Review

Floodplain Management in the Context of Assessment and Changes of Flood Risk and the Environment – a Review

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Abstract

This article presents the problems of floodplain management in the context of the assessment and changes of flood risk, as well as its effects on the environment. The author discusses issues such as the role of floodplain management in the assessment of flood risk, changes in global flood risk, influence of the observed changes in floodplain management, and flood risk on the environment.

Continuous floodplains urbanization has caused an increase in the level of population and property exposure the to the danger of being flooded, increased vulnerability of riverside areas, and increased the potential economic losses. A development of built-up areas in the floodplain has a negative effect on water management in the catchment area. It also causes changes to the hydrological cycle in the environment by reducing the infiltration and retentive capability of soils and increasing surface runoff flow, as well as changes of flood regimes and intensive erosive processes. The development of industrial and business areas in the floodplains also generates higher environmental contamination as a result of flooding.

Nowadays, it departs from perceiving flood protection in terms of "control" and "defence," toward the conception of "giving the rivers their space back," as well as "predicting" flood risk and its management.

A symptom of implementing a flood risk management idea is enacting a Floods Directive, in which the most effective forms of flood control and flood risk reduction is preventative spatial planning in the floodplain.

Keywords: floodplain, spatial management, flood risk, environment

Introduction

Floods are the most common type of natural disaster in the world [1, 2]. They may be caused not only by natural phenomena (i.e. climatic, morphological, and hydrographic), but also by anthropogenic factors (e.g. unreasonable forest and agricultural economy, uncontrolled urbanization, lack of control over erosion processes, lack of flood control) [3]. Extreme natural and anthropogenic phenomena all over the world draw researchers' attention to their ecological and economic impacts [Cf. 4-6], as they may bring enormous human and material losses (loss of lives and property) [7].

The article presents the problems of floodplain management in the context of the assessment and changes of flood risk, as well as its effects on the environment. The author discusses issues such as the role of floodplain management in the assessment of flood risk, changes in global flood risk, and the influence of the observed changes in floodplain management and flood risk on the environment.

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Floodplain Management and the Environment

Floodplain management and development have a negative effect on water management in the catchment area. This problem is frequently brought up by different authors. The negative effects of urban development in flood-prone areas include changes to the hydrological cycle in the environment, as well as changes of flood regimes [8-10]. Floodplain area development decreases the surface water retention capacity and increases the surface runoff, also to rivers, causing higher water levels [11]. Constructing roads and buildings, as well as improper uses of the farm land (contour ploughing, overgrazing) and forests (deforestation), cause intensive erosive processes, fast surface runoff, and sediment transport [3]. Urbanization increases the impermeable area in the basin by developing urban drainage systems, which may be additionally burdened by surface runoff from the suburban areas [12]. Changes in land use and urbanization decrease the capability of the drainage system in the basin to retain flood water and direct it through a network of canals [13]. Authors such as Harvey et al. [14] after: Gao [15], Zong, Chen [16], Wan, and Yang [17] noticed unfavorable spatial and functional transformations occurring in a flood-prone areas, i.e. the declining importance of farming areas to the benefit of urbanized areas, which disturbs water management in China. The vegetal cover in flood-prone areas is then highly significant for the correct functioning of the environment, including proper water circulation. The length of the vegetation period, the tree stand structure, and the rooting complexity and depth strongly affect the infiltration and retentive capability of soils, as well as the rate of surface runoff flow [18-20]. So floodplains perform an important retentive function in the environment, which is pointed to by the European Union Floods Directive [21].

River valleys are natural treasures due to their unique biotopes, including ecologically valuable riparian and marsh ecosystems, which are at the same time endangered forest ecosystems [22]. On the other hand, trees and bushes growing in floodplains obstruct the natural flow of water and decrease the valley cross section [23]. The type of vegetal cover in floodplain areas, which often includes bioindicators, depends on the flood incidence [24].

