A review of flash floods in the Dobrogea Region

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Abstract. The last decade is characterized by an increase in the occurrence of flash floods, fact which is confirmed by the worldwide endeavors undertaken by the WMO (World Meteorological Association) which initiated the signing of a series of memorandums for collaboration with other worldwide institutions meant to lead to the elaboration and implementing of a complex flash flood warning system. The aim of this paper is to analyze the level of implementation of said system in Europe and Romania and the analysis of the flash flood occurrence, specifically in the Dobrogea region of Romania.

1. Introduction
It has become clear that climate change is influencing weather patterns all over the world. Although the impact is not equally distributed or similar everywhere, the effects are noticeable. One of the ways climate change manifests is a change of the rainfall distribution, with vast areas being affected by droughts while others get much more than the average annual rainfall. This is not something we cannot understand or estimate, but the biggest issue is that all previously recorded data is becoming less relevant or reliable as known patterns are becoming no-longer applicable and new issues appear.

This is not an issue for modern weather forecasting since they do not rely that heavily on patterns and have the ability to analyze weather systems in real time based on radar and satellite data, but the same cannot be said about flood protection. Classic flood management design is based on annual average flows in a section of the river bed, and annual average flows are based on previously recorded data. So, if one would be working on the design of a specific river bed calibration, the norms would tell him that he needs to work, starting from the average multi-annual flow, determining the flood return probability (for which the standard across the EU is 1% in localities). The issue here is that the determination of said flood return probability, although mathematically correct, in the context of changing weather patterns, the results will be erroneous for present-day use, and what would have been 1% flood return probability in the past, is no-longer valid. (One could use historical maximums as a guide, but that data is not necessarily available everywhere, depending on whether or not there has been monitoring and recording of the watercourse levels and related rainfall.)

At the same time, human development within the basins is proving to be an important influence in the behavior of rain water that runs off the terrain adding another level of modification of the previously recorded data and thus making it less accurate. Deforestation is a major factor in runoff, but other modifications of parts of the basin are equally important for the changing of runoff behavior, such as
landscape management (changing perennial vegetation to grass lawns) or transport infrastructure (concrete/asphalt roads) [1] which may have a strong influence on runoff (concentration times of the flood wave).

All of the above leads to an increase in the occurrence of flash floods or the situations where rainfall is characterized by relatively large flows over short periods of time, causing all sorts of problems in the basin. Flash floods are becoming more and more common in relatively small basins throughout the world, and their parameters vary to such an extent that in some cases even relatively low rainfalls (10 - 20 mm) may cause issues if it rains in a short enough interval. As a reference, most of the flood damage and material losses in the Dobrogea region (Romania) was caused by flash floods which, considering the local geography and thus the typical geometry of the basins combined with the specific vegetation (mostly steppe and shrubs, very little forest coverage), results in a particular flooding pattern. In the past years, most flood damage in Dobrogea was due to runoff concentrated on the slopes, or activation of dry beds (torrents) rather than overflowing of a main (permanent) watercourse.

An analysis of the official flood data for the Constanta County shows that in the past 7 years (2014 - 2020) only 7.22% of total registered flood damage was due to overflowing of rivers, and that is mostly due to the river Danube causing minor floods in 2015. In the last 5 years (2016 - 2020) only 0.89% of total flood damage is due to overflowing of rivers, the rest is all due to flash floods and runoff. At the same time, 100% of flooded homes are due to runoff and not overflowing of rivers. This shows that the riverbed management is relatively efficient, given the weather patterns, and only runoff on the slopes and dry riverbeds (torrents) is problematic and needs to be studied further and managed better. It is thus important to properly understand methods for evaluation of flash floods and the way they adapt to different scenarios in order to get the most accurate results.

2. Description of flash floods
Flash floods are described as flooding that takes place in a short amount of time so short that it may present no warning. It may be the case of heavy or moderate rains depending on the time interval but also the case of broken dams or melting ice or snow. Generally, the accepted notion is that of any flooding that takes less than 6 hours to manifest from the initial cause (rainfall, etc.) to the flooding effects. Flash floods can manifest locally, or where the generating factors take place, or it can manifest downstream as runoff reaches the riverbed naturally or by means of drains and ditches, cumulating to a flow that surpasses the riverbanks and floods the downstream sector. Worst case scenario are natural Flash floods encountered in areas with canyons, where water level may rise suddenly and without the giveaway signs of local rain because the actual rainfall took place several kilometers away (upstream). Similarly, dangerous flash floods are those generated by human objectives such as the breach of a dam which will suddenly release a vast quantity of water in the downstream sector. Of course, there can be mixt scenarios, such as heavy rainfall causing human objectives to fail thus contributing to the creation of a flood wave. One such example in the Dobrogea Region is the flooding of Costinesti/Schitu in 2005. In the context of unusually heavy rains (over 300 mm) a railway embankment acted as a dam collecting water behind it until the embankment gave way to the water pressure and everything downstream was washed by a 2m high flood wave that destroyed homes and other buildings and breached its way to the Black Sea by means of a huge ravine in the beach.

