Chapter 2

River Basin Management in the Past and at Present and its Impact on Extreme Hydrological Events

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Abstract

River basin and small watercourse river basins should be seen as interdependent and interconnected elements and components. Activities within the river basin can affect water conditions in terms of quality and quantity. Nevertheless, river basin management has an impact on other areas, such as on the social or economic conditions.

Hydrological extremes as floods and droughts are natural phenomena, which cannot be avoided. Their irregular occurrence and variable range adversely affect the perception of the risk it poses, which complicate the systematic implementation of preventive measures. Given this, it is necessary to choose a comprehensive, coordinated and systematic process of planning, control, organization, leadership and management within the river basin.

One way to ensure optimal integrated river basin management is currently hydrological modelling. Hydrologic models are simplified quantitative relationship between input and output parameters of a system. Simulations of these models are then used primarily to assess the impact of proposed changes in the use of scenarios in the basin and the various water management strategies.

The aim of this chapter is to evaluate the current management of selected river basin. The main focus is on finding the fact whether the management of the selected river basin can be designated as integrated river basin management, which takes into account all of the above elements. Retention capacity of the basin is then related to the occurrence and consequences of extreme hydrological situations.

Keywords: river basin, management, flood, drought, hydrological modelling

1. Introduction

Most of the earth's surface, besides dry or permanently frozen areas can be divided into the river basin of surface waters. When natural river basin area is too large for the rational management planning in their area, these are often divided into several subsections according to the hydrological characteristics [1].

Social responsibility is one of the most promising approaches to river basin management. This concept is based on three key ideas.

1. The owners of the land should be included in the management of natural resources

None of the individual owners do not have sufficient information, legal competence, funding and other resources for the satisfactory managing of natural resource management. For this reason, it is clearly preferable that the individual owners cooperate management areas farmed.

2. Physical resources need some forms of management and organization

Individual natural resources need to be managed in the long-term steady manner which ensures a uniform approach to their management. This method of control is only possible through the involvement of landowners in the long-term functioning of organizations such as associations of owners, user organizations, cooperatives, information networks and associations.

3. Management of natural resources is a learning process

Management of natural resources requires the development of new knowledge, attitudes and skills so that managers could adequately cope with the changes and uncertainties [2].

The need for a focused integrated river basin management of large rivers is a matter of the past century. This need arises due to increasing human activities in the river basin areas of major rivers [3].

The river basin area should be seen as interdependent and interconnected elements and components that can as well as various activities within a river basin affect water levels or can have an impact on other areas, such as on the social or economic conditions [1].

Due to this fact, it is necessary to choose a comprehensive, coordinated and systematic process of planning, control, organization, leadership and management within the basin, which will be based on the knowledge that the water in the landscape-ecological perspective is one of the primary components of landscape structure; it is an integral part ecosystem as well as socioeconomic resource [4]. Its quality depends on the way of use [5]. Such an approach reflecting the multidisciplinary nature in the context of the overall socioeconomic development and other interests relating to the use and protection of water resources, for example, in the field of water supply and sewerage systems, agriculture, industry, residential development, water works, transportation, recreation, fishing and other activities, while emphasizing the need for coordination between sectors and proposing adaptation of different systems planning and management within individual basins, is named as an integrated river basin management.

Basically, an integrated management is defined as interdependence and connections of socioeconomic, environmental and technical aspects [6].

Most proper functioning and effectiveness of integrated river basin management occur during extreme hydrological events such as floods or drought [3].

Flood protection is a very important global issue. Globally, floods represent about one-third of the total number of natural disasters. These have resulted in more deaths than all other natural disasters combined, causing property damage and economic losses representing about a third of the total damage and economic losses caused by all natural disasters [7].

The flood is a hydrological phenomenon that occurs as a result of rainfall, snow melting, or other weather events in various combination of human activity, which manifests itself most dramatic increase in surface water runoff, increasing groundwater levels, temporary flooding of the earth's surface or erosion processes. Flooding is defined as a temporary significant increase in water flow, caused by the sudden enlargement of the flow or by temporarily reducing the watercourse profile trough, for example, ice constipation. During these events, water floods the areas outside the watercourse and may cause damage. Floods are divided on natural floods, which are caused by natural phenomena, and special flood caused by other factors [8].

Conversely, drought is very vague, but in meteorology frequently used concept, basically meaning the lack of water in the soil, plants or even in the atmosphere. Uniform criteria for defining quantitative exist with respect to various aspects of meteorological, hydrological, agricultural, soil, bioclimatological and many other conditions with regard to damages in various fields of national economy [9].

A properly functioning integrated river basin management should in these emergency situations ensure the coherence of individual components addressing this critical situation through information channels and ensure the timely and continuous information transfer between these components for effectively dealing with the crisis [3].

The aim of this chapter is on the example of river systems in the Czech Republic introduce historical and contemporary approach to the management of river basins. Its effectiveness is demonstrated mainly on approach to crisis management by droughts and floods. This chapter is a practical demonstration of the effects of changes in the river basin on hydrological characteristics.

2. Management of river basins in the Czech Republic

Water flows in the Czech Republic are divided into significant watercourses in the length of 16,326 km and small watercourses in the length of 86,553 km. Major rivers, and about half the designated small watercourses, are managed by state owned enterprises, that is, Vltava River Basin, state enterprise; Eger River Basin, state enterprise; Elbe River Basin, state enterprise; Oder River Basin, state enterprise and Morava River Basin, state enterprise. Another major administrator of approximately 6.6% of small streams is state-owned company Forests of the

Czech Republic, Ministry of Defense, the management of national parks and other private and legal persons [7].

Flood situation, as well as drought, poses the greatest threats to natural disasters in the Czech Republic. This is mainly due to the geographic location of the Czech Republic. Despite the relatively low altitude of the area, Czech Republic is known as the roof of Europe, mainly because of the location of the river basin edge of three major European rivers—the Elbe, Oder and Danube, on Klepý Mountain (1144 m a.s.l.) in Jeseníky Mountains. The main sources of water in this area are thus precipitation [10].

For good planning of flood protection and improvement of the landscape water regime during periods of drought, it is necessary to know the extent and the possible occurrence of flood situations and drought in historical context. Information about extreme historical hydrological situations is composed partly from calculations of mathematical models that are verified by the actual course of floods and historical monitoring of the impacts of floods and droughts on the individual components of the environment [9].

