UNIVERSITY OF PÉCS
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The Analysis of Natural and Anthropogenic Factors of Disastrous Floods in Transcarpathia

PhD treatise thesis

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1. INTRODUCTION

My interest in the study of floods is due to personal experience. At the end of the XX century (November 1998) and the beginning of the XXI century (March 2001) there were disastrous floods in my region, the north-eastern part of the Hungarian Lowland, i. e. in Transcarpathia's flatlands where the Tisza River and its tributaries flow. These floods left an unforgettable impression on me for I saw and experienced the damage done by the high water to the population and participated in preventive measures against floods.

The scientists researching floods suggest various causes and factors for the emerging of disastrous floods. Some of them blame global warming (PARDEEP, P. et al. 2011; MIN, S.K. et al. 2011) as the first and foremost cause, while others claim that people's economic activity is to blame (JAKUCS L. 1982; KONECSNY K. 2002/b; CSUBATIJ, O. 1968; LISZTOPAD, O. 2001; HENSZIRUK, SZ. – BONDAR, V. 1973), namely the negative influence made on the environment and the irresponsible interference into the interrelated system of natural elements (CSUBATIJ, O. 1968; LISZTOPAD, O. 2001).

There is no unanimous opinion on the causes of the high water in the Upper-Tisza area (mainly in Transcarpathia). Some researchers see the cause of floods in the climate change (BODOLAINÉ JAKUS E. 1983; HOMOKINÉ UJVÁRY K. 1999; JAKUCS L. 1982), others blame the change of methods of timbering and the kinds of trees (KOLODKO, M. – TRETYAK, P. 2004; KONECSNY K. 2002/a; RAKONCZAI J. 2000).

2. AIMS

Natural and anthropogenic factors influence the emerging and the character of floods. The natural elements in our environment (rocks, relief, climate, flora and fauna, soil, rivers, etc.) are closely interrelated. The change of one element invariably causes the change of others. People's economic activity forces the connections between the elements of natural complexes to break. In the study of causes of floods I put forward the aim to research those climate components (temperature, precipitation) and anthropogenic elements (areas covered with forests, areas used for living and agriculture) that could have brought about high water levels in Transcarpathia. In the process of research I did not conduct persistent measurements in the catchment area, thus I could investigate only their territorial order and estimate their role in the emerging of floods. In my research I study each element and factor in the 40-year-period from 1970 to 2009.

Before and during the research there were many questions to be answered and they can be summarized in the following main tasks:

- the review of specialized literature on floods;
- the analysis of the emerging of floods in the period from 1970 to 2009;
- the period floodplain is under water during the flood;
- the change of climate factors (temperature, precipitation) in the period from 1970 to 2009;
- the study of the relation between the climate factors (temperature, precipitation) and the emerging of floods;
- the interrelation between the relief and the emerging of floods;
- the time when high water is accumulated in the Upper-Tisza area;
- the change of forest-covered areas and the role of forests in the emerging of high water;
- changes in Transcarpathia's economic life (cultivation of plants, animal husbandry) that could have influenced the emerging and the procession of floods;
- the influence of technologic factors (built-in areas, communication roads) on the flood run-off;
- determining the regions of influence of flood causing factors (natural, economic, technological).

3. RESEARCH METHODS AND SOURCES

I have analysed the natural factors causing the emergence of floods, as well as their changes in the last decades on the basis of the data from three meteorological stations (Beregszász, Rahó and Ungvár) and have applied statistic methods. The Transcarpathian Hydrometeorological Centre has many measuring stations and I have used their data to study the frequency of high water (Tiszaújlak) and compare the climatic elements on a monthly basis.

I have studied the temperature and precipitation changes on the basis of the statistic analysis of the data in the period from 1970 to 2009 of two Transcarpathian meteorological stations, Beregszász and Rahó. In the case of Beregszász I have used and analysed the data from the Beregszász meteorological station, the data on Rahó have been collected from the Ungvár Transcarpathian Hydrometeorological Centre. Besides the sources mentioned above I have made use of the Ungvár meteorological data collected from the National Climatic Data Center Internet source (NCDC 2010). The earliest, reliable and consistent data are available on the Internet from 1970 and this fact influenced my choice of the year as the starting point. Another important factor is that sometimes offices and stations refuse to render services.

