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ANALYSIS OF THE HAIL PHENOMENON IN BISTRIȚA-NĂSĂUD COUNTY IN 2024: LOCALIZATION, IMPACT, PERCEPTION, AND MITIGATION

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ABSTRACT. – Analysis of the hail phenomenon in Bistrița-Năsăud county in 2024: localization, impact, perception, and mitigation. This study examines the hail phenomenon that impacted Bistrița-Năsăud County during the period 2022-2024, with a particular focus on the significant hail events of 2024. The research integrates climatological data, meteorological observations, and locally sourced information to evaluate the frequency, localization, and intensity of hail across the region. Specific emphasis is placed on areas such as Săsarm, where the June 2024 hailstorm inflicted severe damage on households, agricultural infrastructure, and public amenities. The study not only documents the material and economic consequences but also investigates the community's perception of the implemented preventive and mitigation strategies, such as anti-hail systems and agricultural insurance policies. Findings underline that while some measures were in place, there remains a critical need for more robust and effective climate risk management approaches, particularly in high-risk areas like Bistrița-Năsăud County. Enhanced public awareness campaigns and investment in adaptive technologies are identified as key steps toward increasing community resilience.

Keywords: *hail, storm, intensity, extension, damage, management, perception, mitigation.*

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1. Introduction

Hail is an extreme climatic phenomenon, associated with severe convective storms, and is intensified by current climate change, which contributes to the increase in frequency and intensity of the phenomenon at the European, national, and regional levels. The phenomenon is strongly influenced by morphological conditions, the contribution and consistency of air masses, and regional climatic specificities. Although the hail phenomenon has a major impact on natural and anthropogenic systems, it evolves in narrow strips, typically hundreds or thousands of meters wide, and the damage is correlated with the intensity and aggressiveness of the phenomenon, rather than its spatial extent. Because it occurs during the growing season of vegetation, the damage is considerable, especially in agriculture (crops and agricultural infrastructure) (Moldovan F., 2003).

With the intensification of the phenomenon and the increase of hailstones size, the impact on agricultural land has grown, but more recently, it has also affected homes, agricultural infrastructure, and transportation means. As a result, hail events are among the costliest extreme events related to climate in several European regions, causing substantial damage (fig. 1).

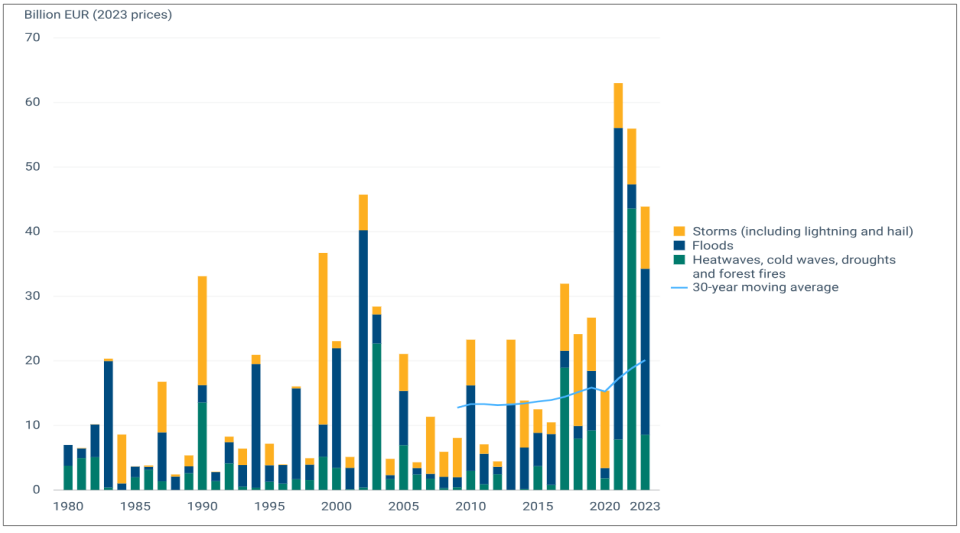

Fig. 1. Annual economic losses caused by weather-and climate-related extreme events in the EU Member States, including hail.
Source: Annual economic losses caused by weather-and climate-related extreme events in the EU Member States | European Environment Agency's home page, 06 Nov 2024

To identify the evolution of the hail phenomenon at the national, regional, and local levels in Romania, we analysed a study conducted by Francesco Battaglioli (European Severe Storms Laboratory). An Additive Logistic Regression model for large hail (ARhail) was developed using convective parameters from the ERA5 reanalysis, hail reports from the European Severe Weather Database (ESWD) and lightning observations from the Met Office Arrival Time Difference network (ATDnet). This study analysed the long-term changes in storms that produce hail. The analysis was based on observations and numerical modeling for the period 1950-2022. The results showed that between 1950 and 2022, the number of hail incidents increased in Europe, including those with hailstones larger than 2 cm in diameter, as well as the number of cases involving hailstones larger than 5 cm (fig. 2) (Battaglioli, F. et al, 2023). We noticed the same pattern of evolution of the hail phenomenon at the national level in Romania, both in terms of intensity and size, as well as in the recorded damage.