Floodplains are areas under extensive environmental protection, where natural science studies are conducted. For instance, the study by Pniewski et al. [24] concerned the evaluation of spatial development scenarios, also as regarded floodplains, from the flood and environmental protection perspective. The most environment-friendly turned out to be the one preserving valuable biotopes [24]. Moreover, Geneletti [25] investigated the "greenness" of development policies in individual areas, taking into account the scale of invading flood-prone areas as an environmental indicator. The intensive investment scenario, which included booming economic activity, infrastructure and services, proved to be extremely harmful for the environment [25]. Other studies concerned soil and water pollution, e.g. the amount and spatial distribution of heavy metals [26-28].

In many cases, floodplains are areas where industry and services flourish, and where critical infrastructure facilities are built, such as sewage treatment plants, which become serious pollutants during floods [Cf. 29]. This kind of spatial economy in flood-prone areas generates higher environmental contamination as a result of flooding [Cf. 5, 25, 29, 30].

Floodplain Urbanization and Flood Risk

Floodplains are extremely attractive for urban development due to their fertile soils, good exposure to sunlight, easy access to water, and plentiful resources. In the past, settlement units steadily developed over vast areas. Currently, due to the fast rate of urbanization settlements, they develop chaotically, including in flood-prone areas [31]. Moreover, the increasing consumption of areas and the growing demand for them, particularly in monotonous regions, cause further settlement expansion in areas known to be flood-prone [32].

As a result of the progressing area development, catastrophic floods causing serious material and human losses are becoming more and more common [Cf. 20]. The increase in flood damage recorded in recent decades has mostly resulted from human activity in floodplains, which exposes the population and property to the danger of being flooded [29]. Floodplain management may also result in the rising costs of protecting threatened urbanized areas against floods [31]. The growing number of people affected by floods and the amount of the economic loss clearly show that flood risk is changing [33].

The increasing flood risk in urban areas results then from the improper management of flood-prone areas. For instance, the Rhine River basin is intended for further economic development, which creates the risk of potentially larger flood damage [34 after: 35, 36]. Similar negative urbanization processes in flood-prone areas can also be noticed in other European countries. For example, the studies conducted in Italy by Luino et al. [29] showed that the areas alongside the river channel are being increasingly filled with infrastructure and buildings (in the studied town of Alba these areas were taken by roads, the town's landfill, a prison, a nomads' camp), which disturb the natural flow of flood waters and cause dangerous elevations of the water level [29].

The increasing vulnerability of riverside areas to flooding is then the result of intensive urbanization and uncontrolled urban development. The factor that most increases a city's susceptibility to flooding is the improper development of newly urbanized areas [29]. Harvey et al. [14] point out that rapid urbanization and economic development have a large influence on potential flood risk (in the case of the Taihu River basin, which they studied), and are rather unquestionable risk factors.

Studies of changes in floodplain management often show that urbanization in flooded areas took place also in the past. For instance, Luino et al. [29] found that past floods and their dynamics were not taken into account in the spatial planning of the Italian town of Alba. According to Luino et al. [29], it is necessary to establish what happened in a given area in the past in order to draw risk scenarios, especially for river valleys. The assessment of the risk of the river returning to its former channel was not taken into consideration in Alba [29], Today's conditions in floodplains are then a product of the urban planning choices made in response to the demand for space, but without assessing the flood risk, also in the past [Cf. 29].