In the process of the research I placed special emphasis on the analysis of linear trends. The analyses and the graphs have been done with the help of Microsoft Excel. I have made use of the

Student t-probe and correlation analysis in the process of the investigation. The maps elaborated by me have been done by means of CorelDRAW 3.

The tables of the forest-covered areas have been composed using the data from the Transcarpathian Regional Statistical Office. In the majority of cases the deficiency of the statistical publications caused problems, thus hindering the continuity and the consistency of the data presented there.

The Analysis of Satellite Photos

To analyse two catchment areas (Talabor and Nagyág) I have made use of two satellite photos. The first one has been downloaded from the NASA website (NASA 2003, https://zulu.ssc.nasa.gov) (Landsat-5, 1990), its resolution is 28.5 x 28.5 m/pixel (one pixel equals to about 800 m^2). The second has been borrowed with permission from the Natural Geography and Geoinformation Department of Debrecen university (Landsat-7, 2000), its resolution is 30 x 30 m/pixel (one pixel equals to about 900 m^2).

The analysis has been performed with the help of the IDRISI *2.0* software. The photos contain 4-4 colour categories (LÓKI J. 2002). The categories have been named according to the flora components (coniferous woods – dark green, deciduous woods – light green, plough-lands – pink, highly hydrous areas – blue).

Determining the Run-off Factor

Determining the low water run-off above the Nagyszőlős (starting from the Nagyszőlős bridge) Upper-Tisza catchment area has been done in the following steps (NAGY B. et al 2002):

1. First of all, we have determined the average run-off factor in the Upper-Tisza catchment area. We based our calculations on the Kenessey method, thus, the run-off factor has been subdivided into three parts:

$$\alpha = \alpha_1 + \alpha_2 + \alpha_3,$$

where α_1 denotes the surface descent, α_2 means the soil infiltration conditions, and α_3 stands for the influence of the surface vegetation (ALMÁSSY E. 1977).

To take into account the descent we have made allowance for the following correlations:

- steep descent (> 35 % downfall): $\alpha_1 = 0.30$
- medium descent (11–35 % downfall): $\alpha_1 = 0.20$
- gentle descent (3.5–11 % downfall): $\alpha_1 = 0.11$
- flatland (< 3.5 % - downfall): $\alpha_1 = 0.05$.

We have covered the Upper-Tisza (Transcarpathian) catchment area with a 10 x 10 kilometre square grid. We have used a 1:100 000 scale map to determine the descent indices in the grid in percentage, then we have transformed it into α_1 value. The conditions of infiltration:

- highly watertight soil: $\alpha_2 = 0.30$
- medium watertight soil: $\alpha_2 = 0.20$
- pervious soil: $\alpha_2 = 0.10$
- highly pervious soil: $\alpha_2 = 0.05$.

As to the soil's mechanic composition we had no grid resolution data, therefore we generally considered the surface medium watertight ($\alpha_2 = 0.20$). The vegetation:

- waste solid rock: $\alpha_3 = 0.30$
- meadow, pasture: $\alpha_3 = 0.25$
- cultivated area, forest: $\alpha_3 = 0.15$
- closed canopy forest, warp: $\alpha_3 = 0.05$.

2. To determine the size of the water supply area we have to know the run-off time from the catchment area's particular points. This consists of two parts: the time of the flow of water on the surface and in the watercourse (at the bottom of the valley). The water does the first stage on the surface covering it altogether or in the form of numerous trickles; it is influenced by many factors, thus making it difficult to calculate. These include besides the slope angle the characteristics and the condition of the surface, the vegetation and the leaf mould. Korbély and Kenessey suggested an empirical formula to calculate the speed of the water flowing down the slopes to the valley

$$v = 2\sin(\varphi^{0,6}),$$

where v is the speed of the water in m/s, φ is the angle of the slope in degrees (V. NAGY I. 1975; ALMÁSSY E. 1977). Knowing the speed of the flow and the length of the slope we can determine the time of the surface flow.

Another formula to calculate the flow of water down the slopes to the valley takes into account the amount of precipitation and 0.10 m high grass (STELCZER K. 2000):

$$v = 1070P^{1,5} I^{1,16},$$

where v is the speed of the water in m/s, P is the amount of precipitation in meters, and I is the area's downfall in m/m.