2.1. Flood situations

The longest and most complete evidence of flood conditions is preserved flood for the upper reach of the Vltava River. From immemorial, time floods were frequent and regular phenomenon, as evidenced by the occurrence of 136 large floods in this from the beginning of the eleventh century. Among the largest floods that were at least initially documented by hydrological records were floods in the years 1118, 1141, 1159, 1272, 1310, 1315, 1342, 1445, 1463, 1481, 1501, 1675, 1770–1772 and 1890. Between catastrophic floods, there are included floods from July 1432, by which almost all the mills on the river Vltava and other rivers were destroyed, flood in 1581, when the dam of Staňkovský pond was broken, flood in 1582, when high water flooded the whole region of Netolice and Bechyně. These large floods were caused primarily by rainfall during the summer. An example of the catastrophic winter floods caused by snow melting, or a combination of snowmelt and rainfall floods is one of February 1784, at which many pond dams were damaged, the floods of March 1845, which occurred after a long winter with plenty of snow and intense ice phenomena on watercourses [11].

On the Berounka River basin, one of the largest tributaries of the Vltava, flooding is historically documented for much shorter time. Recorded and reported are only the great floods of 1845, similar to the upper Vltava caused by the sudden melting of large masses of snow, combined with persistent and heavy rainfall, the flood of 1872 in the upper river basin area of the Berounka, which is not fully documented, but according to the preserved record, it was a very short sharp rain in several hours with a very high intensity, and the flood of 1890 caused by several days of rain in the Pilsen region [12].

On the lower section of the Vltava, flood conditions are usually the result of stopping the flood wave from the upper basin. Equally important fact is also overlap with flood waves of the main tributaries, such as the Sázava River. An example of such a flood is the aforementioned situation resulting from 1845 due to the spring thaw. Similar examples are then floods of 1890, 1917 and 1920, which were significantly contributed by water from Sázava [10].

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A similar situation exists in the monitored river basin Eger, where the records are from the period after installing the gauge on the river in 1862. In that year, there was recorded significant winter flooding. The records also show that in this basin apart from isolated events of 1919 and 1981 occurred in practice until 2002, no significant flooding [13].

Compared detailed monitoring of the situation on the Czech territory, the territory of the Morava River basin is evidenced significantly less important historic flood conditions. The best-documented situations include the years 1363, 1480, 1598, 1620, 1714, 1883 and 1891 [14].

During the recent past, a significant event in the history of the whole country, were mainly two summer floods in the 1997 and 2002 and winter flood of 2006 [15].

In the long term can be deduced from the observed data, especially the fact that in the Czech Republic, floods usually occur randomly, but in a comprehensive multi-year episodes. Historically, river basin managers responded to this fact by modifications in economy, and above all by modifications of watercourses in river basins [16].

2.2. Periods of drought

Historic drought usually affects the entire Czech Republic. About how the drought is significant in various areas decides especially the local long-term precipitation conditions. In addition, the dry season is usually accompanied by above-average temperature conditions, which further aggravate the water balance. The earliest record of the drought is in the Kosmas Chronicle, where he writes that the winter between 1090 and 1091 was warm and snowless. Dry periods occur in every century, and unlike floods there cannot be searched regularity [17].

In the area of upper Vltava River basin significant droughts can be identified according to the flow indicators in the years 1971, 1972, 1983, 1936, 1958, 1961, 1990, 1999 and 2003 [11].

In the Eger and the lower Elbe River basin occurred, except for the above-mentioned period, significant dry periods in the summer of 1973 spilling over into the spring months of 1974. The local drought manifested itself even in the summer of 1976, 1983 and the spring of 1984. Other major drought, which was the longest recorded, has been documented in this area since 1990, with the exception of the spring 1992 until the spring of 1993. In some localities, overlap was observed until the end of the summer 1994 [13].

For Moravia are the most important periods of drought for surface waters documented in the years 1962, 1992, 1994–1995 and 2004 [15]. Already this observation shows that in the eastern part of the Czech Republic, the issue of drought is less pronounced than in the Czech part of the republic, especially the northwest parts (Eger River basin) [13].

2.3. River basin management in response to extreme hydrological events

Integrated river basin management consists mainly in the protection of area from floods and from the negative effects of drought and improves the water regime of the landscape through a variety of measures directed if the local situation allows into the places with particular problems [9]. Basic measures are divided into three areas:

(1) Increase of natural river basin retention

Increase of natural river basin retention can achieve nature-friendly measures on watercourses in the river basin area. These measures consist of the revitalization of watercourses, erosion measures, biotech and agro-technical changes and procedures and increasing of water retention within river basin by land consolidation.

(2) Technical flood protection

Flood protection by technical elements is focused exclusively on the built-up area where it is necessary to find the optimal solution design. The solution may be increasing of the water-course capacity in urban areas, construction of dams, increased capacity on stream and other objects. The most effective way of dealing with the formation of a sufficiently large storage space in the form of polders or areas designated for flood overflows. To achieve the maximum effect of flood, protection is necessary to create the perfect combination of measures increasing natural retention and technical measures.

(3) Flood prevention

Preventive measures are mainly legislative measures, flood protection plans, forecasting and warning service, regulation of the use of floodplains or manipulation rules of waterworks [3].

2.3.1. Measures in the watercourse channels

Basins in the Czech Republic have always been the subject of numerous anthropogenic modifications. The interference with the natural character of the river basin occurred at various levels—from changes in use of the river basin, strengthening river channel, construction of river basin facilities in the profile of the watercourse, flow path geometry modifications and changes in riparian vegetation. These interventions are largely reflected not only in the river network, but also play role during the runoff process. This fact is of utmost effect during extreme hydrological events such as floods or drought, which may result in changes in the rate of progress of flood waves or their concurrence. This leads to major changes in the extent of flood damage and losses to the health and lives of the population [18].

The main causal flow adjustments were and still are the protection of property and built-up areas from the effects of floods. Another reason for the flow modification was efficient use of the force of water flows for agriculture, transport and industry. A large part of watercourses of all sizes and categories in the past undergone some degree of technical adjustments. The first change in the nature of streams have been documented since the middle ages, in the form of the construction of dams and other artificial backwater for improving the use of energy from flowing water. These adjustments were associated mainly with building the traditional mills but also the mills for processing of metallic ores in crushing mills for glassworks, mills processing harvested timber or processing wool and fabrics. Fundamentally flow adjustments are connected with industrial revolution, which brought the expansion of steam-powered machinery in the late nineteenth century. With the development of settlements and the rise of industrialism arose effort to use energy and transport potential of the waterways and to protect property from the effects of floods. These measures first hit the significant flows in lowland areas with high population and industry density [7].

