A concept for flood early warning

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Abstract. Bulgaria is exposed to a number of natural hazards and risks negative consequences have a significant impact on the environment and the population, industry, infrastructure, cultural heritage, etc. Floods are the second most common disaster in Bulgaria. In the present work a statistical analysis of the floods in Bulgaria for the period 2010-2020 is made. The present paper also proposes an idea for an early warning system for floods. The idea is to work on early forecasting, which will help to timely notify municipalities and regional fire departments in order to quickly control the floods and its consequences.

1 Introduction

A flood is a natural hazard, a natural phenomenon that is the result of heavy rainfall, intense snowmelt, ice, sliding stones and lumps causing flooding of riverbeds, rains that uproot trees, destroy buildings, etc. They can also be caused by huge waves (tsunamis) along the ocean coast due to earthquakes, volcanic activity, cyclones, tornadoes, storms, etc. Major flooding of our inland rivers dates back centuries due to torrential rains.

Although flooding is a natural phenomenon, human activity and intervention can be significant, such as alteration of natural riverbeds related to urbanization, agricultural activities and deforestation, changes in river basin conditions, etc. Earth's climate is changing rapidly and the likelihood of flooding is expected to increase. In recent years, floods in Europe caused a lot of damage - loss of human life, property, crops, etc. A flood is a natural disaster in which parts of the earth's surface are inundated with water [1]. Unlike other natural disasters, floods are highly predictable both in terms of their occurrence and distribution, and in terms of possible consequences. The floods appearance is largely influenced by human activity and human intervention in natural processes. During the last decade, the problems related to flood appearance in Bulgaria have been intensively studied [2, 3, 4]. The aim of the current paper is to achieve a positive impact, sustainable change and the prevention and assessment of flood risk, management and mitigation of the consequences of floods in the territory of Bulgaria.

2 Floods in Bulgaria

European Commission's guidelines contained in the "Draft list of flood types and stand consequence" from 16.02.2011 distinguish some types of floods according to their source:

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- River floods – inundation of land by water from natural or improved drainage systems. Such floods are caused by rivers, drains, mountain streams, short-term one-off and/or periodic flows (e.g. inland), etc.
- Flooding from heavy rainfall – due to heavy rainfall, the drainage infrastructure in densely populated areas or the natural ability of soil outside populated areas to absorb rainwater cannot absorb the large volumes of water.
- Groundwater flooding – groundwater rushes to the surface. This process may be due to a sudden increase in groundwater, which is also often associated with high surface water levels.
- Marine flooding – Flooding from seawater, estuaries or coastal lakes. This flooding can be caused by extreme tidal levels, sustained high winds, and large waves such as coastal tsunamis.
- Infrastructure flooding – from artificial reservoirs or drainage facilities. They can be caused by accidents or insufficient capacity of reservoirs (dams), treatment plants, water supply and sewage facilities.
- Snowmelt flooding - can be combined with precipitation or ice jamming/blocking.

According to the mechanism of occurrence, floods are divided into:

- Natural overflow - inflow of water above the water level capacity of a drainage, river bed or bank.
- Spill protection structures – e.g. spillways or embankments.
- Failure of protective or infrastructural facilities – for example, breaching and failure of a dam wall or failure of pumping equipment.
- Blockage/Retention of water – due to blockage of the natural path of water drainage such as silting under bridges from natural sediments or municipal waste. According to the frequency of occurrence, floods could be divided into:
- Flash flood – occurs quickly and without the possibility of prediction. It is usually due to intense rainfall over a relatively small area.
- A flood with an average rate of occurrence – occurs more slowly than a flash flood and has some chance of being predicted.
- Slow-onset flooding – takes longer than average to develop. It can be predicted relatively early.