3. Taking into account the size of the catchment area under investigation we have not determined and mapped the surface run-off time in detail. Instead, we determined the general accumulation time in the water-course and transferred it to the whole catchment area. The speed of the water flow down the slope (and, correspondingly, the time as well) greatly depends on the angle of the slope. Our area and map investigations together with the

specialized literature show similar results – in the Upper-Tisza catchment area 20–30° slopes prevail. Thus, the Korbély–Kenessey formula has given us the 0.21–0.27 m/s run-off speed on the valley slopes. The formula taking into account the amount of precipitation (STELCZER K. 2000) has resulted in 0.12–0.20 m/s in case of 5 mm precipitation and 0.33–0.57 m/s in case of 10 mm. For further calculations we have used 0.2 m/s (equals to 0.72 m/s) which has been proven by area analysis. To determine the time the water gets into the watercourse we needed not only the speed of the water flow, but also the distance it makes. Taking into account the fact that in a research area in the North-Eastern Carpathians the river system density is generally 2 km/km^2, we suppose that the distance the water from precipitation makes to get into the watercourse does not usually exceed one kilometre, i.e. it takes about an hour and a half for the water to get into the watercourse.

4. The run-off time into the watercourse has also been calculated taking into account the speed and the distance. In the area the speed of the flow changes from point to point, however, the average speed is enough for our research. We understand the latter as the speed of the actual run-off in the area with medium speed at each point of the territory under investigation. We have used the following variant of the Chézy formula to determine the medium speed in the watercourse:

$$v_k = C \sqrt{mI},$$

where m is the average depth of the water (m), I is the downfall of the water surface, C is the factor of speed;

the value of the latter depends on the raggedness of the watercourse, its form and the downfall of the water surface.

Accumulation of Water in the Floodplain

Accumulation of water in the floodplain has been determined by means of two methods.

1. Measurements have been done to see how the level of the area outside the dam differs from the floodplain level;

2. Sediment collectors have been placed in the investigated high water area to analyse the amount and the character of the sedimentary river drift which represented 1 m^2 actual surface. The material has been polyethylene and it has been fixed at its four angles. The sample territories have been chosen to cover two relatively high and two lower parts. The sample territories represent all kinds of floodplains characteristic of the area from ground to natural levee.

Calculation of the Downfall Curve

I have used Google Earths Internet site to determine the Tisza downfall curve from the Black-Tisza source to Tiszaújlak Tisza-bridge part.

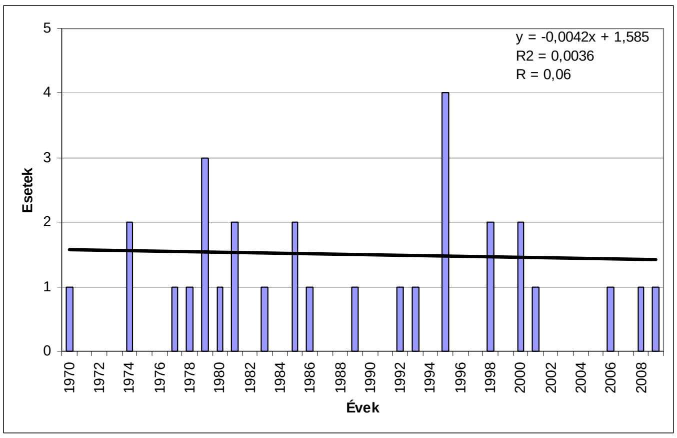
1. I have determined the height above the sea level of the Black-Tisza source, of the junction point of the Black -Tisza and the White-Tisza, as well as of the Tiszaújlak river part;
2. I have determined the length of the river (divided into sections between the settlements) from the source of the Black-Tisza to the Tiszaújlak Tisza-bridge;
3. I have elaborated a graph using the data collected and the Microsoft Excel software.

Besides the methods mentioned above the research includes the following ones: analysis of the specialized literature in Transcarpathian and Hungarian libraries, visiting the area (making photos) when the forest coverage and the study of vegetation were conducted.

I collected warp when I visited the area in 1998 and 2001 (both times in the same place) in the estuary of the Tisza's left tributary, the Borzsa after the high water.

