Mapping the effects of the 23 July 2020 hailstorm that occurred in Suceava, Romania

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ABSTRACT: The hailstorm and accompanying winds that affected the city of Suceava on 23 July 2020 and neighboring areas compromised crops, uprooted and broke trees, and caused minor damage to buildings. Field observations to plant life and buildings were conducted in order to assess the extent of the damage. Scores were given to crop health state on a scale ranging from no damage to total crop loss, in order to map out the affected territory and the degree of damage sustained by the vegetation. Based on these observations, a hazard map for this particular event was generated, showing the extent of the destruction. Weather data like wind speed, temperature, rain quantity and barometric pressure was collected from privately owned weather stations operated inside the affected area. Graphs based on the weather telemetry were included in the paper to better understand the scale and the time frame of the event. Beside documenting the impact of this weather event, the study also showed the utility of using a network of low cost, automated weather stations, for providing local weather data to a level of detail otherwise impossible to access. It was concluded that the damage inflicted to vegetation affected 9 administrative districts on a total area of 80 km^2 in a time span of 30 minutes.

KEY WORDS: crop damage mapping, hail, storm, hazard.

1. Introduction

Hailstorms and winds are natural hazards that can cause significant damage to crops, trees (Istrate et al., 2021), buildings and infrastructure (ACSE, 2016). On 23 July 2020, a violent hail storm with strong wind gusts capable of uprooting trees and damage crops took place in the city of Suceava, Northern Romania, an area where events of such magnitude are infrequent (Tănasă, 2011) and, when they do occur, are poorly documented. Lacking a standardized damage recording system (Nielsen, 2006), a method of discriminating between various damage levels had to be developed. The adopted system in this study allowed for a means of mapping out the damage in terms of both spatial spread and severity. Even though the current climatic situation for the discussed territory might not indicate the necessity for protective measures against the effects of high winds and hail damage to crops (Chattopadhyay et al., 2016), documenting such extreme events could prove useful for future reference. Hail related losses trends are rising across Europe, with annual losses amounting to millions of USD (Púčik et al., 2019).

2. Study area

Suceava County is located in Northeastern Romania. Its seat is the city of Suceava, a 50 km^2 area split in the middle by the Suceava river. It sits in the Suceava Plateau (part of the Moldavian Plateau), a hilly region to the East of the Carpathian Mountains. The Suceava Plateau is in the temperate climate, with strong continental influences. Although high wind speeds of 40km/h or more are not very frequent, averaging 9 to 10 days per year, especially during winter and spring (Tănasă, 2011), the climate of the region is complex and ever evolving, over the last century having recorded a 1 °C air temperature increase and, surprisingly, a precipitation increase of 20mm, the latter being explained by violent and potentially hazardous rainfall episodes amid longer periods of drought (Mihăilă and Briciu, 2012). The studied area lies in the lower range of mean annual hail days in the country, with 0-1.5 days/year, based on records for the 1961-2014 period (Burcea et al., 2016), while the mean hail diameter is 8-11 mm and the maximum hail diameter is 20-30mm. The average time of day in which hail episodes occur is 13-15 UTC for the same area and period. On average, most risk prone cultures in the area are potato and beet, while corn, sunflower, wheat and orchards are the least affected (Istrate et al., 2021).

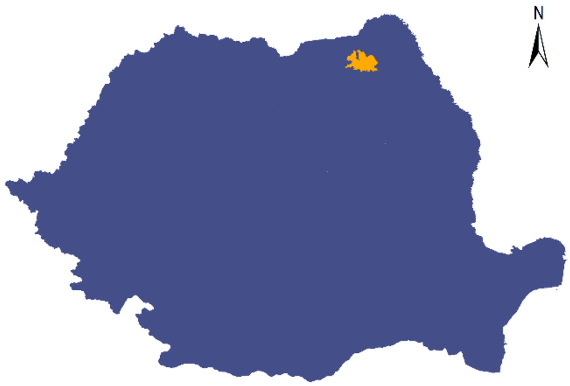


Figure 1 The location of the Administrative Divisions of Romania affected by the storm (in orange).