Depending on the intensity, recurrence and impact on the environment, hydrometeorologists give the following classification of floods [1]

1. A small flood occurs once every 10-20 years and the lowest part of the riverbed flows out without causing damage.
2. Dangerous floods – every 20-40 years the river submerges the adjacent river terrain in a large section. They can cause damage and pose a danger to people and animals in the immediate vicinity.
3. Highly dangerous floods - They happen every 40-80 years. Rivers flood a lot at dangerous depths (over 1 m) and velocities (over 20 m/s). Damage to bridges, culverts, retaining walls, adjacent land, buildings, etc. They pose a major threat to coastal residents.
4. Extraordinary floods - every 80-150 years the river submerges all or most of the river valley, the water depth exceeds 1.5-2 meters, the flow speed is 2.5-3 meters per second and the river instead flows along the valley of the river bed and bridges that undergo major changes, dams, buildings, hydrotechnical facilities are destroyed. They cause enormous material damage and casualties.
5. Catastrophic floods - 1 time in 150-200 years. Huge territories are flooded, the river valley is submerged and the water flow is completely oriented along it.

3 Assessment of floods in period 2010-2020

According to the Water Act, in Bulgaria there are defined spate areas called "Project units". The methodology sets criteria for determining the boundaries of the project units with aim to optimize the work. Bases for determining the project units are major river basins, some of which are divided into two or more units. The main criteria for separation of project units are the areas of the basins (Figure 1).

Fig. 1. Map of the Basin Districts in Bulgaria.

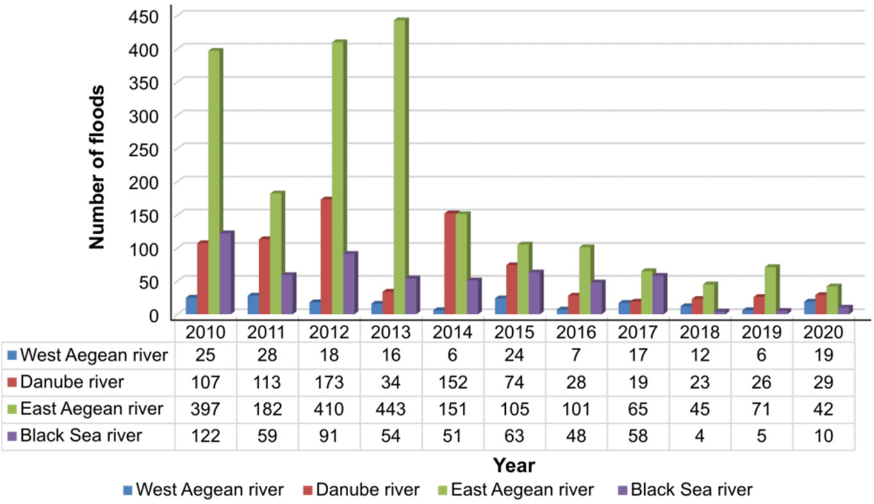
Each of this basin district has a number of river. The name of the river and their catchment is given at Table 1.

Table 1 Rivers and river catchment in each district area [5].

Region	River	River catchment km2
West Aegean	Struma	8545
	Mesta	2789
	Dospat	636
Danube	Erma	436
	Nishava	701
	river west of Ogosta	3910
	Ogosta	4282
	Iskar	8633
	Vit	3227
	Osam	2838
	Yantra	7861
	Rusenski Lom	2985
	Danube Dobrudzha river	8140
	Danube	4217
East Aegean	Maritsa	34166
	Tundzha	8429
	Arda	5795
Black Sea	Batova	339
	Provadiya	2131
	Kamchiya	5358
	Severnoburgas	2185
	Mandren	985
	Yuzhnoburgaski	133
	Veleka	995

	Rezova	183

Distribution of the number of flood in period 2010-2020 per basin district is given at Figure 2 [5].

