Windstorms and flood risk management

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Abstract

Floods are a constant threat to life and property. In the past 30 years, floods have been the most catastrophic natural disaster, affecting about 80 million people per year on average, or half of the total population affected by any natural disaster, causing economic damage. The number of people affected by riverine floods has been increasing in recent years. As increasing human activity downstream of rivers results in greater flood damage, the floods themselves, in turn, are also increasing in size and frequency due to human activities in the upstream section of the river system. An increasing trend in extreme flood events can be observed in many countries not around the world but also within a Pardubice region. The Pardubice region is mostly flat country, so the windstorms and floods have increasing influence in comparison with all other disasters. In contribution will be discussed risk model containing two cores flood and high wind

Key words: Risk management, Entropy, Flood, Wind

JEL Classification: D89, M15, Q 54

1 Introduction

Generally risk management can be defined as the culture, processes, and structures that are directed towards the effective management of potential opportunities and so on. Risk assessment involves estimating the level of risk – estimating the probability of an event occurring and the magnitude of effects if the event does occur. Essentially risk assessment lies at the heart of risk management, because it assists in providing the information required to respond to a potential risk and in case of the spatial approach taking into account the critical infrastrucure.[28], [20]

In a resource management setting, environmental risk assessment may be used to help manage, for example:

- natural hazards (flooding, landslides),
- water supply and waste water disposal systems, and
- contaminated sites
- critical infrastructure..

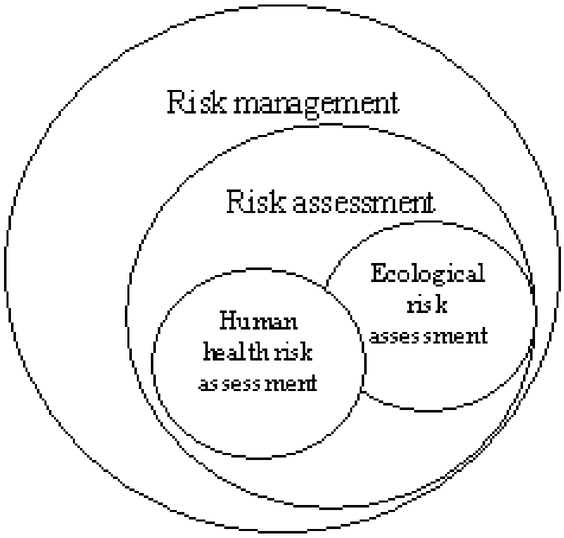


Fig. 1 Risk managewment according [20]

2 Flood Risk Management

There are three components determine flood risk i.e. flood hazard, vulnerability and exposure. However, flood risk has been defined in several ways in the natural hazard literature; however one of them is the following definitions framework:

- Hazard: the threatening natural event including its probability/magnitude of occurrence
- Exposure: the values/humans that are present at the location involved
- Vulnerability: the lack (or loose) of resistance to damaging/destructive forces

Flood risk can be mathematically calculated as the product of hazard, exposure and vulnerability. By following this approach a large GIS database can be designed and developed in order to spatially represent the three components of risk.

Floods have become a serious problem lately so the proper response of the human society is necessary to save human lives and properties. In according to [10]: "Flood risk management is the process of data and information gathering, risk assessment, appraisal of options, and making, implementing, and reviewing decisions to reduce, control, accept, or redistribute risks of flooding." Flood risk management has to take into account large amounts of data, interrelationships between all risk management measures. Improved and remote access to available data and models, sharing and communicating risk analyses can significantly help flood risk management [3], [10]. A simplified diagram of the quantitative risk assessment is shown in the Figure Spatial matter is not explicitly expressed in the figure but it is hidden behind almost all the steps.

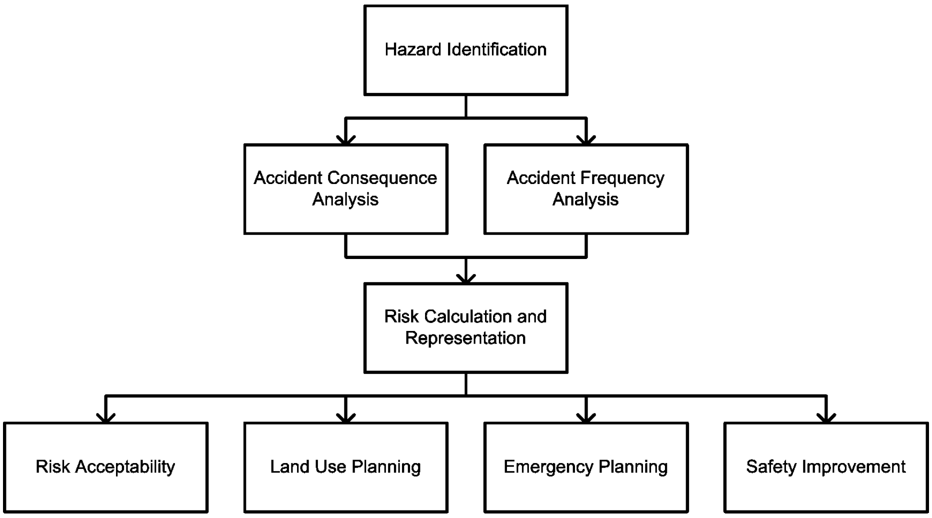


Figure 2. Simplified Diagram of the Quantitative Risk Assessment [3]

During the risk management process it is very important to protect critical infrastructure **Error! Reference source not found.** which can be significantly impacted by flooding as well.