The extent of the area studied was directly dependent on the limit of the destruction caused by hailstone and wind gusts during the storm (Fig. 1). Crops and vegetation were affected on an area of over 80 square kilometers around the city, where the epicenter of destruction was located. It appears that the hail storm unfolded along the Suceava River valley, from WNW to ESE, having its most upstream point near the village of Pătrăuți, and its most downstream point near the town of Verești.

3. Methods

In order to assess the damage caused by the storm, a field survey spanning a 14 Day period was conducted (between 23 July – 5 August 2020). Within this time period no other overlapping meteorological events occurred in the area that could have additionally affected the state of the vegetation. Observation was the main method used to collect the data. The observation sites were scattered throughout the territory in an outwardly fashion – starting from the center of the area, where the most damage occurred, and moving toward the periphery, until no plant damage related to this event could be observed. Each site was recorded and classified based on the state of the plants and other landmarks in relation to the storm. If the observed features could have been damaged prior to the event in question (judging by the aspect/age of the affected feature), they were not recorded or included in this study (as this was the case for some toppled telecommunication poles).

To discriminate between damage levels, a 5 classes damage scale was developed, with values ranging from 0 to 4. The sites with no signs of damage received a score of 0, whereas the most affected areas, in which total crop loss was recorded, received a score of 4 (Fig. 2). The number of classes was chosen to fit the five distinctive levels of vegetation states that could be distinguished between the sites. The following list shows this scale model in more detail:

0 = no visible signs of hail or wind damage to vegetation;

1 = light damage visible on foliage, with no consequence to crop yield;

2 = distinct damage visible on plant foliage and stems; few compromised crops (up to 1/3), some broken tree branches, isolated cases of broken or uprooted trees;

3 = foliage from trees partially missing, with few uprooted or broken trees; many crops compromised (up to 2/3);

4 = complete foliage loss from trees, many trees uprooted or broken; light damage to buildings and infrastructure; crops completely compromised.

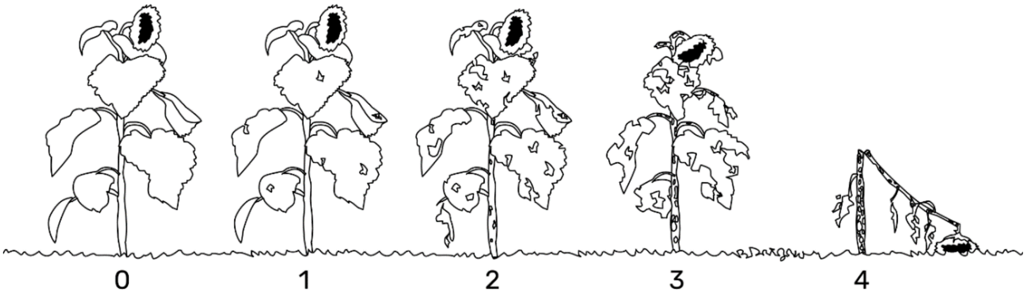


Figure 2 The 5 classes model used to assess the damage illustrated on a sunflower plant.