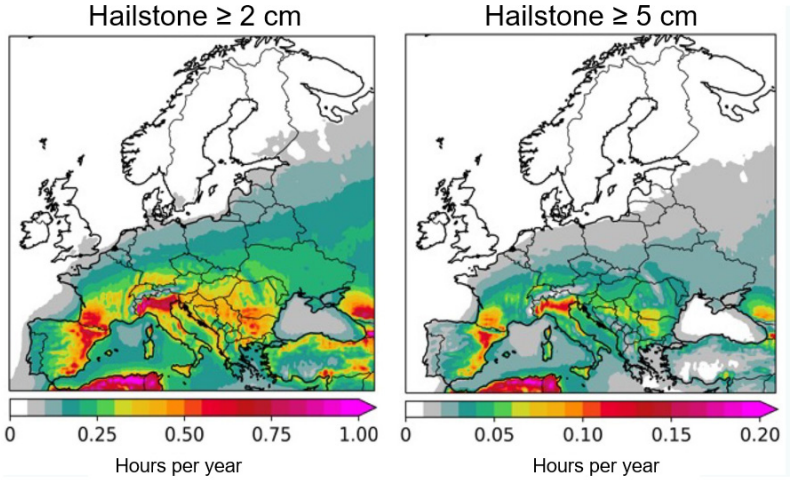

Fig. 2. The trend for large hail cases (number of hours per year) between 1950-2022 (Battaglioli, F. et al., 2003)

According to the European Severe Weather Database, between July 1 and July 22, 2023, 2262 hail cases were reported in Europe, 38 of which were in Romania (InfoClima.ro).

One remarks that there is an overlap between the locations of aggressive hail occurrences and the main agricultural regions of Europe, which results in the high value of damage and the increased vulnerability associated with this phenomenon.

In Romania, the normal occurrences of the phenomenon are specific to the transitional season from spring to summer (the months of May, June, and July), with exceptions such as hails in April and September, which are due to climatic anomalies. In the North-Western region of Romania, the hail phenomenon predominantly occurs in the counties of Satu Mare, Sălaj, Cluj, and Bistrița-Năsăud, conditioned by the intrusion of humid and cold air masses from the Icelandic Low and their collision with warm air masses from the Someș Plain, Someș Corridor, Someșul Mare Corridor, Someșul Mic Corridor, Someș Plateau, and the Transylvanian Plain.

2. Characteristics and Evolution of the Hail Phenomenon in Bistrița-Năsăud County

In Bistrița-Năsăud County, the hail phenomenon occurs in the Someșul Mare Corridor, Ilva Valley Corridor, Șieu Corridor, and the North-Eastern part of the Transylvanian Plain. Due to the climatic and geographical conditions, hail is most frequent in Bistrița-Năsăud County in June.

By performing a time analysis of the hail phenomenon in Bistrița-Năsăud County, we found that in the last decade, this phenomenon has become increasingly frequent and more intense. Previously, there were 3-4 events per year in which the hailstones were small (under 10 mm), only partially affecting agricultural crops. Currently, one notices that the hailstones are larger, reaching up to 50 mm, and most often lead to the total destruction of agricultural crops, significant damage to forest vegetation, agricultural infrastructure (greenhouses, hothouses, livestock facilities), agricultural machinery, transportation, and homes.

The analysis of the evolution of the hail phenomenon in Bistrița-Năsăud County for the period 2022-2024, based on reports from institutions responsible for managing emergency situations, reveals an obvious alignment with the general occurrence patterns noticed at the European and national levels. In the context of global climate change, characterized by increased frequency and intensity of extreme weather phenomena, hail has represented a significant risk factor in this region. Over the three years analysed, 23 events were recorded, varying in intensity and hailstone size, with diameters ranging from 3 mm to 50 mm. This variability reflects the diversity of local weather conditions and the role of regional climatic specificities.