Flood Risk and Its Management

The increasing number of catastrophic floods observed in recent years, resulting in large numbers of fatalities and huge material losses [20, 29, 37], provoked a discussion about the European flood control policy [38]. During the International Decade of Natural Disaster Reduction (IDNDR) 1990-99, it was noticed that the previous flood control paradigm was wrong [39, 40]. Complete protection against flooding does not comply with the rules of sustainable development and is not possible to achieve due to its high costs and the intrinsic uncertainty of floods [41]. It was concluded that, metaphorically speaking [after 32, after 42], "building higher floodbanks" cannot be the one and only solution to the growing problem of flood risk. Currently, government policies of individual countries depart from perceiving flood protection in terms of "control" and "defence," toward the conception of "giving the rivers their space back," as well as "predicting" flood risk, its factors and management [e.g. 43-47]. In this way, an improper flood control policy was replaced with the idea of flood risk management as more effective [e.g. 33, 39, 48, 49]. Moreover, Steinführer [37] stresses that regional environmental protection policies in many countries are also starting to move from flood control to flood risk management [41].

Flood risk management involves a wide range of issues and tasks, such as forecasting flood hazards, their social, economic and ecological impacts, and considering the means and tools of risk reduction [Cf. 41]. Flood risk management encompasses the whole hazard cycle, i.e. flood prevention, control, preparedness and reaction to it, crisis management, as well as recovery and conclusion [37].

A symptom of implementing a comprehensive approach to solving the problem of growing flood risk was the enactment of the Floods Directive by the European Union in 2007 [21], which defines the framework of flood risk management and is an answer to the problem of natural floodplain management and development.

Risk analysis is an important step toward a more integrated perception of the potential effect of flooding. It particularly concerns, on the one hand, the flood hazard assessment, its seriousness, and the probability of flooding, and on the other – the assessment of social, economic, and ecological consequences of flooding (i.e. flood sensitivity) [33]. Flood risk means then "a combination of the probability of flood and related potential negative consequences for human health, environment, cultural heritage and economic activity," within the meaning of the Water Law [50].

In literature, the concept of flood risk is understood in several different ways. According to Morgan, Henrion [51], and Stein [52], risk involves 'exposure to a chance injury or loss.' Downing et al. [53] believe that risk is the expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Koomen et al. [54] treat flood risk as potential damage and casualties in flood-prone riverside areas, and define them on the basis of the spatial distribution of different kinds of land. Schetke [30] describes the potential flood risk as the vulnerability of settlements to flood due to the external influence on the environment, as well as the assessment of the economic and social impacts of housing development in the flood-prone areas. However, the definitions of flood risk do not fully depict all problems, as they do not take into account its ecological aspects. A full picture of flood risk is presented in Crichton's Risk Triangle (Fig. 1). According to Crichton [55], risk is the probability of losses and depends on three elements: hazard, vulnerability, and exposure.

Flood risk understood like that may be easily referred to as the *Source-Pathways-Receptors* model, often used to describe flood risk [56]. In this model, hazard is seen as a "source," i.e. weather phenomena or sequences of events that may cause floods (e.g. heavy or long-lasting rainfalls or storms) [14, 57]. "Pathways" are mechanisms that direct weather-induced flood waters to places where they may influence the "receptors." "Pathways" include roads, river flow, surface runoff in urban areas, riverside processes, and the lack of defensive systems or urban drainage systems [14]. "Receptors" are people, government, and commercial organizations, as well as built-up and natural areas that affect flooding [14]. Thus, hazard directly refers to the "pathway," because it defines the character and degree to which the receptor is exposed to danger. Hazard is then the geographical location of the receptor, as well as the features of a given location, which may increase or decrease it [56, 58].

Fig. 1. Flood risk triangle [57].

Vulnerability is strictly connected with "receptors," because it defines their specific features, as well as the degree to which they are sensitive to the hazard [57]. The term "vulnerability" refers then to the natural features of the threatened elements, which define their potential of being harmed [59]. Vulnerability may be understood as a combination of susceptibility and societal value [60], and it can be expressed through direct and indirect impacts (material and non-material) [61]. Contrary to the societal value, which is independent of the hazard, susceptibility means the process of creating damage [Cf. 62]. In accordance with the rule of sustainable development, we may list three areas of flood vulnerability: socio-cultural, economic and ecological [Cf. 61]. The social and cultural vulnerability refers to the loss of life, influence on health (injury), loss of vitality, stress, loss of private belongings, and the loss of cultural heritage. Economic vulnerability refers to direct and indirect financial losses as a result of the damage of assets, basic materials, and goods. Ecological vulnerability refers to the anthropogenic contamination of water, soil and ecological systems, including their biotopes (fauna and flora) [Cf. 61]. The damage caused by flooding depends then on the vulnerability of the exposed elements [61]. Consequently, flood risk is the product of hazard and vulnerability [63], and it depends on the level of "receptors" sensitivity, the character of the hazard, and the physical properties of the environment [64].

