind impactul şi riscurile climatice în România/Studies on climate impact and risks in Romania*, https://doi.org/10.5593/sgem2023/5.1/s20.30

Nicolescu, M. (2014). Schimbările climatice şi influenţa acestora asupra agriculturii. *Conferinţa „Ferme mici şi asociere"*, Craiova.

Robu, Delia-Elena (2018). *Evoluţia albiilor de râu din câmpia joasă a Someşului, teză de doctorat/ The evolution of riverbeds in the Someş lowland, doctoral thesis*. Suceava.

Rădoane, M., Rădoane, N. (2006). *Geomorfologie aplicată/Applied geomorphology*. Editura Universităţii Suceava

Sandu, I., Pescaru, V., Poiană, I., Geicu, A., Cândea, I., Ţâştea, D. (2008). *Clima României*. Bucharest: Editura Academiei Române.

Sandu, I., Simota, C., Mateescu, E., Alexandru, D., Oprea, O-A., Anghel, D., Trif, A., Dumitru, M., Calciu, I., Dumitru, S., Vizitiu, O.P. (2014). *Cod de bune practici agricole, în contextul schimbărilor climatice actuale şi previzibile, realizat de Administraţia Naţională de Meteorologie şi Institutul Naţional pentru Cercetare-Dezvoltare pentru Pedologie*. Bucharest: Agrochimie şi Protecţia Mediului – ICPA.

Sandu, M., Strateanu, A., & Udrea, L. (2022). Contribuţia agriculturii româneşti la încălzirea globală şi impactul schimbărilor climatice asupra culturilor de legume. Analele Universităţii Valahia din Agricultură Târgovişte, 14(2), 17-22. https://doi.org/10.2478/agr-2022-0015

Stoian, M., Drăcea, R., Deaconu, E., Chiripuci, B., Constantin, F., & Ciobanu, L. (2024). *Explorarea impactului schimbărilor climatice asupra structurilor asociative ale agriculturii româneşti: o abordare prospectivă pentru atingerea durabilităţii/Exploring the impact of climate change on the associative structures of romanian agriculture: a prospective approach towards achieving sustainability*, https://api.semanticscholar.org/CorpusID:273833481

Institutional websites:

Acasa - ANPM

Air Quality Carei: Live air quality and pollution Forecasts

EDO map

Home | Ministerul Mediului (mmediu.ro)

http://peseta.jrc.ec.europa.eu

https://www.mdlpa.ro/pages/habitat

IPCC WGI Interactive Atlas

Meteo Romania | Site-ul Administratiei Nationale de Meteorologie

NASA: Climate Change and Global Warming

PMRI_actualizat_ciclul-II_-ABA-Crisuri_versiune-preliminara-1.pdf

Special Report on Climate Change and Land — IPCC site