Completely separate category in historical changes and adjustments of the rivers and their river basin are the adjustment associated with boating activities, or to transport material, especially along rivers. In the Czech Republic, the largest piece of such technical constructions is canals. From the still existing water works, we can mention Schwarzenberg channel and Vchynicko–Tetovský channel in Šumava Mountains. Along with other waterworks in the form of small water reservoirs called Clause used to serve for transport of harvested timber by the water for further processing. Both canals will be subsequently described in a case study in this chapter [11].

Another, now defunct water work is Fláje Channel in Erzgebirge from 1624. This channel, which is about 160 years older than above-mentioned channels in Šumava Mountain, was used to transport timber from the area of Fláje in the Saxon town Clausnitz. The channel was in operation only until the end of 1872. After that the channel was cut out, and today, it is virtually non-functional [13].

Special utilization was the last of canals built on one of the largest rivers in the Czech Republic called Bata's Channel on the Morava River. This water project, built in the years 1934–1938, was determined not to transport wood, but to transport the mined lignite. Unlike the above three canals, this was partly conducted riverbed Dřevnice and Moravia, and so it is not a purely artificial waterway [14].

An important milestone and a stimulus for change in the river basin areas was the so-called "provincial" flood in 1890, which hit the bulk of the country. Nevertheless, the control of small streams was already laid six years before. It was the so-called Amelioration Act from 1884. In many areas, the modification of water flows was brought through the land reform in the years 1919–1935. These adjustments primarily affected major rivers, but also small streams in the agricultural landscape. Modifications consisted mainly in straightening and damming streams as possible to prevent further flood conditions. It was often a modification of water flows inside the town, for example, in Pilsen rivers Mže and Radbuza. A series of alterations to streams was carried out in the framework of public works for the prisoners of the First World War and the unemployed during the economic crisis. These adjustments also affected the river basin of mountain waterways all over the country, for example, Úpa or Blanice river basin. The great flood in 1890 also gave an impulse to show the first stone masonry dams like Mariánské Lázně Dam from 1896, Kamenička and Harcov Dams from 1904, Pařížov Dam from 1913 or the Les Království Dam from the 1919 [10, 13, 16].

Straightening and regulation of flows are most often spoken in connection with the period of the socialist regime since the late 1950s of the twentieth century till the end of the 1980s of the twentieth century. This is many times related to extensive and often insensitive interventions into the network of watercourses which is connected very often with the intensification of agriculture collectivization and industrial and mining activities. An example is the huge range of water flows collected in the pipes, the proportion of drained land or completely transformed river basins such as Bílina River [7].

At that time, there was also a significant measure in the fight against drought. The idea of creating a network of backwater on the Vltava River to improve water management and shipping and energy purposes dates from the late nineteenth century. In response to the aforementioned significant period of dry years around the year 1947, the Czech Republic started to implement previously established concept of large water reservoirs. The task of these reservoirs was primarily to create enough storage capacity in the event of another dry year. At the same time, however, the dam should play a role in energy and to some extent the flood. Examples of these dams are a system known as the Vltava cascade, which currently consists of eight dams and one submerged weir degree on the Vltava River. System, as we know it today, was built from 1930 (water reservoir Vrané) to 1992 (waterworks Hněvkovice and Kořensko). In the beginning, there was the purpose of constructing the navigability of the river Vltava and obtaining energy from water source. Nevertheless, the largest water works was between the years 1951–1966 (Lipno, Orlík, Slapy and Kamýk) as a result of the catastrophic drought which affected the entire region of the Republic and had an impact mainly on water supply and agricultural production [11].

Currently, the solution of protection against extreme events on watercourses and water reservoirs addressed through action plans basin. Direct flood protection is ensured through adjustments riverbeds, whether it is meaningful and appropriate implementation of the regulation on large waterworks or through a revitalization action on small watercourses in the agricultural landscape. In connection with the protection of the area from flooding, it is also creating new retention reservoirs that are able to transform and slow down the passage of flood waves in river basins. Very often, it is the water works without a constant level, in the form of dry reservoirs and polders. An important part of flood protection is also clear and unambiguous definition of flood zones and adherence to a set of management of these areas. Thus, the stage would especially be protected against building of houses. This fact is unfortunately often underestimated or sometimes even non-compliance. The severity of the consequences of major and minor flooding is often intensified by just these buildings in floodplains. The extent of development in floodplains considerably increased since the 1940s of the nineteenth century, when they first began to extensively use hydropower for industrial purposes. In addition, construction activity in the vicinity of watercourses is usually cheaper than in hilly terrain above the rivers. It cannot be said that the company did not realize the danger of flooding. After several times mentioned provincial flood in the late nineteenth century, a technical concepts of flood protection were created, based on the construction of levees and dams. The problem is not the concept of direction to prevent floods as such but to reduce the consequences of irresponsible assets located in flood plains [7, 18].

In connection with protection against drought in recent times, increasingly mentions the possibility of repeating the solution from the middle of the last century, through the construction of new water reservoirs in the country at major watercourse. The bulk of these efforts are channelled into streams in mountain and foothill conditions. One option is the possibility of restoring the previously existing water reservoirs (e.g., the so-called klauzy, reservoirs for improving the flow of navigable canals for floating timber, for example, in a mountainous area of Šumava Mountain). The second option is the identification of new sites suitable for creating storage space, for example, planned waterwork Nove Heřmínovy. Total about 200 potential sites for the construction of new water reservoirs are currently identified in the Czech Republic by Management of river basin. When constructing new dams serving for accumulation of water in the dry season, it is still important to keep in mind their further use for example in flood protection. Even the best water work can be potentially dangerous and can threaten the management of the river basin. An example might be a tear loose dam on the Bílá Desná in Jizrské Mountains in 1916, or worsening flood flows below the dam Slezská Harta or Vír Dam in 1997 [16].

Besides protecting of river basins from flood and drought belongs to the concept of integrated river basin management also navigability of waterways. Currently, navigability is ensured only on part of the Elbe and Vltava. With longer-lasting periods of drought, there appear more and more problems with maintaining minimum flows to these traditional sailing routes. Currently in the management of river basins included in these two rivers navigability of Elbe up to Pardubice and navigability of the Vltava River between Prague and České Budějovice. Both projects entail considerable investment to build locks and overcome various height levels weirs and dams reservoirs [10].

2.3.2. Measures in the area of river basin

Integrated river basin management not only focuses solely on actual water flows but also focuses on the whole river basin area. In such locations, it is defined and then the most important question of the development of the use of the various areas in terms of agricultural and non-agricultural activities.