The factors generating flood risk listed by Schanze [33] include climate, land use, social and economic conditions, available technology, and policies. In some cases, climate changes seem to be the main cause of the changes in flood risk, while in others – it is the changes in land use or social changes that play the most significant role [33].

Flood Risk Assessment

The fact that it is possible to assess the probability of flooding, as well as its social, economic, and environmental impacts, is extremely significant [38, 65-68]. There are many ways of assessing flood risk. Modelling potential damage and losses has gained some importance in recent years [33]. Loss assessment takes into account spatially and temporally varied data concerning the number of the population [69], land use [70], historical events [71], and inundation depth [42].

According to Aubrecht et al. [42], the assessment of flood impacts focuses on direct economic losses, taking into consideration the concept of damage, which relates to the scale of the losses to inundation depth and the use of buildings – the primary factors causing damage disparities, included in the models of flood loss assessment [72]. For instance Aubrecht et al. [42] after Dutta, Herath [73], used a method based on geographical information systems (GIS), categorizing the forms of building use and integrating them in flood simulation. Types of buildings are also considered by Aubrecht et al. [42] after Blong [74] to be the main factor affecting flood costs [42]. The functional object grouping is done by integrating various spatial and space-related data sets concerning spatial development plans, company addresses, and details. In order to integrate these different types of information, an appropriate model was developed, using the ArcGIS model builder by ESRI [75]. The studies conducted by Aubrecht et al. [42] indicate that the integration of the functional information about a building is necessary to improve the quality of damage assessment and optimize the flood damage forecasts. The results of the flood risk scenario calculations were compared with a given reference sum (of actual flood losses) and in the case of introducing building-level land use data, loss revaluation was the smallest [42]. According to Aubrecht et al. [42], the flood risk assessment method that was used may be improved by introducing additional parameters, both as regards the hazard itself (e.g. inundation depth), and vulnerability (e.g. type and age of the building), just as it was done in the studies by Van der Hoeven et al. [76].

In order to assess flood risk, Luino et al. [29] first classified areas according to the forms of land use, dividing them into six land categories:

(1) Residential areas (already existing and planned)
(2) Public services (communal buildings, schools, hospitals, barracks, churches, sewage treatment plants, cemeteries, etc.)
(3) Industrial and commercial areas, hotels (already existing and planned)
(4) Sports and recreation grounds (sports halls and clubs, football pitches, gardens and parks)
(5) Factories and landfills
(6) Farming and riverside areas.

The above categories were then grouped according to the level of their vulnerability to flooding, applying the following parameters:

(a) Population density of permanent residence or at given parts of the day
(b) Machines or private property
(c) The occurrence of socio-recreational activity and/or losses resulting from the damage of farming zones
(d) The occurrence of valuable nature areas.

The first group, of the highest vulnerability to flood (level 1), is made up of residential and public services areas, the second group, of medium vulnerability (level 2), is formed by industrial and commercial areas and hotels, while the third group, of the lowest vulnerability (level 3), consists of sports-recreational and farming areas. Finally, the assessment of flood risk – the potential damage level – was based on a matrix (Fig. 2) presenting the relations between three zones of different intensity of inundation (flood probability) and areas of different flood vulnerability [29]. In this way, the areas representing high risk are e.g. residential estates and public services areas in the inundation zone of a very high and high level of flood hazard. On the other hand, low risk is recorded in farming and sports-recreational areas, situated in the furthest inundation zone. Flood risk assessment also included the extent of past floods. According to Luino et al. [49], such an analysis of flood risk level may be a useful tool in urban development planning, as well as in reducing flood risk.