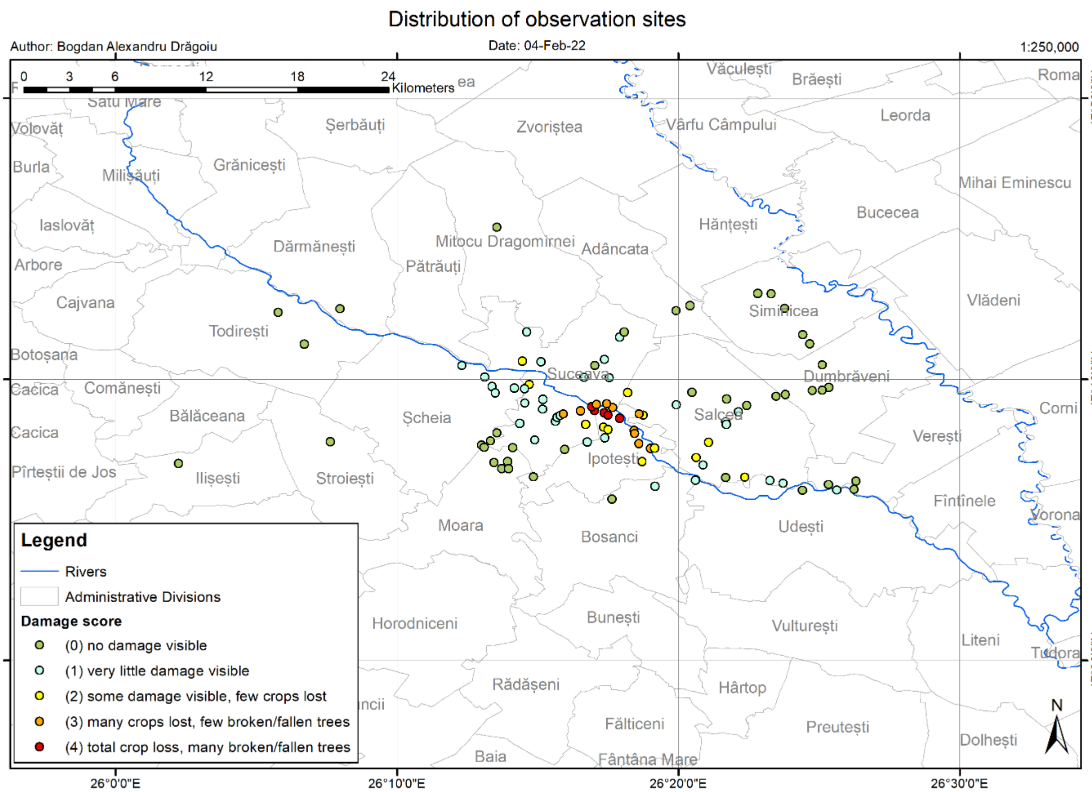


Figure 3 A map of the sites in which observations were conducted.

Vegetation, buildings and infrastructure were checked for visible marks and damage. The evidence was photographed and the coordinates were recorded by GPS. Scores were then assigned to each of these locations and collected into a database for analysis (Fig. 3). The database created contains the following relevant fields: location, address of landmark, description of what was observed (the affected plants/objects and their state) and the damage score.

The final database consists of 100 sites on which the results of this study are based. All observations were made *in situ* and the damage evaluation was done by a single observer in order to preserve consistency. The equipment used was basic. It included a GPS enabled smartphone, the smartphone camera and a DSLR camera. The data was then processed by interpolating the values using GIS software.

Meteorological data for the day of 23 July 2020 is available from several privately owned weather stations operated by radio amateurs worldwide. Parameters such as air temperature, pressure, wind direction and wind speed are typically recorded. This weather station telemetry is then injected into the Automatic Packet Reporting System (APRS). While these personal stations are not necessarily placed and operated in ideal conditions, with some parameters being more prone to measurement errors than others, the data is still valuable and accurate enough for this type of study (Mandement and Caumont, 2019). Moreover, with the increase in extreme weather events witnessed in the past few decades (EASAC, 2018), these stations could provide useful historic data which otherwise would be unavailable. At the time of the storm three of such stations were operational in the vicinity of Suceava: A) YO8KGT Radio Club in Suceava, located near the town's center, B) YO8SKY in Tișăuți (4.6 km South-East of point A), and C) Suceava Airport, LRSV (8.2 km North-East of point A).

4. Results and discussion

During this event the winds damaged over 4 hectares of forested terrain, whereas the accompanying hailstones destroyed crops and even inflicted minor damage to few buildings. The terrain types affected by the storm were varied, including urban fabric, individual vegetable gardens, various crops, parks, grassland, floodplains and more. The full extent of the storm affected over 8000 hectares of land, 1000 hectares of which registered significant crop loss. Even though the storm spanned a relatively short amount of time, from 18^{30} to 19^{00} local time (15^{30} to 16^{00} UTC), the damage in some areas was significant. Signs of damage caused by the storm were visible on vegetation and, to a lesser degree, on buildings. Damage caused by hailstones was best seen on sunflower crops, corn crops and fruit bearing plants, whereas wind damage was best indicated by broken tree branches or, in the most severe cases, by broken or uprooted trees (Fig. 4-11). Signs of damage were also readily observed on grapevine, apple trees, walnut trees, tomato plants and beanstalks. Destruction of wheat fields was less noticeable. In the areas that scored 1 on the damage scale the impact on fruits was minimal and mostly without consequence, as observed in a check-up conducted in the following weeks. In the areas that scored 2 or more on the damage scale, plants and fruits were spoiled to various degrees by hailstone strikes.