Disasters like floods are connected to a certain place so GIS are very often used to evaluate and model their possible impacts. For example, a modelling and simulation system called CIMS was designed to allow modelling of cascading effects and interdependencies of the critical infrastructure. The system uses agent-based approach to model infrastructure elements, the relations between elements, and individual component behaviour. CIMS can be used for simulations of possible impacts. Genetic algorithms and multiple criteria multiple alternative DSS (Decision Support System) algorithms are used as the most important methods [6]. Next example of multi-agent approach is French study which proposed a simulation model to prevent the flood risks in an agriculture landscape [14].

Project named “Water Risk Management in Europe - WARMER" can be given as an example of EU funded activity aimed to support design of a real-time web-based system for risk management. In this project, remote sensing data are combined with in situ measurements. A prototype of the web-GIS (named DISPRO) was formerly developed and then used to provide access to various types of information. DISPRO supports OGC WMS [30].

A hierarchical risk-based analysis framework was created in the UK [23]. It is a three-tiered methodology which uses risk-based probabilistic approach. It provides simulation-based reliability analysis of system and simulation modelling of inundation at the most detailed level.

Many methods take into account surface and use remote sensing data coming from various sources, e.g. [22]. Another work used a system engineering approach, 2D mathematical modelling methods and GIS to carry out a risk analysis [5]. Sensor networks are used to monitor river basin and provide early warning flood detection service [1].

The entropy principle was used to assess regional uncertainty and indirectly the regional information available about floods within a basin [11].

2.1 Assessment of risks by means of entropy

Two risks were chosen for assessment: the flood inundation probability and wind velocity for selected region. At first tables for flood we created showing how much the landscape was inundating due to various x-year water levels (in percentage share) – see Table 1. The second step was to create table for wind covered landscape with different wind velocity intervals, again in percentage share – see Table 2.

For the expression reduction uncertainty of the basin about flood and wind events in regional scale, the entropy and joint entropy was chosen. Although the entropy principle has been usually used in the form of POME (Principle of Maximum Entropy) to infer on distributions of flood events [26], (1), it may also be employed as Shannon's informational entropy [11] to assess the regional information about floods and winds within a basin.

$$H = -\sum_{i=1}^{n} p_i \log \frac{p_i}{m} \qquad (1)$$

Where *m* is a suitable measure over the space of possibilities (hypothesis space).

In our case the Shannon entropy (2) and joint entropy (3) [4] were used for forecasting risk caused by both, flood and wind, with a focus on the Pardubice district. Low value of the entropy and/or joint entropy signalized less risk and high values signalized increasing risk, respectively.

$$H(z) = -\sum_{i=1}^{n} p(z_i) \log_2 p(z_i) \qquad (2)$$

For independent event the joint entropy was used. If we denote z_1=flood, (f), and z_2 =wind, (w), the joint entropy will be [4]:

$$\mathrm{H(f+w)} = \mathrm{H(f)} + \mathrm{H(w)} =$$
$$= -\sum_{i=1}^{n} p(f_i) \log_2 p(f_i) - \sum_{i=1}^{n} p(w_i) \log_2 (w_i) \qquad (3)$$

Increasing entropy means higher risk level and from system theory it means disorganization of the system.

Table 1. Percentage Water Landscape Coverage due to x-year Water

X-year Water [No. of years]	Percentage Share of Landscape Inundating [%]
5	1,43
10	1,86
20	2,44
50	2,98
100	3,98

Table 2. Percentage Wind Landscape Coverage

Wind Velocity [m/s]	Percentage Share of Landscape Covered by Wind [%]
4,01 – 5,0	10,00
5,01 - 5,5	28,34
5,51 - 6,0	25,98

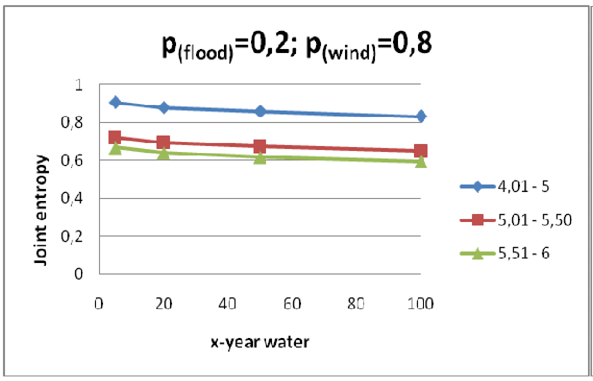
3 Results

Pardubice district was selected for our case study. It is a small area in the Czech Republic. Its area is 890 km^2. It is a very flat region around the biggest Czech river Elbe, located a little bit above 200 m above sea level. There is just one important mountain in the region – Kuneticka hora (307 m above sea level).