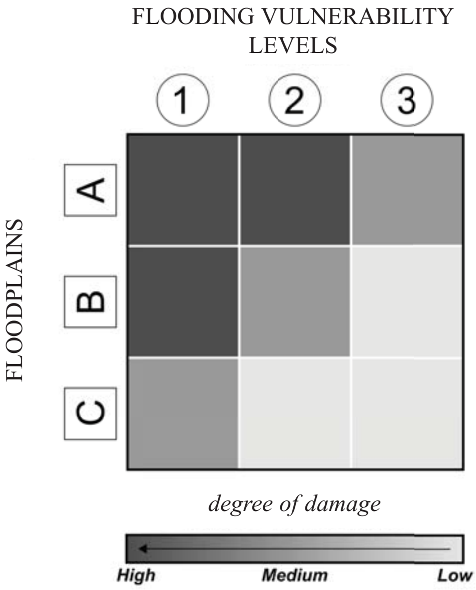

Fig. 2. A flood risk matrix [29].
The risk level: from light grey – the low degree of damage, to dark grey – high degree of damage;
floodplains: A – ordinary floodplain, B – 200-yr return period floodplain, C – 500-yr return period floodplain; flood vulnerability level: 1 – high, 2 – medium, 3 – low.

Another interesting approach to defining the future changes in flood risk is the use of the PSIR model (*Pressure-State-Impact-Response*) [77, 78], nesting the SPR model (*Source-Pathway-Receptor*) described earlier [46]. Nesting the PSR model in the PSIR model makes it possible to describe the whole system of flood risk management, and facilitates its assessment and modeling [14]. Within the qualitative assessment of flood risk, the "driver" (or factor) means any phenomenon that may potentially influence flood risk through a change of the "source," "pathway," or "receptors" [45, 47]. Harvey et al. [14] distinguish between uncontrollable (e.g. precipitations or storms) and controllable (e.g. urbanization) "drivers." The "responses" refer to the measures that may be taken in order to reduce flood hazard and risk in the future, and include spatial planning, land management in rural and urban areas, preparation of rescue operations, river and riverside protection, and flood damage reduction. The flood factors in the PSIR model were divided into three thematic groups:
(1) Climate change
(2) Socio-economic factors
(3) Flood control systems

Land use, urbanization, and economic development were treated as socio-economic factors ("drivers"), increasing the negative social and economic effects of prospective floods. They were also categorized as "pathways" within the SPR model.

Consequently, land use served the purpose of establishing flood risk again, its significance being described as high and uncertainty as low, due to the fact that the effects of changing the type of land use are relatively well documented [14].

Schanze [33] believes that the assessment of the potential flood risk and its changes lacks certainty, which results from the general character of the study (the main assumption of social development, a large scale of research) and limited accuracy, leading to problems with the assessment interpretation. What is more, using the past as the basis for understanding the future seems to be rather insufficient, due to the fast development of societies and considerable changes of the global climate. The number of historical facts concerning the people affected by flood and the scale of damage is very limited or non-existent, so they may not be used in assessing the flood damage. Moreover, the effectiveness of past measures of risk reduction is not always well-documented, as a result of which the future effects of taking precautions are hard to predict.

It should also be stressed that apart from the fact that the analysis of flood hazard and risk should be carried out from different perspectives and on many levels, the cooperation regarding future changes requires particular organization and a more reliable network. What is important, the understanding of future changes and the uncertainty of actions should be realized first of all by the people facing the flood risk. It helps the local authorities to introduce some strategies of coping with changing conditions [33]. However, the potential effect of flooding, defined as "an acceptable risk level," is often presented in a vague way, and the remaining risk is ignored [32].