Because heavy rains in a short time period is a characteristic associated with convective rain, worldwide they are implicitly attributed to hurricanes or other types of tropical storms. Still, although tropical storms imply convective rain, that does not mean it is the only possible scenario and convective rain does occur elsewhere.

3. Impact
The impact of flooding is a well-known fact with two major components, respectively the environmental impact and impact on human habitation. Floods can cause severe disturbance in ecosystems or in some cases it can entirely destroy local ecosystems.
Flash floods are often associated with high velocity of water flow which tends to destroy vegetation, carrying logs, mud and sometimes boulders downstream, as well as other debris, and depositing them all around the path of the flooding. This can lead to the destruction of certain specialized species that develop in the floodplain area causing imbalances in the ecosystem. It can take years or decades for the ecosystem to recover and some species might be lost altogether either completely destroyed by the flood, or by the modification of the riverbed (modification of spawning grounds for fish, etc).

The impact on human habitation is also severe leading to loss of property, loss of revenue or famine due to destruction of crops, and worst-case impact results in loss of life. From the loss of life perspective, flash floods are more likely to be associated with casualties due to the speed of manifestation of the flood effects which does not allow enough time for flood defense or evacuation measures to be put in place and sometimes victims don’t even realize the immediate danger.

This study is focused on the evolution of the flash flood in Dobrogea region. Dobrogea is located in south-east of Romania between the lower Danube and Black Sea (figure 1).

![Figure 1. Dobrogea region [2].](image)

From the climatic point of view, Dobrogea region could be divided in two regions [3]: (i) the Eastern region (20 – 50 km on the littoral) which comprises the territory of Danube Delta, its south and the Razim Sinoe lagoons and; (ii) the western region. The climate of first region is continental influenced by the Black Sea and the second one has a temperate continental climate. The average temperature decreases from the Black Sea and Danube towards the interior: the temperature on the coast varies between 11.7°C (Constanta) - 11.6°C (Mangalia) and 9.9°C (Corugea – in interior of Dobrogea). The annual precipitation varies in wide limits (260 – 500 mm approximately), the highest values being registered in the North and center of the region [4]. This area is subject to frequent droughts since it’s average precipitation is much lower than the country average of 600 – 800 mm. The Black Sea presents a strong influence on the air humidity throughout the Dobrogea region, but strongest within the first 15 - 25 km from the shore.

The hydrographic network consists of rivers that are generally under 50 km long with very low multi-annual mean flows of 0.43 m$^3$/s (Telita) to 0.64 m$^3$/s (Casimcea). The area, especially in the
central and southern sector is littered with hills and hundreds of dry valleys, and generally little forest coverage.

An analysis of the County Operational Reports Regarding Dangerous Meteorological Phenomena [5] for the Constanta County shows that in the past 7 years (2014 - 2020) only 7.22% of total registered flood damage was due to overflowing of rivers, and that is mostly due to the river Danube causing minor floods in 2015. In the last 5 years (2016 - 2020) only 0.89% of total flood damage is due to overflowing of rivers, the rest is all due to flash floods and runoff. At the same time, 100% of flooded homes are due to runoff and not overflowing of rivers. This shows that the riverbed management is relatively efficient, given the weather patterns, and only runoff on the slopes and dry riverbeds (torrents) is problematic and needs to be studied further and managed better. It is thus important to properly understand methods for evaluation of flash floods and the way they adapt to different scenarios in order to get the most accurate results.

![Repartition of flood damage in the Constanta County between 2014 and 2020](image)

**Figure 2.** Repartition of flood damage in the Constanta County between 2014 and 2020.

Total recorded damages due to flash floods in the Constanta county, for the specified interval was 77.22 million lei. The precipitation context was a normal one, without many record rains being registered in this interval, with one notable exception in October 2015 when the locality of Corbu was affected by flash floods caused by a rainfall of 122 mm in about 3 hours (175.8 mm in the 24h interval). The interesting characteristic of this particular flash flood is that the intense rain only manifested over a small area of about 10 km² [6].
Total recorded damages due to flash floods in the Tulcea county, for the specified interval was 22.98 million lei. The precipitation context was a normal one, without many record rains being registered in this interval. The year 2015 was a little different because in the winter there were precipitations (snow and rain) that accumulated (an estimated 200 mm in some places) and when the spring thaw came, together with a relatively high level of the river Danube, vast areas of farmland were inundated because of high ground water levels and the soil being saturated. As this is not a phenomenon that occurred fast,
it cannot be associated with flash floods and so it was considered similar to an overflowing of the river Danube and categorized as such.

Generally, the coast, the east and south-eastern part of Constanta county are more affected by the flash floods (figure 5).

From a spatial point of view, the available data shows that the flash flood situations tend to manifest over relatively small areas at a time, although about 50% of the time the reports show that multiple localities were affected. The local geometric parameters of the basin are reflected in the reports as some localities situated in sloped areas or surrounded by hills have multiple reports of flood damage. This is consistent with known runoff patterns.