The diameter of the hailstones of this event ranged from 5 to 15 mm, rarely larger, averaging 10 mm. The damage caused by both hailstones and winds ranged from minor to extreme, with crops compromised by hailstones and trees broken or uprooted by wind gusts. In the center of the area, where the most damage occurred, some buildings sustained minor damage (pierced exterior PVC paneling, chipped plaster and wooden walls, chipped roof tiles). There was no damage visible on cars or windows of buildings. Some wooden utility poles were also toppled. However, it appears that only one type of utility pole was affected. These were recently installed and, based on records of knocked down poles prior to the event on the 23rd, the assumption of faulty installation of these poles must be taken into account.

Figure 4 A corn field in Moara with no signs of damage (3 August 2020). Damage score 0.

Figure 5 Sunflowers with minimal hail damage in Burdujeni (5 August 2020). Damage score 1.

Figure 6 Sunflower crop with light hail damage in Prelipca (1 August 2020). Damage score 2.

Figure 7 Hail damaged corn field in Lisaura (28 July 2020). Damage score 3.

Figure 8 Compromised corn field in Lisaura (28 Jul 2020). Damage score 4.

Figure 9 Broken and uprooted poplar trees in Lisaura (29 July 2020). Damage score 4.

Figure 10 Highly damaged apple tree near Plopeni (5 August 2020). Damage score 4.

Figure 11 Damaged building wall in Mirăuți, Suceava (29 July 2020). Damage score 4.

Some news reports indicated a layer of hailstones up to 50 cm, but those reports were somewhat misleading, since such depths occurred in ground depressions where the hail granules were transported and deposited by rain water. The average layer depth could not be accurately determined. Based on few measurements taken immediately after the storm and on photos/video taken during and after the event, the average layer depth appeared to be well under 10 cm (Fig. 12).

Figure 12 A garden in Tișăuți during the storm (used with permission from the author, Drăgoiu Andrei).

According to the weather data recorded for that day at the three stations near the storm site, the atmospheric pressure dropped before the storm, followed by an increase during the event. The air temperature values dropped by as much as 10 °C, while wind speed picked up, with gusts exceeding 90 km/h (25 m/s) (Fig. 13a-l).