Flood Risk in Settlements Studies

Flood risk is often used as a criterion in the studies of urbanized areas development. For instance, Poelmans and Rampaey [79] took into account the spatial distribution and the flood risk level when establishing the area's construction suitability.

In the studies that aim to reduce the expansion of housing estates around cities in order to preserve natural resources and maintain the sustainable development of settlement units, the potential flood risk was treated as one of the environmental indicators – parameters defining the abiotic elements of the environment (air, water, soil, etc.), which must be taken into account when assessing the impact of settlement development. The indicator was based on the evaluation of the changes caused by the development of areas showing typical landscape features (e.g. floodplains), and it was used to measure the impact of land development on the local population. It was also stressed that the flood risk indicator is gaining importance, especially in the face of climatic changes and floods, which are becoming more and more extreme[1)] [30].

Moreover, during a simulation of the land use structure and urbanization in a Dutch province, done for spatial planning purposes, different development variants were considered, taking into account such issues as water management,

[1)] However, in Essen the flood risk indicator was of minor importance in the multi-criterion MCA-DSS assessment of achieving environmental goals in strategic urban planning.

human health and security, and controlled urbanization. One of the elements that determines area development and depends on the spatial distribution of infrastructure was flood risk [54]. The technique applied for its assessment was Van der Hoeven et al. [76] method, which combines the results of hydrological modeling and the criteria of assessing the socio-economic impacts. The scale of potential damage (in Euros) and the number of people at risk were defined on the basis of the spatial distribution of land used in different ways [76]. In the context of rational water management, the simulation pointed to retentive areas, capable of storing water at the time of excessive precipitations or floods, while in the context of protecting human health and life, its aim was to prohibit residential housing in highly flood-prone areas. Special regulations were also formulated for riverside areas, which face a higher flood risk [54].

The results of a visual analysis of the spatial structure of new built-up areas, conducted in 1976-2000 for two Belgian cities by Poelmans, Rompaey [79], show that new urbanization undertakings are likely to avoid flooding in hazard areas. Flood risk is then an important factor of "pushing away" built-up areas from the riverside areas.

Flood Protection and Spatial Planning

A large number of housing estates, infrastructural systems, industrial plants, and enormous farming areas face the danger of being flooded. Therefore, it is essential to create legal, spatial planning and technical documents in order to predict hazards and provide appropriate measures of flood control [3]. In order to reduce the negative effects of river processes (lateral and bottom erosion), as well as the potential flood damage, the structural and non-structural intervention must comprise the whole catchment area at the same time [3]. Effective protection against floods caused by torrential rains requires well-coordinated actions as regards water management, forestry, agriculture, power industry, environment protection, and local economic development [3].

According to Ristic et al. [3], long-term flood control includes building water reservoirs and limiting erosion. The risk of faster surface runoff may be greatly reduced by altering the land management, e.g. by afforestation, the recultivation of degraded forests, meadows and pastures, delimiting farming areas in order to decrease the formation of erosion material, as well as increasing the infiltration of water to the soil and the land's retentive properties [3].

According to Salazar et al. [80], the strategy of "retaining water in the landscape" by decentralized means, such as afforestation or small reservoirs and micro-ponds, may play an important role in flood management only in meso-scale catchments in the case of small and medium floods, and an insignificant role during the largest floods. This has been confirmed by two projects conducted in the catchment areas of the Rhine and Mosa rivers by Hooijer et al. [49] and Bronstert et al. [8], respectively. They showed that the water retention measures in the upper course of a river, in the forms of a network of canals and changes in land use, may considerably reduce the occurrence rate of small and medium floods in small basins, or help reduce medium floods in large basins. However, the occurrence rate of large flood events in large basins in the lower course of the river was not particularly affected [80].