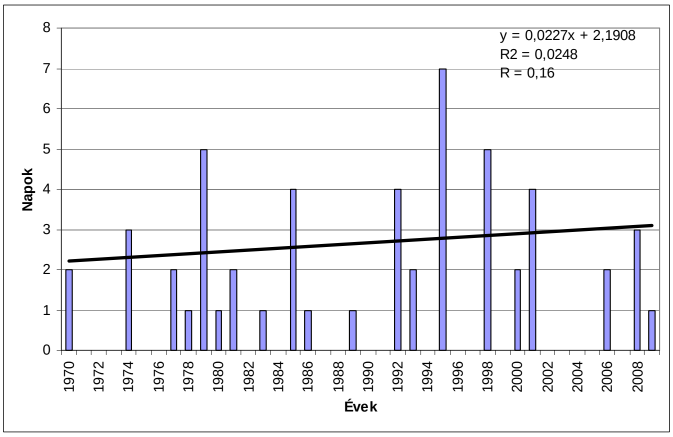
4. SUMMARY OF THE RESULTS

1. The Tisza flood-basin has overflown 30 times from 1970 to 2009 (*graph 1*). In the 40-year period under investigation the frequency of floods decreased, however, in the period before the disastrous 1998 and 2001 floods (from 1970 to 2001) the data show a slightly increasing tendency. We can see an increase in the frequency of floods from 1977 to 1986 when, with the exception of 1982 and 1984, the river overflew into the floodplain annually. Between 1970 and 2009 the greatest number of floods happened in 1995 (4 times). The frequency of floods caused by the Tisza and the correlation between the years in the 40-year period has not shown significant changes with a 95% probability. The frequency of high water (between 1974 and 2001) was repeated every three years and the floodless period did not last for more than two years. However, there were no floods for 4 and 5 years respectively in the period from 1970 to 1974 and from 2001 to 2006.



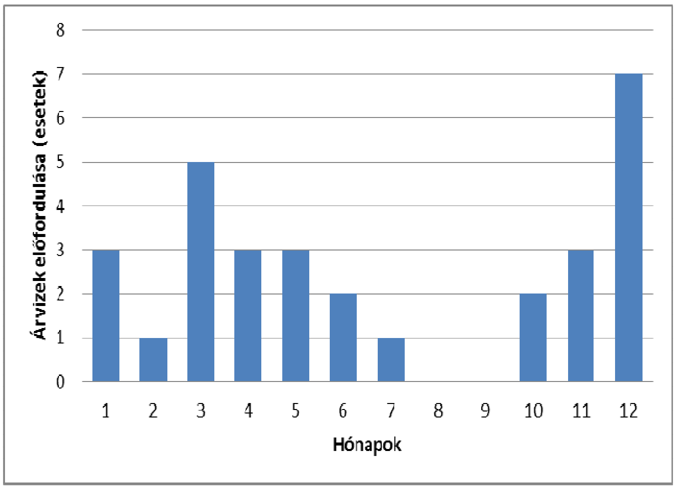
Graph 1: The frequency of the Tisza overflows (the number of cases) into the Tiszaújlak floodplain between 1970 and 2009.
Source: the storage of the TRANSCARPATHIAN HYDROMETEOROLOGICAL CENTRE, 2010; Edited by Izsák T.

2. The areas were usually flooded for 1-2 days, however, in 1985, 1995, 1998, 2008 the flood stayed for 3 days, in 1992 and 2001 it lasted for 4 days. In 1995 the high water stayed the longest – for 7 days (*graph 2*). During the disastrous flood in 1998 the river overflew into the floodplain twice for a total of 5 days, in 2001 it remained in the floodplain once for 4 days. The study of the length of floods caused by the Tisza in the 31-year period before the disastrous 1998 and 2001 floods renders significant changes probable.



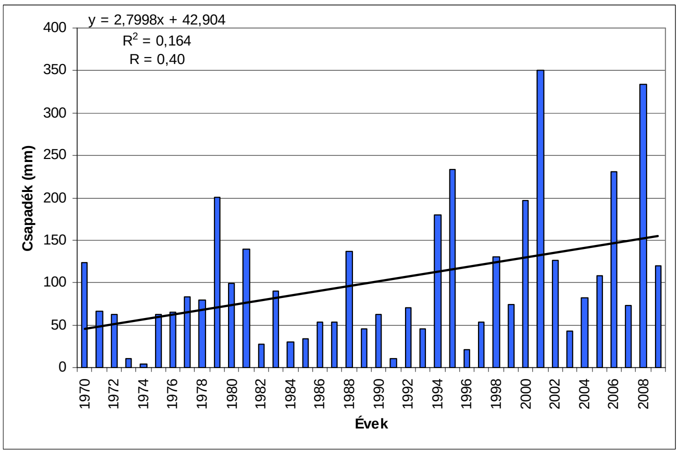
Graph 2: The coverage of the floodplain with water (in days) in Tiszaújlak during the floods in the period from 1970 to 2009.
Source: the storage of the TRANSCARPATHIAN HYDROMETEOROLOGICAL CENTRE, 2010; Edited by Izsák T.