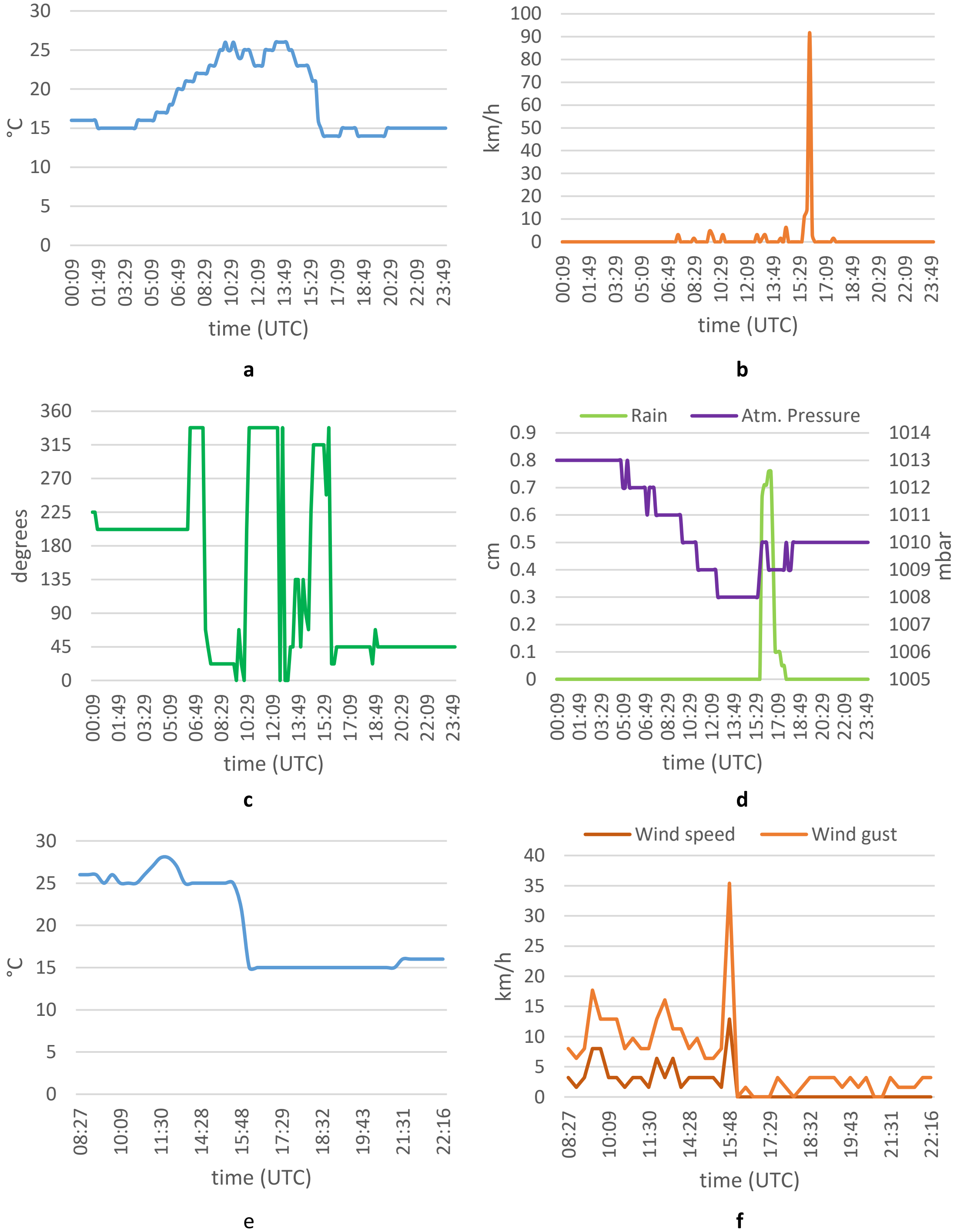
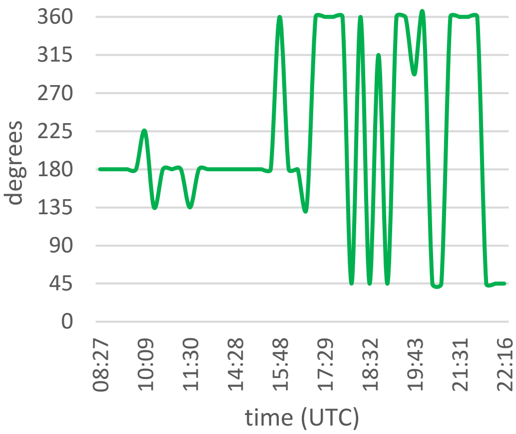


Figure 13 Parameters: a. Temperature at Suceava Center., b. Wind gust speed at Suceava Center, c. Wind direction at Suceava Center, d. Rain and air pressure at Suceava Center, e. Temperature at Tișăuți, f. Wind and gust speed at Tișăuți.



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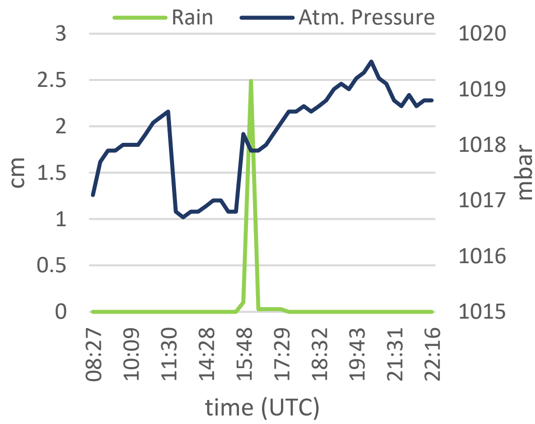