The frequency of hail events in the county is comparable to that in other exposed regions, indicating the presence of determining factors such as the area's rugged morphology and the dynamics of warm and cold air masses, which facilitate the formation of convective storms. The size of the recorded hailstones is similar to those reported in other areas of Romania, as well as in Central

Europe, where the hail phenomenon causes significant damage to agriculture, infrastructure, and local communities. This trend highlights the importance of implementing proactive measures, such as anti-hail systems and agricultural loss insurance, which are essential for reducing economic and social impact.

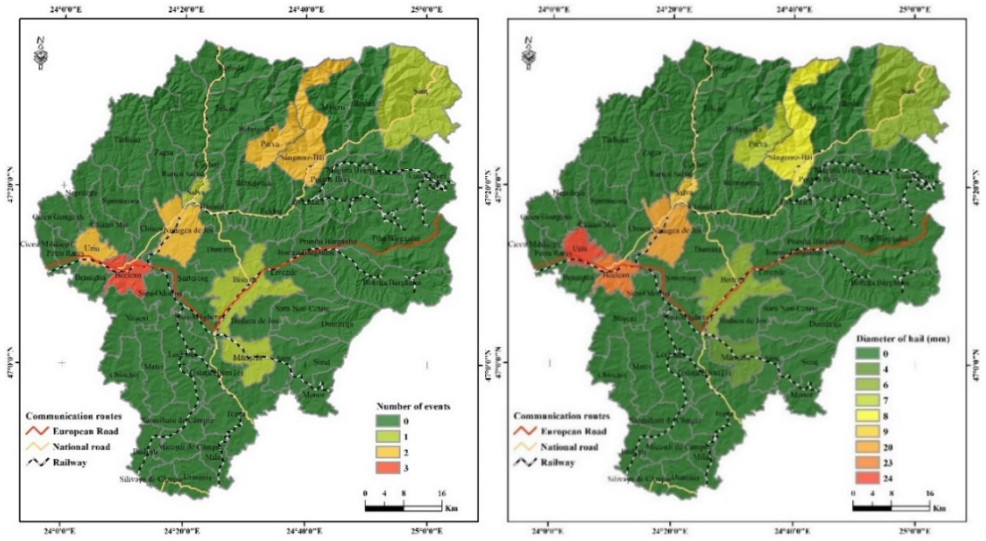

Fig. 3. Spatial Distribution and Hail Diameter in Extreme Weather Events of 2022, Bistrița-Năsăud County.
Source: Modeling performed based on data from the National Administration „APELE ROMÂNE", Someș-Tisa Basin Water Administration, Bistrița-Năsăud Water Management System

In 2022, there were 8 weather events with hail that affected 9 administrative-territorial units (UATs). As seen in fig. 3, hails in 2022 were predominantly noticed in Someșul Mare Corridor (Uriu commune, town of Beclean, Nimigea commune, Șanț commune), Rebra Valley (Parva commune), Borcut Valley (town of Sângeorz-Băi), and Șieu Valley (Mărișel commune). Pursuant to the map's color scheme, one can analyse the diameter of the hailstones in 2022. According to this, the hailstones size varied between 4 mm and 24 mm, with the largest size recorded in Cristeștii Ciceului, Uriu commune, and the smallest in Domnești, Mărișelu commune.