If we divide the territory of the Czech Republic in terms of agricultural production to favorable and less favorable locations, there will be recorded entirely different evolution in the use of these areas [19].

Before Second World War, there were the biggest changes in land use, especially in the areas of traditional intensive agricultural production, especially in the area of lowlands. In the context of agricultural production, these were mainly conversion of grassland to cropland and the intensification of its use. In the non-agricultural sector, it was mainly in these areas recorded an increase in built-up areas. In other production areas, no significant changes were recorded, with the exception of the least-favored mountain areas, where at the beginning and during of Second World War the process of production extensiveness began [20].

In this period, the Czech Republic noted a number of significant historical events. This was primarily the completion of the industrial revolution and the associated industrial and transportation expansion of the state, such as the construction of the railways. Secondly, it was mainly the two World Wars and bound to them above described land reform [21].

Despite the large number of significant changes both political and legal, this period is marked by the smallest changes in land use. This fact is mainly due to the fact that people especially in the early centuries were not willing to significantly change their habits and traditional farming methods [18]. In the Czech Republic, during that period was the development and use of land equal in all areas, including mountain and foothill areas. The reason was the desire for independence and self-sufficiency of food. This fact has not changed even the first agrarian reform after the First World War, rather to encourage this trend [22]. The reason for the shift of agricultural activities from big manufacturers is that they were able to deliver products at the national and international market for small-scale production and whose only task was to secure the aforementioned self-sufficiency. Conclusion especially post-war period marked by presidential decrees and the subsequent expulsion of large masses of the population from border sites heralded changes in land use for the next period [23].

The beginning of the period around the end of the nineteenth century is marked by increasing the area of arable land. At the end of the century, the percentage of arable land was the highest ever recorded—more than 50% of the country. Arable land was used for newly planted crops mainly technical, such as the sugar beets and potatoes. New areas of arable land were acquired primarily at the expense of pastures and meadows, but also at the expense of new water areas that were drying out. One of the reasons for the constant search for new land for growing crops was low efficiency and intensity of agriculture [19].

Around the beginning of the twentieth century, the application of the results of industrial and technological revolution made possible to reduce the area of arable land and convert these areas into other categories [18]. At the same time, there was also a slight decrease in pasture area. The reason is mainly the less need for livestock, which was replaced by machine forces. Positive on the whole change was the of increase valuable areas of woods and meadows. We cannot also forget the increasing urbanization in this period as well as the construction of railways. All this has led to a significant increase in built-up areas [24].

After the end of Second World War, significant breakthrough occurred in the evolution of land use. In areas with poor agricultural productivity continued the established trend of decreasing of production, mainly due to population displacement and also due to the greater involvement of agricultural technology [25]. For this reason, there was a cancellation of a large area of arable land and its conversion to permanent grasslands, where there was a presumption at least livestock production. Where even this kind of agricultural production, there were arable areas converted to forests [26]. The conversion to other land was often administrative. This fact is not recorded only in our country, although there is accentuated by the political situation, but also in other parts of Europe, where the marginalization of mountain areas was also under the pressure of increased mechanization of agricultural production. This fact can be documented by the example of Italy [1], Slovenia [27], Austria [28] and other alpine countries [29]. Even in highly traditional production areas in the lowlands, situation for agricultural production was not favorable. This was mainly due to development of industrial activities and the related construction of new industrial and residential buildings. For these activities, substantial occupation of agricultural land was carried out, even the finest soils [30].

This trend started in the period after 1948, but not ended after the revolution and still persists. Areas in mountain and foothill areas are increasingly being converted to grassland and forest areas. Lowland locations mainly in the vicinity of large cities have become interesting for investors and are often used for further development of residential and commercial buildings [7].

In general, we can say that in the long term, the agricultural land was converted to non-agricultural land more in less productive areas than in the traditional areas of agricultural production [22]. The most significant changes in these areas occurred in the period of communism, the loss of farmland, especially in mountainous areas amounted to 35%. This decrease can be primarily attributed to a reduction in arable land and the conversion of arable land to other non-productive categories. An interesting changes were in the acreage of grassland, which in 1989 throughout the country significantly decreased [31]. After 1990, however, there is the significant increase. Magnifying acreage of grassland, however, does not show the whole country evenly. The increase is more pronounced in the less favored areas (over 20%), probably under pressure of subsidy policies, while in lowland areas is only an increase of several percent [22]. A similar trend is then recorded in other parts of Europe [32, 33].

The period between 1948 and 1990 is marked at the beginning by displacement of the German population and the allotment procedures. This situation, however, was overshadowed by subsequent reforms in agriculture and political changes in the country. The main impetus for change in land use was mainly the formation of agricultural cooperatives and related collectivization of agricultural production. In addition, especially in border areas came the influence of building of the so-called iron curtain and the associated restrictions [7].

On a national point of view, this further loss of areas of agricultural land. The reason is the aforementioned policy changes, but also changes in the farming itself [19].

In the first place, it was left a large amount of agricultural land in the border areas is typical for this period. The reasons for this fact are twofold: land close to national borders has become inaccessible, or accessible only to permit. Therefore, there was not possible to continue to manage, even extensively [20]. Plots were left to spontaneous succession or converted to forest complexes. Border area and outside this band, however, suffered from other problems. The main drawback is the large slope of the land, relatively high fragmentation of land ownership, and inadequate soil moisture and the non-suitable conditions for intensive agricultural production. Because of these shortcomings, there is not possible without significant interference to apply modern technology and mechanization [25]. Plots were therefore often abandoned, left fallow or converted to other categories of use, such as meadows, pastures and forests. As already mentioned, much land was transferred to the category of other area [34].

Changes in farming practices and agricultural production brought another major change in land use. This change was extensive construction of agricultural buildings to a range of urban and rural areas, or within open countryside. This is the construction of various storage and handling areas and especially new large-scale production complexes for livestock production such as cowsheds, piggeries and large poultry [35].

There were changes related to the development and industrialization of the country, especially towards heavy industry. For these purposes, there was carried out large-scale occupation of farmland mainly in lowland areas around major rivers. Occupied areas were built up by industrial areas [19].

In connection with the construction, it cannot be forgotten the big farmland appropriation for the construction of new residential areas of the major cities. This was largely in building blocks of flats around agglomerations [36].

After 1990, the period of transformation from a centrally planned economy to a market economy country began. This period is marked by significant shifts in ownership of agricultural and non-agricultural land in restitution reforms [18].