The maximum registered rain for the Dobrogea area in a 24-hour interval, as reported in the flood reports was 175.81 mm, in the Constanta county in the year 2015. Tulcea county has a maximum rain of 82.6 mm in 24 hours, reported in the year 2016. For the specified time interval, Tulcea county reported higher average rains (37.86 mm) than the Constanta county (31.59 mm). The latest research [7] demonstrates a trend in the extreme rainfall frequency occurring which could lead to an increase in the number of flash flood events. In this respect, a strategy for flash flood assessment and management must be created and implemented.

![Figure 5. Repartition of localities affected by flash floods in the Constanta county – 2014.](image-url)
While the data shows a somewhat constant pattern of flash flood (runoff) damage in the Constanta county, whereas Tulcea county has great variations from one year to the next, we believe this might be due to issues in the reporting process.

Some local authorities have obligations regarding flood damage intervention, and when they can intervene and don’t have to ask for county help, they might not report the flood damage at all. Although reporting is mandatory, we know from experience that some local authorities fail to do so in a proper and timely manner. The two counties have a different local and county level approach to reporting proceedings and we assume that the data for the Constanta county is more accurate, but not by a very large margin. This impacts the whole evaluation giving it an error margin that we estimate to be of up to 30% of reported flood damage, although it is impossible to accurately evaluate the error margin given the lack of available information. In the time interval, a gradual improvement in the detailing and accuracy of the reports is noted which shows a better understanding of the importance of the evaluation and reporting activities. We estimate this to be the result of the awareness campaigns and personnel training led by the D-LWBA in the last 5 years.

4. Conclusions
The financial impact of flash floods is significant, especially due to the fact that when compared to other flood types it represents 88.66% of all registered flood damage. Value-wise, the total registered damage was evaluated at over 113 million lei (a rough equivalent of 23.2 million Euros), of which over 100 million lei (20.5 million Euros) are attributed to flash flood damage. The information regarding flash flood damages, unfortunately, is incomplete, as many localities don’t report every event or only report it partially due to lack of trained personnel for the evaluation of flood damage and the proper reporting of flood-related events. The financial evaluation is not very accurate as well since many of the properties situated in the rural area don’t have a clear financial value associated and thus it must be determined indirectly, or by using general values (lump sums). Because of this difficult process, some damage is not even recorded or disregarded as too little to justify an evaluation. While this might be the norm and the populace has learned to cope with minor to medium effects of floods (not flood resilience but rather a traditional acceptance that the effects are impossible to avoid), it generates errors in the appropriate evaluation of damage due to flash floods diminishing the actual value and giving a false sense of a smaller scale. The evaluation itself is not the objective of this paper so we will not study it.
but rather mention the fact that actual damage and associated values are higher than what is officially recorded.

A secondary issue is the uneven coverage of rain gauge stations and thus potentially incomplete data sets for a relevant analysis. At times, one has to rely on rain data from a rain gauge located over 30km away when reporting, and that data isn’t reliable considering that rainfall cannot be considered uniform at such distances. This limits one’s ability to properly correlate rain intensity to flood damage. The Constanța county, for example, has some 40 permanently monitored rain gauges administered by the Dobrogea-Littoral Water Basin Administration. Considering the county’s total area of 7071 km², an average coverage of 176.77 km² per rain gauge results. While considered a normal coverage, [8] concludes that even under ideal situations the representativeness or auto-correlation length of precipitation is surprisingly small when measuring a correlation factor of 0.5 between rain gauges located just 4km apart. A recent study [9] points that the optimal rain gauge coverage is of about 25 km² per station. The spatial distribution is less than optimal though and in the Constanța county they provide some cover for the northern and central part of the county, while the south and the south-east of the county has very poor coverage, with vast areas not covered. Although modern methods make use of radar and satellite rainfall data, they can be prohibitively expensive for some areas, so rain gauges are still a necessity, albeit they may be automatized and designed to require as little logistics as possible.

As a consequence, in some of the reports we were unable to determine the exact time of the rainfall or the average rainfall. One way this issue is treated is the borrowing of data from private sources, such as local agricultural enterprises which sometimes have their own rain gauges, or local administration (mayor’s office). This data may prove unreliable since the administrators of the rain gauges may have no training in using them and have no permanent monitoring or monitoring protocols, and the whole process of identifying “private” rain gauges is based on luck and the willingness of private entities (3rd parties) to share their data.

A complex monitoring and early warning system under the tutorage of the World Meteorological Organization is the Flash Flood Guidance System, or FFG. This system is based on multiple input sources (radar and satellite forecasting, soil humidity, etc.) in order to constantly assess the flood risk and produce early warnings. This system has proven useful and effective in Turkey according to Ertan Turgu [10]. In Romania, this system is being tested by the National Institute for Hydrology and Water Management but it still needs to be calibrated in the many different basins and is not yet in general use in Romania. While the relevance and necessity of such a system are clear in the context of climate change and the resulting increase in flash flood occurrences, the implementers of the FFG system in Romania will have to find solutions to known issues, shown before, in order for it to represent a reliable information and early warning platform.

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