Classified into months (*Graph 3*) the Tisza overflew most often in December (7 times) and March (5 times), however, in the 40-year period (1970–2009) the river never overflew in August and September. In other months there were generally 1-3 floods.



Graph 3: The frequency of floods in months in the period from 1970 to 2009.
Source: the storage of the TRANSCARPATHIAN HYDROMETEOROLOGICAL CENTRE, 2010; Edited by Izsák T.

In 1970–2009 the amount of precipitation increased in March (*graph 4*) and decreased in December. During the other months there was either a slight increase (in January, February, April, September, October) or an insignificant decrease (in May, June, July, August, November).



Graph 4: The change of the amount of precipitation in Rahó between 1970 and 2009 in March. Source: the storage of the TRANSCARPATHIAN HYDROMETEOROLOGICAL CENTRE, 2010; Edited by Izsák T.

In the 40 years under analysis (1970–2009) the frequency of floods shows a decreasing tendency, however the time the land was covered with water grew longer, thus increasing the amount of water going down the flooded areas and leaving an ever thicker layer of warp. In 1998 the thickness of warp at the estuary of the Borzsa was 4.2 centimetres, in 2001 it increased to 5.7 centimetres.

3. With the help of the trend-lines I have determined that in Transcarpathia in 1970–2009 (on the basis of the data of the Beregszász and Rahó meteorological stations), particularly in Beregszász in the period from 1970 to 2009 the average annual temperature has increased by 1.6°C (from 9.5 to 11.1°C), in Rahó – by 1.2°C (from 7.0 to 8.2°C). The average annual temperatures and the annual correlation coefficient testify to significant changes in both stations.

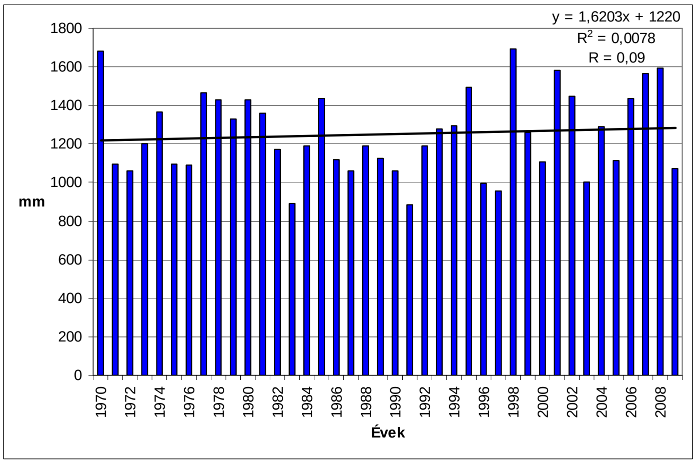
The annual absolute maximum temperatures had been gradually increasing in the course of years. In Beregszász in the period from 1970 to 2009 the temperature increased by 4.1°C from +31.8°C to +35.9°C, in Rahó it increased by 3.5°C from 30.0 to 33.5°C). The minimum temperatures had been changing as well in the period under investigation. The annual absolute minimum temperature in Beregszász in 1970–2009 increased and reached 1.0°C (–18.5°C and –17.5°C), in Rahó it decreased from –18.8°C to –19.2°C (–0.4°C). The lowest temperature in Beregszász was in 1987 (–26.6°C), in Rahó in 1987 and in 2004 the temperature was–24.0°C. The annual absolute minimum temperature did not show significant changes.

In Beregszász the annual absolute temperature amplitude between 1970 and 2009, according to trend-lines, was 50.0°C and 51.2°C, the absolute temperature amplitude was 1.2°C; in Rahó the annual absolute temperature amplitude was 48.9°C and 52.9°C, the absolute temperature amplitude was 4°C) showing an increasing tendency, however, the change is only significant in Rahó.

I have researched temperature changes on the basis of the data of three meteorological stations and the Student t-probe breakpoint analysis. All the three stations have significant breakpoints (in Rahó in 1988–89 in Beregszász and Ungvár in 1998–99), which testify to discrete, not continuous processes, their emergence is also conditioned by climate-forming factors.