The reason for this change in land use is disintegration of agricultural cooperatives, the transfer of land to private farmers, but also nationwide reduction of state support for agricultural production and the partial replacement of the support subsidizing non-agricultural activities in the country. As in previous years and now, there is a conquest of agricultural land for construction purposes. This phenomenon is mainly connected to the concept of suburbanization, that is, the expansion of built-up areas around agglomerations of large cities for residential and commercial purposes [37]. This is basically the construction of satellite towns, transshipment terminals, warehouses and shopping centers on the so-called greenfield. Paradoxically, after the pre-1990 period in our country, there appear a large number of areas designated as the so-called brownfields [38, 39]. These are the sites that have been used either for agricultural production, industry or the military, and now left abandoned and unused. Unfortunately, these built-up areas are in most cases left to decay and place of their use is still the appropriation of new areas of agricultural land [40].

3. Case study of the river Otava

To demonstrate the impact of changes in the management of river basins, especially in connection with the use of the river basin, was selected Otava River, its upper reaches to the city of Susice. This area has long been inhabited and used for many different aspects of human activity. The study will cover the changes that have occurred in the area since the mid-twentieth century (before this time was practically river basin management since the mid-nineteenth century unchanged) to the present.

Otava River is beginning in the Pilsen region in the southwest of the Czech Republic. It is a left tributary of the Vltava River originates at the confluence of smaller watercourses Vydra and Křemelná at Čeňkova saw in Šumava Mountains. The entire basin of water flow consists of a large number of sub-basins of natural waterways and also one man-made shipping channel.

Otava River basin is quite rugged. Especially, the southern part of the area is predominantly mountainous. Geographically, it falls into the area of the Sumava Mountains and the foothills of Sumava Mountains, with an average altitude of 1003 m above sea level. Watershed average slope XXX°.

From a geological point of view metamorphic rocks (gneisses and migmatite) and magmatic Moldanubicum rocks (granite and granodiorite) are dominated. The magmatic types of rock are mainly in the top parts of the mountains. Peat bogs also frequent occurred in the uppermost part of the river basin. Sand and gravel are then located mainly around watercourses. In the flatter northern part of the river basin, there are also disseminated limestone and erlan islands.

From the pedological point of view, forest land in the form podsols completely dominates due to the high percentage of forested land. Cambisols, stagnosols and in permanently wet areas with high ground water gleysols occur mostly on agricultural lands. Modal fluvisols are developed around watercourses. Mainly in the northern half of the river basin, there are located small patches of leptosols.

From the climatic point of view, the Otava River basin falls mostly in cold climatic area with long-term average annual air temperature of 3.7°C (average temperature in January—4.4°C and an average July temperature of 12.5°C). The northern plains of the basin are located in the temperate climatic zone, characterized by an average annual temperature of 7.2°C (average temperature in January—2.5°C and an average July temperature of 17.0°C). Rainfall totals are very diverse with long-term average annual value for mountain areas 1486 mm and for the flat part 631 mm.

3.1. Material

The first of two parts, of which the Otava River is composed, Vydra is created by the confluence of three rivers in the mountain village Modrava at an altitude of 978 m above sea level. The largest and longest of these flows are Roklanský (Mlýnský) stream, which rises at an altitude of 1264 m above sea level and collect water from numerous other streams and bogs as Javoří stream or Rokytka. The basin of Rokytka stream was in the middle of the last century important with water tank for the free navigation of timber. One of the largest of them, Roklanský tank should hold up volume 14,000 m^3. Another tank was built on a tributary Rokytka. This tank was holding back up to 18,000 m^3. Virtually in all river basins of other tributaries, the dam was also built, which was called Klauzy (Novohutský stream—15,000 m^3, Studený stream—3000 m^3, Javoří stream—16,000 m^3). The second component of the waterways from which consists Vydra River is also Luzensky or Modravský stream that originates at the confluence Luzenský and Březnický stream near the path to Březník. At the end of Luzenský valley, there is one of the largest navigable reservoir Březnický dam with a height of 4 m and a total accumulation space of 21,000 m^3. Luzenský stream receives water from the nearby mountains and bogs, the largest of which is the Cikánská moor stream draining the same name peat bog. Just before the confluence with the waterways were two corridors lead into the bed of the now noticeable tanks Ptačí a Černohorská. The last of the sub-tributaries of Vydra River is Filipohutský stream that collects water from Tetřevské and Filipohutské moor.

After the above-mentioned confluence of three major rivers, even as Vydra, the river has considerable energy and adopt progressively more right-hand and left-hand tributaries, the most important of which is the right flowing Hamerský stream and left smaller flowing Popelský stream, Hrádecký stream and Zhuřský stream. After 12 km, Vydra after the confluence with Křemelná at an altitude of 627 m above sea level at Čeňkova saw changes in the Otava River.

The important point is called Rechle, gate bridge, is located 2.2 km from the establishment of Vydra River at court Antýgl. At this point, there is the beginning of artificially built Vchynicko–Tetovský channel. The canal was designed and built by Ing. Josef Rosenauer between the years 1799–1801, as second after the Schwarzenberg channel built between the years 1788–1821. After branching out, Rechelský bridge at an altitude of 937 m above sea level surpassed water from the Vydra River by original 14 km long route and 255 m elevation to the Křemelná River at an altitude of 682 m above sea level. In the original arrangement, the channel ends with a wooden structure slip to Křemelná River.

The other watercourse from which the Otava River is formed is Křemelná River. Křemelná River rises at an altitude of 1050–1170 m above sea level on the slope of the ridge between Pancíř and wetlands under Jedlová mountain. The total length of the river is about 30 km, and after overcoming total 463 m altitudinal gradient it casts of Vydra at Čeňkova saw. Compared to Vydra River, Křemelná River is leisurely, meandering watercourse. Because of this, it was used in the past as an energy source for many aquatic power plants, mills and smelters and glass rising. The river Křemelná has four significant right-sided tributaries, Slatinný stream, Jezerní stream, Prášilský stream and Sekerský stream. First mentioned tributary brings into the Křemelná River water from a large wetland fen under Pancíř, which is located near the source of Křemelná River. At the same time, there are other small streams such as Sklářský stream, Černý stream or Drozdí stream. The latter, Jezerní stream flows from the smallest of the Šumava lakes, lake Laka. The penultimate tributaries, Prášilský stream overcomes a 12-km route quite significant elevation of 400 m from the village Prášily to the confluence with Křemelná. Just before the confluence takes on Prášilský stream of water from the Jezerní Brook, who, unlike his namesake, flows from the Prášilské lake. Sekerský stream flowing from the Jezerní hřbet is the last tributary of Křemelná River.