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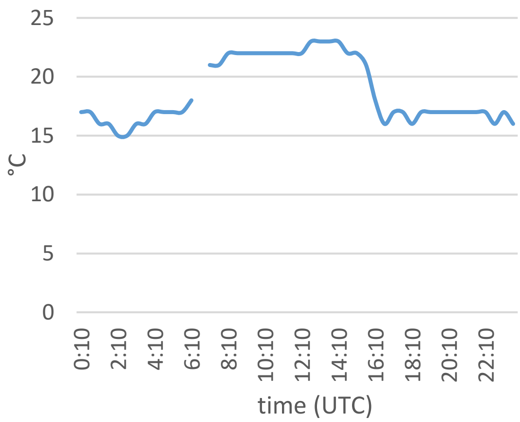

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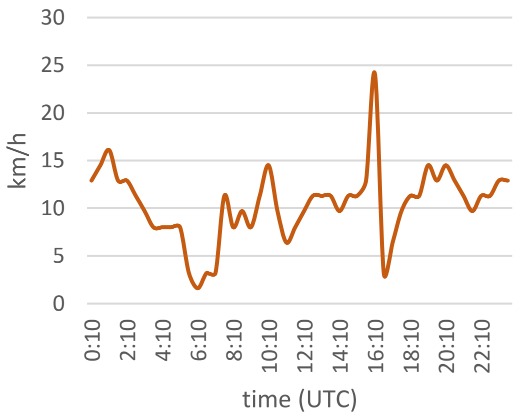

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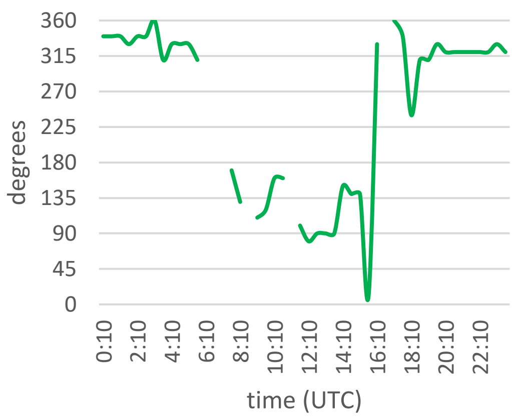

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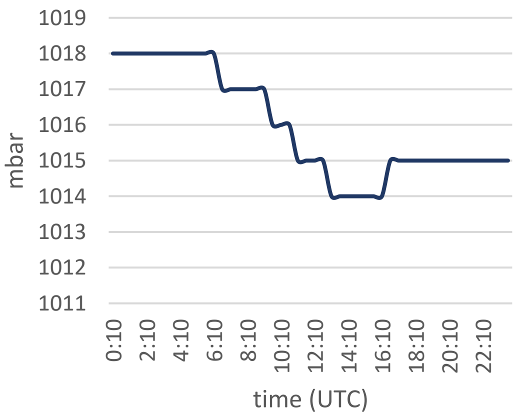

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Figure 13 (continued) Parameters: g. Wind direction at Tișăuți, h. Rain and air pressure at Tișăuți, i. Temperature at Suceava Airport, j. Wind gust speed at Suceava Airport, k. Wind direction at Suceava Airport, l. Air pressure at Suceava Airport.

The map showing the full extent of the damage was modeled by interpolating the observation sites based on their damage value (Fig. 14).