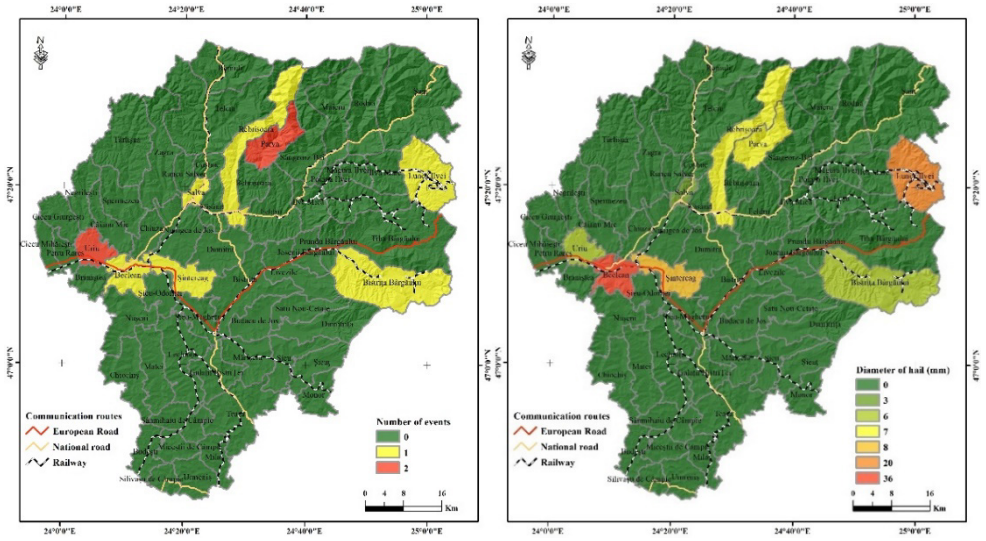

Fig. 4. Spatial Distribution and Hail Diameter in Extreme Weather Events of 2023, Bistrița-Năsăud County.
Source: Modeling performed based on data from the National Administration „APELE ROMÂNE", Someș-Tisa Basin Water Administration, Bistrița-Năsăud Water Management System

In 2023, there were 6 weather events with hail, affecting 8 administrative-territorial units (UATs). By examining the cartographic representation of the hail events in 2023, one remarks that the majority of events occurred in Someșul Mare Corridor (Cristeștii Ciceului commune, town of Beclean, Șintereag commune, Salva commune, Rebrișoara commune), along Bistrița Ardeleană Valley (Bistrița Bârgăului commune), Ilva Valley (Lunca Ilvei commune), and Rebra Valley (Parva commune). According to the color scheme of the maps, the largest hailstone diameter was 36 mm (Beclean), while the smallest diameter was recorded in Salva.

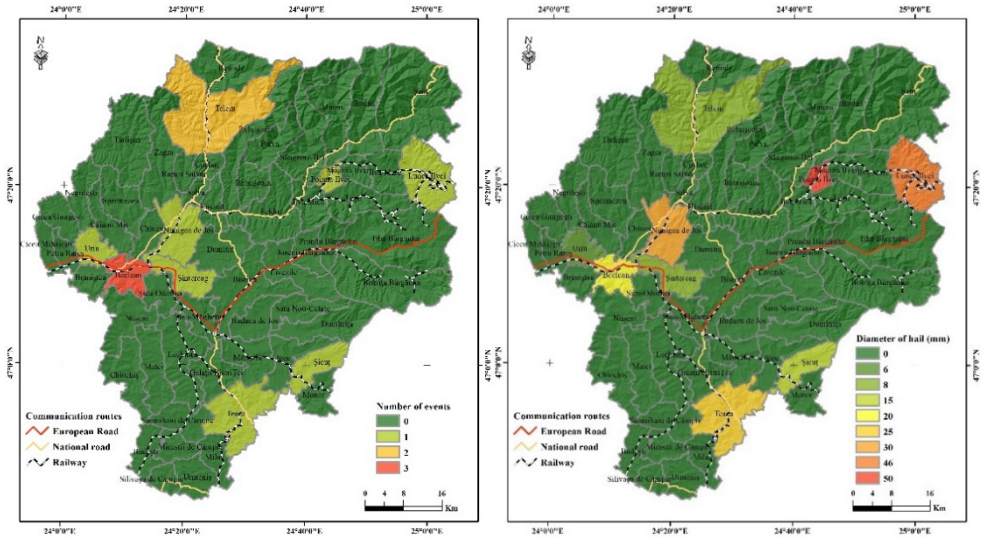

Fig.5. Spatial Distribution and Hail Diameter in Extreme Weather Events of 2024, Bistrița-Năsăud County.
Source: Modeling performed based on data from the National Administration „APELE ROMÂNE", Someș-Tisa Basin Water Administration, Bistrița-Năsăud Water Management System

Analyzing the hail events of 2024 (fig. 5), one notices that there were 6 events, which occurred in 10 administrative-territorial units (UATs), 9 of which resulted in material losses. The hail events are spatially located in Someşul Mare Corridor (Cristeştii Ciceului, Beclean, Şintereag, Mocod), Sălăuţa Valley (Telciu), Ilva Valley (Lunca Ilvei, Ilva Mare, Poiana Ilvei), Şieu Valley (Şieuț), and in the North-East of the Transylvanian Plain (Dipşa Valley, Teaca commune). The largest hailstone diameter was recorded in Ilva Valley (Poiana Ilvei and Lunca Ilvei).

The most aggressive hail events in recent times occurred in 2024, which prompted us to carry out this study. In 2024, several hail events took place in Bistrița-Năsăud County, two of which caused major damage (see Table 1).