4. Among the natural factors causing floods greatly influential are the amount and the variability of the amount of precipitation. In the period from 1970 to 2009 the amount of precipitation (based on the data of the analysed meteorological stations) was gradually increasing.

The highest amount of precipitation in Beregszász occurred in 1998 reaching 969.8 mm. The lowest amount of precipitation was in 1973 (476 mm). The average annual amount of precipitation comprises 697.8 mm between 1970 and 2009. Amount above the average occurred in 21 years, while amount below the average was in 19 years of the period under investigation. In Rahó the highest amount of precipitation was in 1998 as well (1693 mm), the lowest amount fell in 1991 (883 mm). The average annual amount of precipitation comprises 1253 mm between 1970 and 2009. Amount above the average occurred in 19 years, amount below the average was in 21 years of the period under investigation.



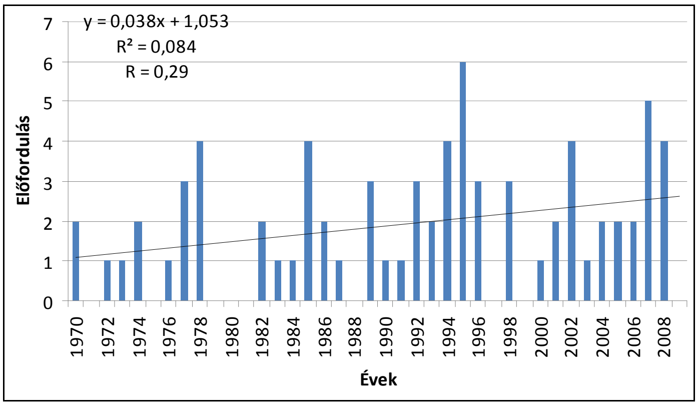
Graph 5: The change of the annual amount of precipitation in Rahó between 1970 and 2009. Source: the storage of the TRANSCARPATHIAN HYDROMETEOROLOGICAL CENTRE, 2010; Edited by Izsák T.

With the help of the trend-lines I have determined the change of the amount of precipitation in Beregszász in the period from 1970 to 2009. It has increased by 15 mm, in Rahó (*graph 5*) there has been a 60 mm increase, however neither case is significant.

5. Having analysed the floods caused by the Tisza and the average amount of precipitation I have come to the conclusion that there is no relevant connection between the average amount of precipitation and the frequency of floods. The highest amount of precipitation in Rahó occurred in 1970 and 1998, while the floods were most frequent in 1975 and 1995. In the 32 years (1970–2001)

before the disastrous floods in Transcarpathia in 1998 and 2001 the amount of precipitation decreased, however, in general, in 1970–2009 we can see a slowly increasing amount of precipitation.

In 17 cases I have found connections between precipitation over 40 mm (they have become more frequent between 1970 and 2009, *graph 6*) and the occurrence of floods, including the two disastrous floods (on 4 November 1998 precipitation amounted to 64.4 mm, on 5 March 2001 precipitation amounted to 92.2 mm).



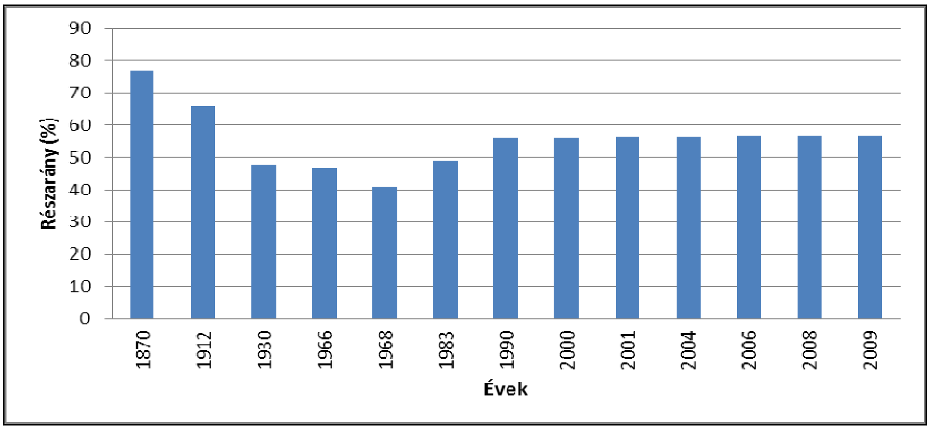
Graph 6: Precipitation over 40 mm/day in Rahó between 1970 and 2009.
Source: the storage of the TRANSCARPATHIAN HYDROMETEOROLOGICAL CENTRE, 2011; Edited by Izsák T.