However, according to Ristic et al. [3], the most effective forms of flood control and flood risk reduction are: officially introducing the rule of no construction in floodplains, moving residential buildings and infrastructure away from the floodplain zones, and controlling the urbanization process. The best tool to limit the harmful effects of floods is sensible spatial planning [3]. It is the key element of land management, which consists of the objectives, rules and suggestions regarding the type, structure, and intensity of land use in a given area [29]. According to Luino et al. [29], spatial management regulations should define potential sites of rational urbanization. Regulating activity in river channels will lead to restricted urban development in riverside areas [81]. Despite the fact that jurisdiction and spatial management regulations vary in different countries, general legal regulations concerning spatial management in floodplains aim at restricted land use and development of new investment areas [31].

In Poland, for instance, after the legislative implementation of the EU Floods Directive [21] toward the end of 2011, the rules of managing flood-prone areas were tightened by excluding the possibility of exemption from the general no-construction rule in particularly flood-prone areas in local spatial development planning. The changes in spatial planning introduced in the country look promising and it is highly probable that they will stimulate preventive spatial management in flood-prone areas.

The aim of spatial planning in floodplain areas is to reduce the expected flood damage and the risk of investment development. Therefore, it is advisable to analyze different alternatives of floodplain management [82]. The planners' task is then to actively participate in wide-ranging and sustainable flood risk management [Cf. 32], which should be focused first of all on the analysis of the state of development of flood-prone areas. Such an analysis provides a lot of information about the local disparities in floodplain management, including the distribution of residential and industrial-service areas. It also makes it possible to replace the assessment of flood damage with the assessment of cost reduction as regards flood control [32]. Taking into account the division into hazard zones, as well as other significant planning variables, it is possible to conduct an analysis of potential savings coming from, for instance, a transfer of individual types of investment to areas that are less vulnerable to flooding [32]. Pointing to areas of varying levels of flood risk is the starting point for establishing the zones of the area that require different planning limitations. Such an analysis should also be used for reviewing current development plans and introducing necessary changes in order to reduce the negative economic, social, and ecological impacts of flooding [29]. Moreover, the analysis of the flood-prone areas management, as well as the flood risk in urban areas, may be the lead-in to the debate between city authorities with the local communities on the future form of the urban tissue.

It must also be stressed that changes in planning alone are not enough to prevent flood damage. In the face of rapid urbanization processes and floodplain management, it is extremely important to increase the social awareness of the potential negative impacts of flooding, which should not be realized only when disaster strikes [80]. Therefore, one way to discourage the development of new urbanized areas in floodplains should be organizing exhibitions of photographs presenting past floods, and showing information programs or warning signs directed at the local community [Cf. 29]. Active social communication and the integration of all entities, including the inhabitants, is the first step toward coping effectively with future problems related to flood hazard and risk [75]. Other fields connected with limiting the development of investment areas in flood-prone areas include insurance and financial policy [29]. In recent years insurance companies have been greatly interested in this issue and have published a number of documents and reports [60, 83-89].

Conclusions

In the rapidly changing environment, the analysis of flood risk is extremely important when it comes to ensuring safety to people and property. To define the level of flood risk means not only to assess the potential material and non-material losses, but also to analyze the negative impacts of the disaster on the environment, such as contamination and unfavorable geo-morphological processes (mass wasting, erosion), which often permanently change the land relief and the river valley [90]. However, it must be remembered that not only does the flood itself (understood as an overflow of water above the river bank line) have a negative impact on the environment, but also the way floodplain areas are managed determines the level of environment degradation and contamination, e.g. due to the localization of a sewage plant or landfill in flood-prone areas. The study of flood-risk assessment is focused mainly on the analysis of the economic and social impacts of flood, disregarding the important ecological impacts, which are more difficult to relieve due to their long-term character.

A way to solve the problem of increasing flood risk, especially in urban areas, is making preventive spatial planning in the areas exposed to flooding. Also, the development in the floodplains should be limited in order to conserve valuable river biotopes.

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