Available risk management methods (e.g. flood management) usually concentrate on a precise prediction of one risk. In the case of flooding they concentrate on providing early warning or precise modelling and simulations.

For our case study we chose different approach – to combine two or more risks to provide quickly and overview results which are not aimed at crisis management at this moment. The results should provide introductory information to everyone who is interested – i.e. people willing to buy a new house, etc.

Results of entropy calculation are graphically shown in following pictures, where $p_{(flood)}$ means probability of the flood taking into account x-year water level and landscape inundates in percentage share, and $p_{(wind)}$ means probability of the wind taking into account landscape coverage (in percentage share) by wind with different wind velocity intervals. **Error! Reference source not found.** shows flood inundation entropy calculated for the Pardubice district, **Error! Reference source not found.** shows wind entropy. **Error! Reference source not found.** and **Error! Reference source not found.** show join entropies with different probabilities of flood and wind.



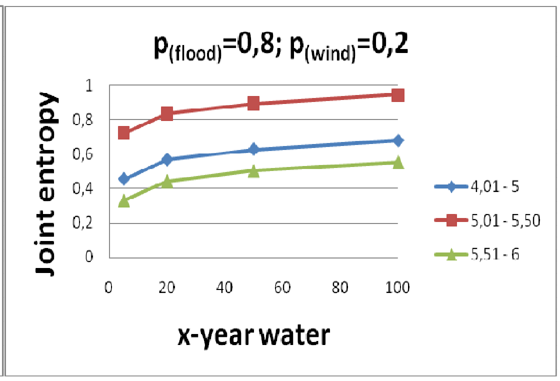
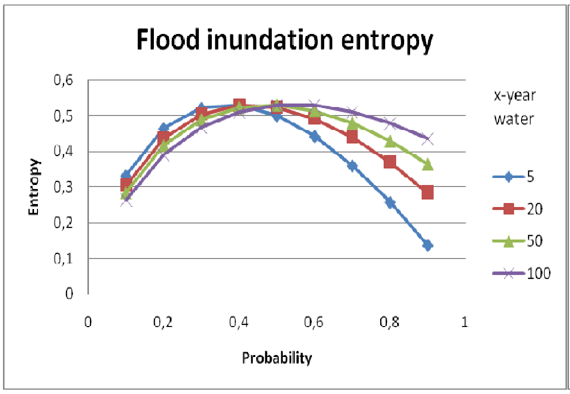


Fig. 4 and Fig. 5 Pardubice Region - Flood and Wind Joint Entropy.



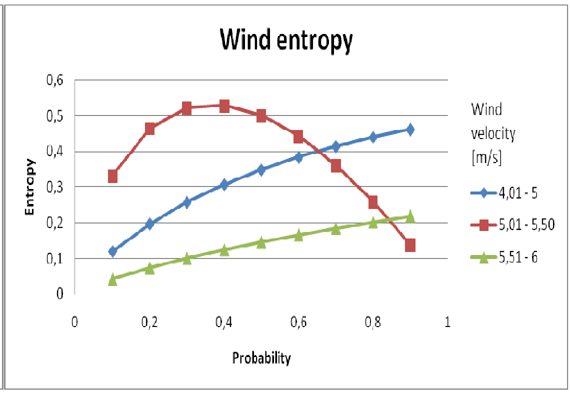


Fig. 6 Flood inundation entropy **Fig. 7 wind entropy**

4 Conclusion

In our contribution a quite interesting approach is used to allow a quick approximation of possible risk by means of entropy calculation. During the calculation it is possible to take into account more risks. Web services can allow fast, easy and remote access to everyone who is interested.

In our approach we do not take into account model of terrain, we do not use sensor networks and other in situ measurements. We do not provide precise prediction of the future flooding and/or windstorms

Instead, utilization of entropy is proposed to provide fast, easy, and remote access for everyone to overview information about possible level of risks in a selected region. To do this, information should be provided for example by means of web-based GIS system. Input data should be obtained through web services because they are coming from various sources.

Utilization of entropy to evaluate level of a risk is an interesting approach. Entropy calculation was used to evaluate regional uncertainty and indirectly the regional information available about floods within a basin [11] but not for evaluating risks themselves. In our approach, low entropy means a fully organized system, i.e. region without disasters. Increasing value of entropy means decreasing organizational order of the system, i.e. more risks occurring in a region. This approach is fully in accord with system theories and can be generalized and used to assess more risks. Together with multi-criteria approach it could be used to evaluate synergic effects of more risks within a region.

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