In 1995, 1998, and 2001 there is also a connection between precipitation and the number of floods. The amount of precipitation in these years was above the average, just like the frequency of floods. In the years with above-the-average amount of precipitation floods occurred. In Transcarpathia the most critical months from the point of view of floods are March and especially December.

6. The relief greatly influences the accumulation time during floods. The run-off time in case of low-water mark of the Talabor and the Nagyág is equally about 30–40 hours, under the conditions of high water the time is reduced significantly due to faster flow. In the Talabor the accumulation time during high water is about 11 hours, in the Nagyág it amounts to 10 hours. In the latest decades there have been no significant changes in the relief that would cause the increase of frequency of floods or a higher level of the floods.

7. Forest coverage is also an important factor in the formation of floods. After World War II till mid-1960s forests were significantly reduced, thus breaking the forests' natural balance, and timbering (from late XVIII century till nowadays) brought about negative processes (mainly floods). The forest covered area was reduced from 76.9% (in 1870) to 41.1% (in 1968) (*graph 7*).

1980s brought about changes with the reduction of timbering, introduction of new wood processing technologies, causing more economical use of wood for ready-made goods. In 2009 the region's 724 thousand hectares were covered with forests, amounting to 56.8%.



Graph 7: The change of forest coverage in Transcarpathia from 1870 till nowadays. Source: BJELOUSZOV, V. et al. 1969; HENSZIRUK, SZ. – BONDAR, V. 1973; MARINICS, O. 1989; KÁRPÁTALJA NÉPGAZDASÁGA 1969, 1989; KÁRPÁTALJA 2000, 2004, 2009; VASZJUTA, SZ. 1991; HRANCSAK, I. et al. 1995; Edited by Izsák T.

The increase of forest-coverage was also conditioned by the fact that the region's settlements since early 1990s were shifting to using gas, thus reducing the amount of firewood. In 1990 among the region's 609 settlements 37 were supplied with gas, in 2009 this number increased to 380. Nowadays there is no settlement without natural gas or propane-butane gas supply. Besides the governmentally licensed timbering illegal exploitation is going on reaching 10.7 thousand m^3 in 1995.

The annual statistic publications claim the increase of forest-covered areas, however, comparing the exploitation and renewal data I have come to the conclusion that the stands of trees are reduced by over 10 thousand hectares (1.4% of the forested area) every year. The greatest loss of forested area (since 1970) was in 1970, the smallest in 2000. One of the ways to maintain exploitation of forests and protect them is to establish a nature conservation area.

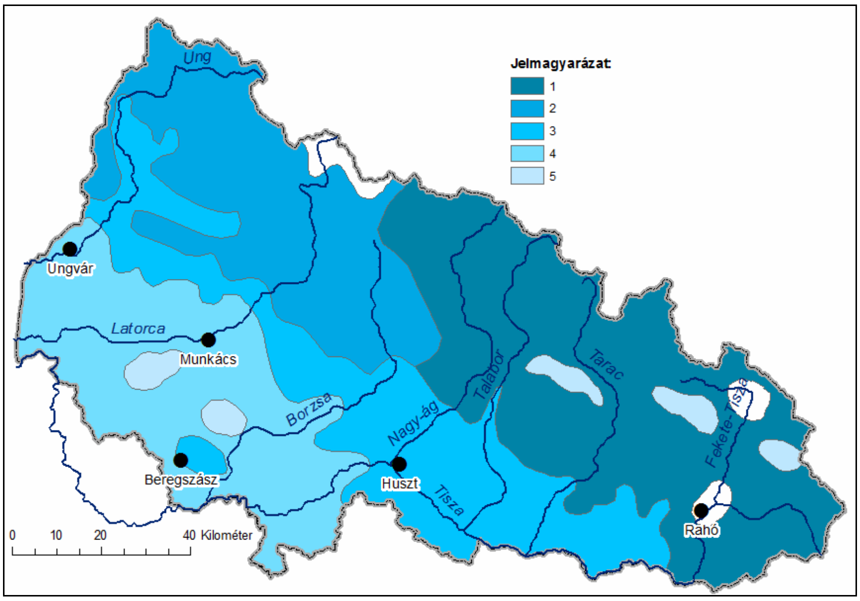
8. The forests' soil mulch, especially the upper dead fallen leaves level is of great importance for storing falling precipitation and melted water, as well as for reducing the size of floods. The water-storing ability of soils depends on their physical components and on the people's economic activity in the forests. The change of the technology of transporting cut-down trees downgrades, pares, increases the density of the soils, thus decreasing their pervious and water accumulating characteristics and increasing the run-off amount. Forest exploitation increases soil erosion, slurry formation which is washed down from the mountain slopes into the rivers. Research at the estuary shows that the thickness of warp is directly proportionate to the reduction of the terrain's slope