3.2. Methods

To quantify changes in direct runoff height in a different river basin management under the same designed rainfall events was used curve number (CN) method, because in the Czech Republic and abroad, this method is often used, among other things, for assessing the impact of changes in land use on the size of the direct runoff [41].

The runoff curve number (also called a curve number or simply CN) is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess. The CN method was developed by the USDA Natural Resources Conservation Service, which was formerly called the *Soil Conservation Service* or *SCS*. The runoff CN was developed from an empirical analysis of runoff from small catchments and hillslope plots monitored by the USDA. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area.

The basic input to CN method is designed rainfall event (P—[mm]) assuming uniform distribution over the entire river basin area. For rainfall–runoff event for a given time is assumed that the ratio between the current retention (F—[mm]) and maximum potential retention of the basin (S—[mm]) is the same as the ratio between the direct runoff (Q—[mm])

and the rainfall without initial abstraction (P–Ia—[mm]). Initial abstraction is expected to be 0.2·S [42]. Using balance equations was derived from these assumptions following equation:

$$Q = \frac{P - 0.2 \times S}{P + 0.8 \times S}, \text{ where } P \geq 0.2 \times S$$

Instead of potential retention described method uses runoff CNs that transform the retention, so that the CN ranges from 0 to 100. Transformation for the variable in mm is following:

$$CN = \frac{25400}{S + 254}$$

Runoff CNs are according [43] determined by:

- hydrologic soil groups (HSGs) divided into four groups A, B, C, D according to the minimum infiltration rates of soils without vegetation cover when thoroughly wetted,
- soil moisture at the beginning of the event,
- land use, that is, the type of vegetation cover, tillage and application of erosion control methods.

To categorize, land use was used the results of Corine Land Cover project, for the years 1970, 1990, 2000, 2006 and 2012.

To categorize, the soils into the HSGs were used method described in [44], which adapts the CN method for steeper area. When categorizing soil into HSG was therefore taken into account not only the infiltration capacity of soils, but also the water retention capacity of the soils and the slope of the territory derived from the digital terrain model. Everything was calculated in software ArcGIS 10.1 in raster format. Data of the infiltration rates and water retention capacities were taken from the "Research Institute for Soil and Water Conservation" in Prague, digital terrain model was constructed in ArcGIS 10.1 based on the contours of the model Zabaged (The geographic base data of the Czech Republic from the "Czech Office for Surveying, Mapping and Cadastre").

For each combination of different HSG categorizations with land use were subsequently determined values of CN and subsequently from these (three), CN values were calculated the mean for each pixel. Since the infiltration rate can be considered as the most important soil characteristic to create direct runoff from rainfall event (primarily in planes), the resulting map of CN values (**Figure 1**) was formed as the maximum CN value determined from HSG by infiltration and average values CN of HSG by all the used categorizations. This emphasized the influence of a low infiltration rate of soils in the flat area and influence of water retention capacity and the slope of the territory in areas with steeper terrain [44].

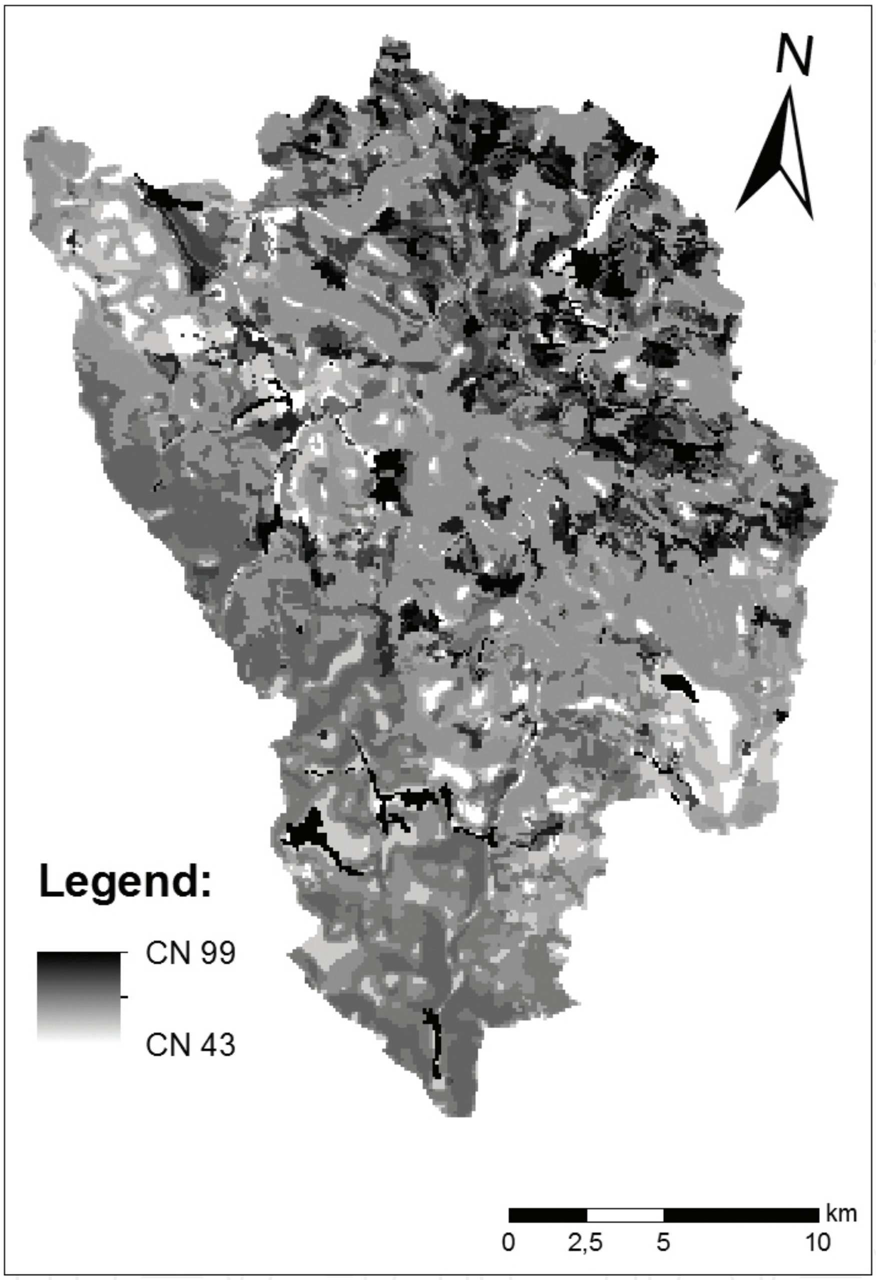

Figure 1. Example of the map of final CN values in the 2012.