Table 1. Economic Damage Caused by Hail Events in 2024

UAT	Date	Houses		Land		Agricultural installations (greenhouses, glasshouses)		Social and administrative buildings	Private businesses
		>25 %	>50 %	Nr. of properties/ Damage degree	Area (hectares)	Nr. of properties	Area (hectares)		
Bistrița	04.06.24	-	-	1 (>75%)	55,31	-	-	-	-
Chiuza	04.06.24	314	25	9 (100%)	530	2	0,33	6	7
Șintereag	05.06.24	41	25	1 (100%)	435,4	9	6,19	7	-
Livezile	13.06.24	2	-	-	-	-	-	-	-
Nimigea	04.06.24	38	-	101 (75%)	205	24	10,85	1	-
Beclean	04.06.24	59	-	83 (100%)	41,34	3	0,18	2	1
Branișste	04.06.24	-	-	3 (100%)	4,43	-	-	-	-
Ilva Mare	10.06.24	78	60	-	-	-	-	-	-
Lunca Ilvei	10.06.24	100	136	-	-	-	-	-	-
Total		**632**	**246**	**198**	**1271,5**	**38**	**17,55**	**16**	**8**

Data source: https://bn.prefectura.mai.gov.ro/

Quantifying the damage resulting from these events, one remarks that 9 administrative-territorial units were severely affected. In 7 municipalities, 632 houses and their annexes were affected by 25% or more, while 246 houses and annexes were destroyed by 50% or more, totalling 878 houses. 198 agricultural producers were affected, 49% of whom had total crop damage (100%), with a total affected area of 1,271.48 hectares. Additionally, 38 owners of agricultural installations (greenhouses, glasshouses, animal pens) suffered damage, with a total destroyed area of 17.55 hectares. According to the reports from the municipalities, there was also additional damage to 16 social and administrative buildings (town halls, schools, churches, cultural centres) and 8 private businesses. The previously analysed data indicates that the most aggressive hail event was on June 4, 2024, with the largest spatial extent, affecting 5 UATs.

Fig. 6. Images captured in the village of Săsarm, Chiuza Commune, during the hail events of June 4, 2024

The hail phenomenon, as illustrated by the images captured in the village of Săsarm, located in Someşul Mare Corridor, reflects the characteristics of an extreme climatic phenomenon. It had a significant impact on the natural environment, households, and the local economy, with direct implications for the rural community. As a result of the hail phenomenon in Săsarm, the damage was substantial, affecting both households and local infrastructure. Major damage occurred to the roofs of houses, with annexes being completely or partially destroyed. Large hailstones, accompanied by gusts of wind exceeding 90 km/h, punctured the exterior insulation of buildings and uprooted numerous trees. Although no victims were reported, the phenomenon caused considerable material damage, requiring intervention from emergency teams to support the population and mitigate the negative effects of the storm.

The hail event in Săsarm also had a significant impact on vegetable fields and greenhouse structures. Large hailstones and the intensity of the storm seriously damaged these agricultural structures, puncturing plastic sheets and damaging metal frameworks, which severely impacted the production of vegetables and fruits. Material damages included the destruction or damage of greenhouses and glasshouses, as well as crop losses due to plant damage. As a result, farmers had to invest in costly repairs or completely rebuild these spaces, significantly reducing their productivity and income. The impact was felt not only economically but also in the loss of confidence in agricultural practices based on protection against extreme weather phenomena, requiring stronger preventive measures for the long-term protection of agricultural investments.

The hail phenomenon was repetitive in most of the administrative-territorial units where it occurred. For example, in Uriu commune, the hail event took place in all three years included in the study, totalling 5 events. In Beclean, hail also occurred annually, with 7 such events recorded. This demonstrates that in this region, hail is no longer an exception but a frequent event, with a high probability and medium to high impact on local communities, agriculture, and infrastructure. This situation calls for the implementation of preventive, mitigating, and counteracting measures to manage the risks caused by this phenomenon. The recurrence of the phenomenon necessitates the adoption of well-founded managerial measures aimed at preventing, mitigating, and fighting the risks associated with hail.

3. Perception of the hail phenomenon

Measures taken by the public administration and individuals are directly proportional to the level of perception and acceptance of extreme climatic phenomena. The reduced perception of hail by the population is an issue that combines factors such as public awareness, climate education, media exposure, and risk perception. In many cases, hail is considered an isolated or trivial event, without fully understanding its economic and social impact.