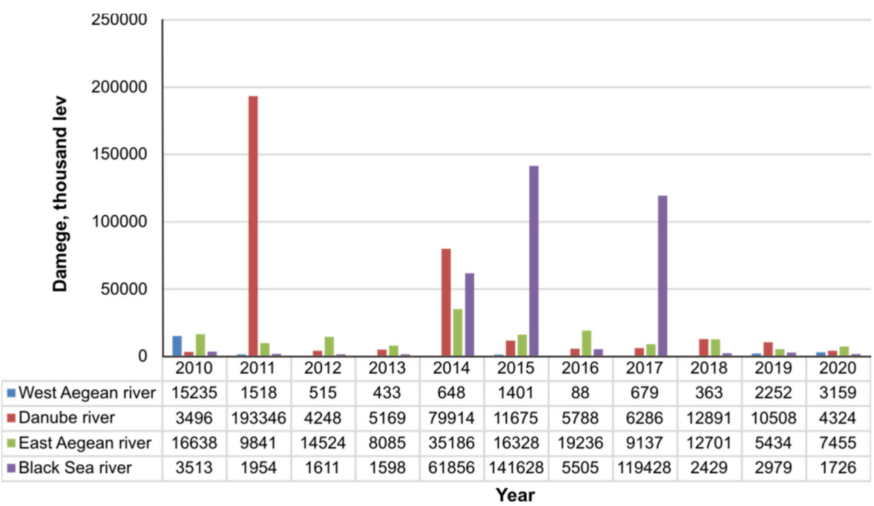


	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
West Aegean river	25	28	18	16	6	24	7	17	12	6	19
Danube river	107	113	173	34	152	74	28	19	23	26	29
East Aegean river	397	182	410	443	151	105	101	65	45	71	42
Black Sea river	122	59	91	54	51	63	48	58	4	5	10

Fig. 2. Floods in Bulgaria in the period 2010-2020 [5].

The most of the floods are in East Aegean river region followed by Danube river region. This can be explained by the fact that we have rivers with the largest river catchment, which is also observed in the second case. There are least floods in West Aegean rive region where the smallest watershed is located. There has also been a decrease in floods in recent years, which can be attributed to the fact of better awareness among the population. In the next section, an integrated system for early prediction of floods in populated areas is proposed.

In Figure 3 is given the damages which the floods costs. It is very clear that the flood damage does not correspond to the number of floods by region. This shows that depending on the type of flood and its strength, it logically leads to greater losses in BGN. Therefore, one forecasting of the floods would lead to a reduction of the damages from the floods on the territory of the Republic of Bulgaria.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
West Aegean river	15235	1518	515	433	648	1401	88	679	363	2252	3159
Danube river	3496	193346	4248	5169	79914	11675	5788	6286	12891	10508	4324
East Aegean river	16638	9841	14524	8085	35186	16328	19236	9137	12701	5434	7455
Black Sea river	3513	1954	1611	1598	61856	141628	5505	119428	2429	2979	1726

Fig. 3. Damage from floods in period 2010-2020 [5].

4 System for early warning

Based on the data shown for floods and damage in Bulgaria, it can be seen that this is a huge problem for the country. There is a great need for early warning of the population and the services for floods. If the flood is detected earlier the smaller the consequences will be.

At the Figure 4, an early warning system is proposed, which will be placed on bridges before settlements in order to warn the population of flooding. [6-8]