In this study, for the calculations of direct runoff, designed rainfall events were used with the annual exceedance probability of p = 0.1; p = 0.02 and p = 0.01 (return period of N = 10, N = 50 and N = 100 years—that is, 10-year, 50-year and 100-year rainfall). Calculation of the N-year designed rainfall evenly distributed over the entire river basin area (assumption of CN method) were done by interpolation (spline method) in software ArcGIS 10.1 of the N-year rainfall in the rain gauge stations within the Otava River basin and its surroundings. The 24-hour designed rainfall for each return period is as follows: N10 = 82.6 mm, 112.2 mm = N50 and N100 = 125 mm.

ArcGIS 10.1 was subsequently calculated (using the formulas given above) the values of the direct runoff (mm) and its volumes (m^3) for each input CN raster for the years 1970, 1990, 2000, 2006 and 2012, and for each designed rainfall events (10-year, 50-year and 100-year). **Figure 2** is an example of the resulting direct runoff volume raster in m^3 calculated for the 10-year rainfall and land use in 2012.

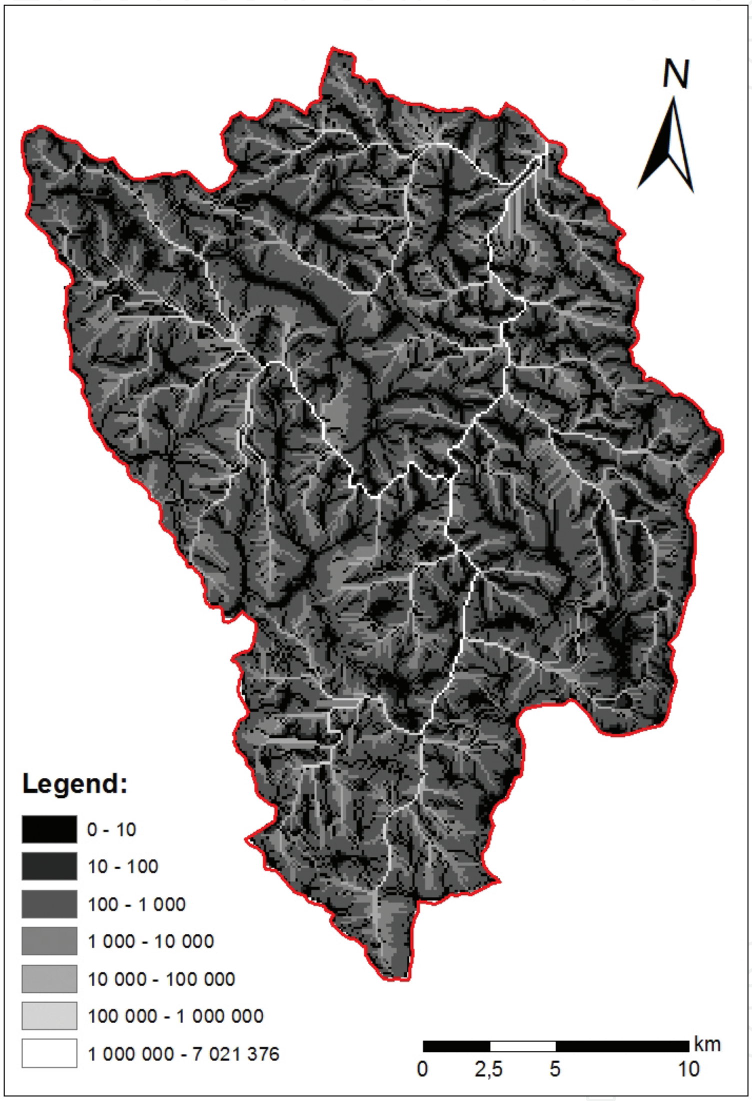

Figure 2. Direct runoff volume [m^3] for 10-year rainfall in 2012.

3.3. Results and discussion

3.3.1. Changes in river basin management

The subject area was under the observation period and often radically altered. As a reference datum, there was the year 1970, which represents the state before until the mid-eighteenth century. It should be noted that the use of territory has changed significantly nearly in the entire surface. Changes are practically constant, and at two basic levels.

1. Conversion of arable land with varying intensity at different management of intensive and extensive grassland

2. Deforestation of large areas of indigenous mostly spruce monocultures and their transfer to the shrub and herbaceous vegetation covering the surface with a discontinuous vegetation

The first-mentioned change in the area is related to the transfer of arable land to various forms of permanent grassland. This change was caused mainly by economic as well as environmental reasons. The first significant change was recorded in 1990. The conversion of cropland to permanent grass cover was related to the change of the political situation in the whole of Central and Eastern Europe. Under pressure of this fact and also under pressure from neighboring countries and consequently the European Union, there have been some partial changes in land use [23]. These changes were reflected off the site of interest, especially in the ongoing reduction in the percentage of arable land throughout the country in the period after 2004. This trend is supported still setting state subsidy policy and the European Union [45]. The main driving force that brought about changes in the conversion of cropland to permanent grass cover was the creation of agri-environment grant scheme. Conversion of arable land has continuing problems with degradation of arable land by erosion, compaction, etc. [46]. The measure is divided into six titles, because grassing can be made by three kinds of mixtures. Then, there can be distinguished grassing of parts near water or in protective zones of water sources and grassing outside these areas. Species-rich mixture is appearing for the first time and represents a certain alternative to tighter regional blends. The aid is effective and permanent protection of soil against erosion, water pollution prevention, increasing species diversity and attractiveness of the landscape. Changes in agricultural commodity markets also brought a reduction in livestock, particularly cattle for milk production. These breeds were either cancelled without refund or farmers switched to less intensive cattle sucker ongoing grazing manner. For this reason, there is a constant increase in the acreage of grassland at the expense of other categories of agricultural land [47].