The main reasons for the reduced perception of the hail phenomenon are:

- Lack of awareness of its impact;
- Hail is usually a short-term event with a limited geographic range, making it difficult to be perceived as a global or long-term problem. Other extreme weather phenomena, such as floods and heatwaves, receive more attention than hail, leading to its underestimation;

- The lack of detailed information in schools and educational programs about hail and related phenomena contributes to a reduced perception;
- Severe hail-related events are reported rarely or only in extreme cases, limiting public awareness;
- The lack of investments in preventive infrastructure means that those affected may suffer significant financial or personal losses without being prepared to manage these risks.

In this context, measures to improve perception and acceptance are necessary, such as:

- Awareness campaigns and educational programs highlighting the impact of hail on agriculture, economy, and safety;
- More documented media articles focusing on vulnerability, hail-related damage, and management measures.

The appropriate perception and acceptance of an extreme phenomenon inevitably leads to the implementation of preventive and counteraction measures at both institutional and individual levels.

4. Management measures of hail-induced risks

Currently, in Bistrița-Năsăud County, there is no hail management system adapted to the new climatic trends, and there are no hail protection systems in place. Due to the fact that agricultural land consists of small plots, with no associations or large agricultural producers, the insurance system is either ignored or difficult to implement. Therefore, hail risk management must be improved and involve a combination of active measures to reduce the economic and social impact of this meteorological phenomenon. The strategies can be grouped into several categories:

1. **Prevention and mitigation technologies**:
    - ***Hail protection systems***, which involve rocket launchers or the use of ground-based silver iodide generators designed to create a condensation nucleus that limits the formation of large hail, transforming it into rain or smaller hail;
    - ***Protective nets***, mainly used in agriculture; these physical nets protect crops and orchards from the impact of hail;
    - ***Drone use***, a technology involving drones dispersing substances similar to silver iodide to control hail formation. This technology has already been tested in some regions (Doe, J., & Smith, R., 2020, pp. 12-25).

2. **Agricultural insurance**: Hail insurance is essential for farmers. It compensates for economic losses and is subsidized in many countries.
3. **Monitoring and early warning**: The use of weather radars and satellites allows for the forecasting of storms with hail potential. Early warning systems enable farmers and communities to take protective measures (such as sheltering equipment, protecting animals, etc.).
4. **Education and training**: In the context of limited perception, this is an important management measure. Information campaigns would help farmers and local authorities understand the risks of hail and implement appropriate solutions (Brown, C., 2021, pp.45-48).
5. **Innovative solutions**:
    - ***Climate modeling and forecasting***: Advanced research in hail formation offers tools to forecast the size and frequency of hail in different regions;
    - ***Integrated climate risk management***: This includes adapting infrastructure and supporting the transition to more resilient agricultural practices.

These measures, when implemented together, contribute to minimizing the damage caused by hail and supporting a more resilient economy. National and local authorities, alongside international organizations, play an essential role in implementing these solutions.

5. Conclusions

The hail phenomenon in Bistrița-Năsăud County, particularly between 2022 and 2024, has significantly impacted local communities, causing major disruptions to agricultural lands, infrastructure, and economic activities.

Analysing hail events from this timeframe reveals an alarming trend: increased frequency and severity of hailstorms, as seen in notable incidents such as those in June 2024. These findings underscore the challenge of managing this extreme climatic phenomenon in the context of ongoing climate change.

Institutional and community perceptions of hail risks remain insufficient, leading to gaps in preparedness. Data collection on hail events is fragmented, and the absence of a systematic approach to inform the population about prevention and mitigation measures exacerbates the vulnerability of affected areas. For example, many localities lack access to real-time warning systems or comprehensive knowledge about protective actions, such as anti-hail technologies and agricultural insurance.

To address these challenges, implementing protective measures such as anti-hail netting, advanced monitoring systems, and enhanced insurance programs is critical. These strategies would reduce material losses and bolster the resilience of communities to extreme weather. Moreover, integrating these measures with broader climate adaptation strategies is vital for mitigating the long-term effects of hail, particularly in high-risk zones like Bistrița-Năsăud County. Ensuring public awareness and institutional coordination will be pivotal in fostering a more prepared and adaptive response to such climatic threats.

The conclusions provide a roadmap for policymakers and stakeholders, offering insights into the development of regionally and locally tailored strategies for mitigating hail risks. This framework emphasizes preparedness and adaptation in the context of intensifying climate change effects, relevant not only for Bistrița-Năsăud County but also for other regions facing similar challenges.

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