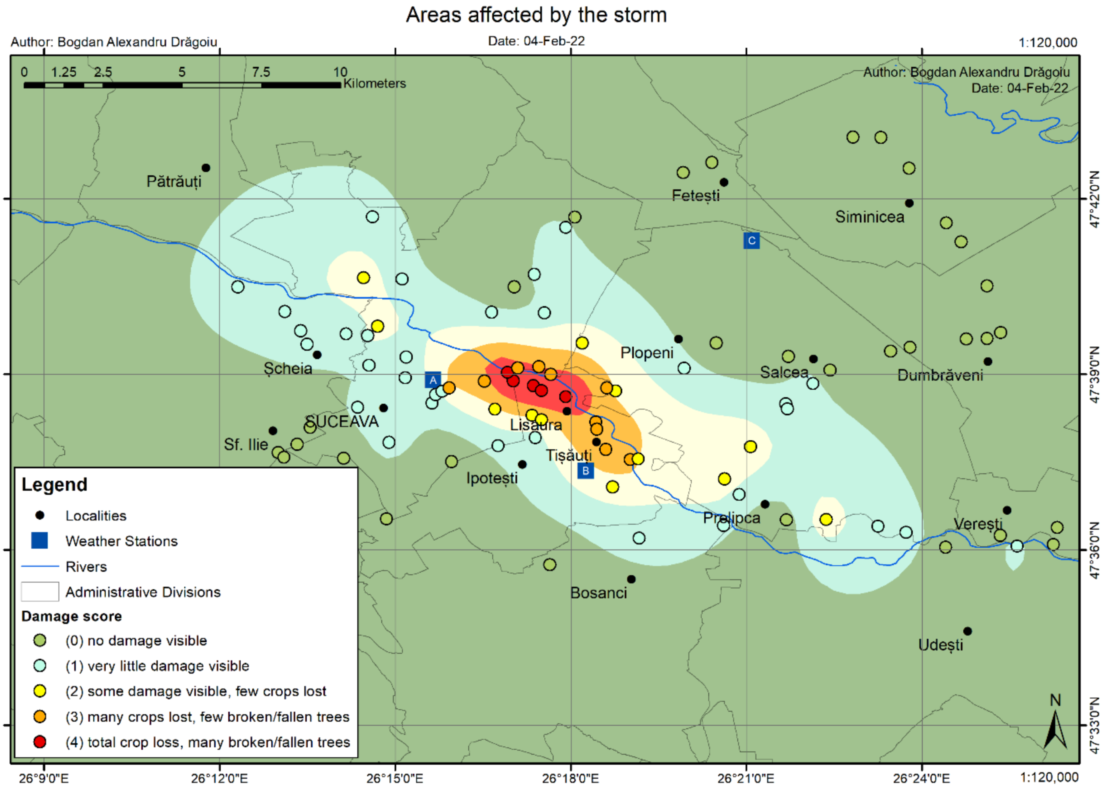

Figure 14 Mapping the damage caused by hailstones and wind gusts. The location of the weather stations from which the graph data was used is marked on the map by the points A (Suceava Center), B (Tișăuți) and C (Suceava Airport).

Some European Severe Weather Database hail reports indicated damage to vegetation with hail diameters of 2 cm and above, while damage to buildings and cars starting with hail diameters of 4 cm and above (Púčik et al., 2019). However, given the observed damage in the case of the event in Suceava, hailstones of much smaller diameters (between 0.5 to 1.5 cm) carry enough destructive force to compromise crops entirely and even cause light damage to buildings.

Assessing the economic impact of this particular event is beyond the scope and the resources of this study, given the extent of the area and the many types of land cover affected. For example, crop damage depends, besides hailstone diameter, on the type of crop, as well as on the location of the crop in the affected area, while damage to buildings is dependent on factors such as hail accumulation on roofs (overloading), the angle in which the hailstones impacted the elements of buildings and the materials used. In addition to crops and buildings there are many other natural or man-made objects that can be affected by high winds, such as trees, power lines, pylons and poles, bridges, vehicles etc., and factoring these in without actual numbers is a challenging endeavor, especially if seeking reliable results.

5. Conclusion

Storms that are accompanied by hail and strong winds are capable of producing significant damage to vegetation, buildings and installations, even in short lasting events like the one that occurred in Suceava on 23 July 2020. In a storm that spanned only half an hour, some 1000 hectares of crops and forested terrain were lost. The entire “footprint” of the storm covered an area of approximately 8000 hectares in Suceava City and the neighboring villages. To better document the effects of the storm, a damage assessment model was created and, based on it, a map of the event. The field work consisted of assessing hail and wind damage sustained by vegetation and man-made structures, on a scale from 0 to 4, with 0 being at one end of the scale, where no damage was observed, and 4 at the other end of the scale, where most damage was observed. The plants and objects showing signs of damage were photographed and the GPS coordinates recorded. The observation sites were selected randomly along various access ways, from the epicenter of the affected area, where most damage occurred, towards the periphery, until no damage related to the event could be observed. A map showing the extent of the storm was created by interpolating the collected data points. Weather data was collected from weather stations privately operated to show various weather parameters before, during and after the event. Personal weather stations, through their dense spatial distribution and availability, could prove a useful tool for tracking meteorological events, especially with the increasing trends in extreme weather in the past decades.

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