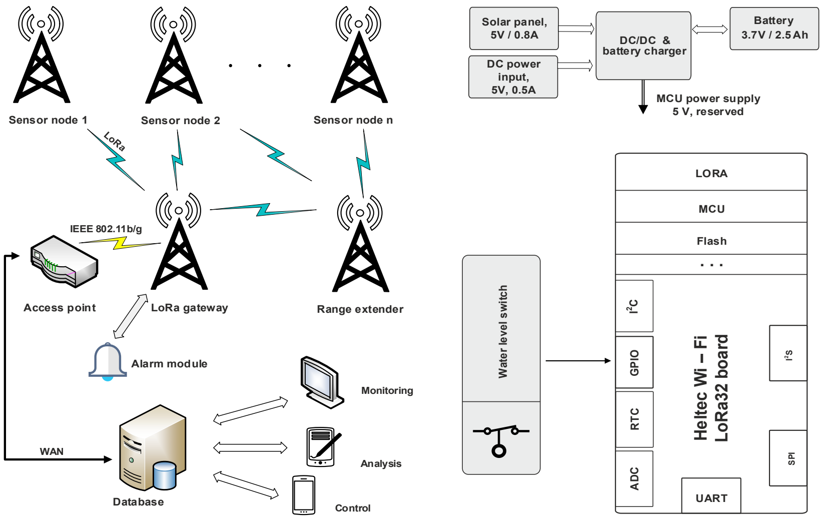


Fig. 4. Scheme of proposed early warning system.

The system is implemented based on spread spectrum transceivers (LoRa), which provides large area coverage while keeping power consumption low. A large number of sensor nodes can be easily added, and one or more range extenders can be added if more distance is needed between them. With the devices we tested, a distance between the sensor node and the gateway of the order of about 10 km is achieved outside of populated areas in direct line-of-sight and about 2.5-3 km in populated areas and in the presence of more buildings. The gateway, besides performing the standard functions of information exchange between the two different network topologies(Wi-Fi and LoRa), in this particular application also triggers the alarm output, which ensures reliable operation of the system even in case of problems or absence of internet connection. The connection to the internet and the recording of the data in a database is more to facilitate remote diagnostics and to ensure system availability. Each of the sensor nodes transmits to the database its unique identification number, the battery charge level and the status of the contact that opens when the water level is high, at a specific programmable time interval (in this case an interval of 30 sec. ÷ 2.5 min.). The identification numbers of all sensor nodes are available at the gateway, so that if there is no communication for more than 5 minutes with any sensor node, a warning is displayed that there is most likely a problem with that particular sensor node, so that adequate measures can be taken to restore the full functionality of the system. When a contact is opened, the sensor node starts transmitting a signal to this effect every 2 seconds, in which case no battery level is monitored and sending the signal has the highest priority. Particular attention has been paid to redundancy of the sensor node power supply. Each node is powered by a high capacity Li-Po battery (2,5Ah) capable of providing autonomous operation of the sensor node for at least 3 days. The battery is charged by a solar panel which is capable of charging it from 10% to 80% in about 4-5 hours. Each sensor node has been developed based on Heltec Wi - Fi LoRa32 board. Range extenders have been implemented with the same board, and here also solar panel power has been used so that they can be installed in remote areas where mains power is not available. The Gateway is installed in a location with internet connectivity and where the decision center is located. Network power is usually available there, so only a battery is needed to ensure power redundancy.

5 Conclusion

An analysis of floods in Bulgaria for period 2010-2020 is given. This can be very helpful for assessment of the risk of floods in Bulgaria. It is presented an idea for early warning systems for floods, which are extremely necessary for our country, and in order to protect people and environment. The proposed integrated warning system can help reduce damage to floods, as well as to warn the population located near places of floods. Incorporating flood risk assessments into planning and in the management of densely populated areas subject to high risk of floods and implementation of damage avoidance measures will contributed to increasing the sustainability of the built environment and others infrastructure.

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References

1. D. Slavov, Pr.Int.Sc.Con.D.T., (2021)
2. V. Spiridonov, S. Balabanova, Climate and Land Use Impacts on Natural and Artificial Systems, (2021)
3. R. Velichkova, IOP Conf. S. M.S.E **878** (2020)
4. R. Velichkova, R.Angelova, I. Simova, E3S W. of C. **207**, (2020)
5. www.nsi.bg
6. S. Antonov, CreBUS 2019; Category number CFP19U17-ART; Code 152084,(2019)
7. D. Stoitseva-Delicheva, V. Karlova-Sergieva, A. Marinchev, V. Galabov, Ch. in H. E. &R, pp. 18, (2019)
8. I. Kralov, J. Genov, I. Angelov, IOP M. S. and En., 878(1), 012036, (2020)