The second described change—loss of forest areas—was first recorded in 1990. It was a change to a smaller portion of the territory over the coming decades. The cause must be sought in the past. During the eighteenth century, when the last big wave of settlement, there was a large loss of forest area. Due grazing in the forest and favoring mining hardwood was negatively affected species richness [48]. In addition, the clear-cutting for the needs of glassworks and subsequent afforestation of even-aged spruce monocultures is causal primarily wind calamity of October 1870. After this, natural disaster areas were promptly reforested by trees. Spruce seedlings were imported for this purpose from all parts of the former State and their genetic composition differs from the original Šumava spruces [49]. This led to a weakening of natural populations of native spruce that were already years adapted to local conditions. The result is often highly unstable growth with reduced resistance to diseases and pests like against bark beetle [50]. Another negative influence for resilience of forests was caused by the discharge of pollutants and acid deposition into the atmosphere [51]. Pollution took place from the beginning of the Industrial Revolution until the 1980s of the twentieth century. In our country, stronger steps against atmospheric pollution were taken after 1989. As a result of these changes, the forest is weakened, decreasing vitality, and substantially increases the risk of possible damage by disturbances [50]. The most significant disturbance on the area of interest is considered the influence of wind and insects [52]. Based on historical sources, the important fact is that a wind storm or gale in the past in the Bohemian occurred quite frequently, but their frequency varied over the centuries [53, 54]. Currently, it is more frequent, but their appearance and in the future to be reckoned with frequent wind warps at high speeds [55].

Loss of forests between 1970 and 1990 has its cause in the first place outside the area of interest. During the years 1983 and 1984, the areas of neighboring Bavarian National Park were affected by two powerful winds, which damaged large areas of valuable forest ecosystems in the first zone of the national park [52, 54]. Heavily damaged forest in non-intervention part of the Bavarian National Park has become a breeding ground for the rapid development of the bark beetle, which subsequently began to spread into the surrounding forests. Czech part of Šumava was hit by bark beetle in 1990 [54]. Monocultural local spruce forest significantly contributed to the rapid development of the bark beetle in Šumava, which reduces the ability of spruce forests to withstand the stresses caused by strong winds [56].

Already so weakened and reduced stands of forest were damaged even more. The next big hit in the Šumava mountain spruce came on the night of 18–19 January 2007 when the Bohemian Forests caught wind of hurricane force, named Kyrill. The highest recorded wind force in national park was 176 km h^{-1}. Thus, strong winds caused extensive damage to forests in dozens of square kilometers [55]. It fell victim to around one million cubic meters of wood.

Windstorm hit the most senior parts of the Šumava National Park. The subsequent massive loss of forested areas between 2006 and 2012 took care of warm and dry late winter and early spring, which caused a very rapid onset of bark beetles [57].

A total of about 217,000 trees in the forests of the National Park Šumava left without treatment. Raw windbreaks have become a source of spread of spruce bark beetles in the area. Mining infested trees in 2010 exceeded historical maximum and reached the highest value in the history of the Šumava National Park. Even in forests left to spontaneous development was the death of hundreds of thousands of adult pines [56].

3.3.2. The effect of changes in river basin management to direct runoff

The resulting values of the heights of runoff and runoff coefficients for individual design rains are shown in **Tables 1** and **2**.

The results suggest the influence of land use changes that have occurred in the river basin in the past, and the formation of runoff. However, the differences in values of runoff are not remarkable. The highest differences were, based on model, between 2006 and 2012. In this period, the large areas near the river basin borders were deforested due to the combination of bark beetle calamity, windstorm and excavation of remnants of forest. In fact, it was the replacement of forest by land cover, which can be characterized as a scrub and herb layer on the forest floor. CN value therefore varies, but the soil is permanently covered with vegetation and soil infiltration properties themselves remain almost identical. By the 100 year designed rainfall distinction is the highest and a difference in direct runoff height is 1.4 mm, which in units of volume is almost 750,000 m^3. The change is therefore evident, but not significant.

Year/designed rainfall	N10 (82.6 mm)	N50 (111.2 mm)	N100 (125.0 mm)
2012	13.6	28.0	35.3
2006	12.9	26.8	33.9
2000	13.0	27.0	34.1
1990	13.8	28.00	35.2
1970	13.8	28.00	35.2

Table 1. Direct runoff [mm] for designed rainfall with periodicity 10, 50 and 100 years.

Year/designed rainfall	N10 (82.6 mm)	N50 (111.2 mm)	N100 (125.0 mm)
2012	16.5	25.0	28.2
2006	15.6	23.9	27.1
2000	15.7	24.1	27.3
1990	16.7	25.0	28.2
1970	16.7	25.0	28.2

Table 2. Direct runoff coefficient [%] for designed rainfall with periodicity 10, 50 and 100 years.

Other changes in land use are differences in heights and volumes of runoff smaller, but even here it can be seen the positive impact of some changes. For example, reduction of direct runoff between 1990 and 2000 for all forms of the rainy season can be put into the context with the grassing of arable land after 1990. In contrast, surprisingly identical values of direct runoff model were calculated in 1970 and 1990, although there had been significant changes in the landscape. However, the loss of arable land, pasture and forest has been "offset" by the increase of meadows and bushes, so that was a mix of changes variously distributed across the river basin with almost no difference for creating direct runoff throughout the river basin.

These results confirm the findings of [58], who based on the long-term observation and statistical analysis suggests that it is virtually impossible that changes in land use (if we exclude drastic interventions such as the permanent removal of vegetation cover from soil or the establishment of impervious surfaces) can permanently significantly change the long-term average height of runoff from the river basin. Similarly, Hanel et al. [59] argue that by larger basins whose area is in the tens or hundreds km^2 and which are not predominantly agriculturally used changing flood runoff volume and flow due to changes in land use is almost unreal. Because in this study there are modelled extreme precipitation events (N = 10 to N = 100 years), the results also confirm the claim [60] that the use of the land has only a marginal impact in the development of flash floods. Also Hanel et al. [59] add that for flooding from extreme rainfall is the effect of land use on runoff volume and flow weaker compared with the importance of causal precipitation. This confirms [61], claiming that during the major floods in 2002 (which also took place at the catchment evaluated in this study), the influence of total rainfall on the height of the flood flow was completely dominant.

This conclusion does not mean that changes in land use and other measures decreasing surface runoff should be avoided. Changes in land use from arable land to grassland or forest naturally improves soil protection against erosion in the river basins and can have a significant impact on flood flow height and peak flow in smaller catchment area, especially for short-term floods.

The above-described changes are reflected in the characteristics expressed in relative terms (runoff coefficients—**Table 2**). Moreover, it is seen that the coefficients of runoff during designed rainfall N = 10 to N = 100 years are in the range of about 15–30%. This confirms the findings of Kašpárek et al. [62] that the runoff coefficients of flood flow even by a very intensive and large precipitation are close to the value of 30%. Similar values are seen on the charts published by Kašpárek et al. [61], which suggests that in exceptional floods in 2002 runoff coefficients were maximally to 30% in the river basin areas larger than 400 km^2 with total rainfall amount varying from 80 to 150 mm.

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