angle. In the plain floodplain areas and in the closed basin-like soaks warp is accumulated. The general filling up of floodplains depends on the run-off time of the floods. It can reach 5–7 centimetres during floods, thus causing a 85–119 cm filling up after finishing the river control activity.

At the rivers' estuaries the frequent change of water level increases side erosion. The destructive influence of erosion can reach 20–30 centimetres annually.

I give a detailed diachronic description of the natural (*map 1*) and anthropogenic factors (*maps 2 and 4*) (as a summary) influencing the emerging of high water in different degrees. The influence categories in the legends to the maps give a short description of the factors influencing or moderating the amount of water that comes to the surface. In determining their role in causing high water the size of the recipient area has been taken into account. The unified flood-causing category system of the maps (from very strong to very weak) enables us to compare all the influential factors. Thus, we can distinguish areas or regions in the Tisza's Transcarpathian catchment basin.

Among the natural factors the most significant (very strong and strong) in causing floods is the mountainous relief (*map 1*), divided into two kinds: highlands and midlands influence.



Map 1: The allocation of the natural factors causing high water in Transcarpathia.
Edited by Izsák T.

Legend:

1. <u>Very strong influence</u> –highlands which are predominantly situated higher than 1000 m above the sea level. Some parts are rock waste lands or frequently snow pastures. Narrow catchment areas with the quickest exhaustion time belong to the southern run-off, 40–50 km long valleys.
2. <u>Strong influence</u> – midlands which are predominantly situated between 500–1000 m above the sea level, with steep slopes, highly covered with forests, and relatively far from the recipient area.

3. Medium influence – agricultural land at 200–500 m above the sea level with gentle wide slopes which is frequently cultivated, thus causing significant infiltration and evaporation loss.

4. Weak influence – agricultural cultivated land under 200 m below the sea level, practically plain area with loose soil, situated in the densely populated Beregszász-Munkács area which is close to the recipient area.

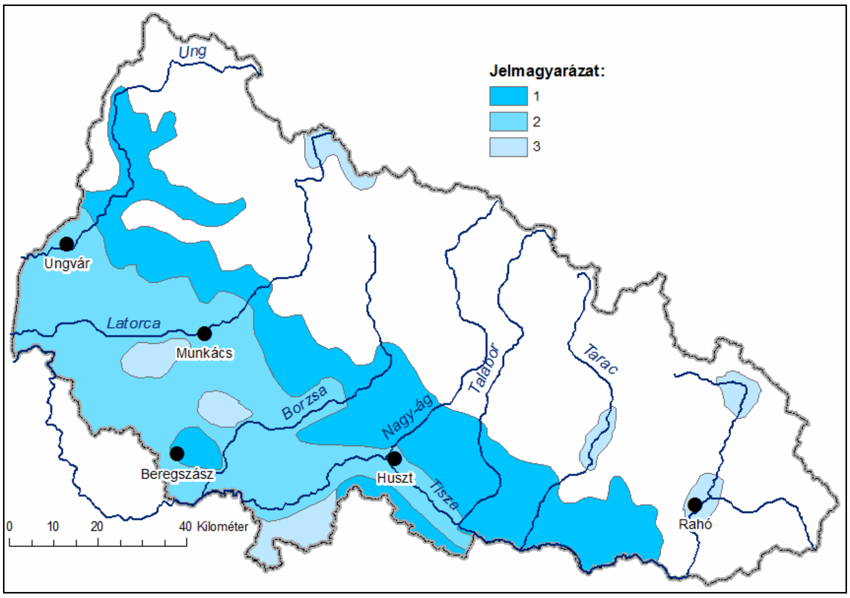
5. Very weak influence – snow-covered pastures and rock waste land with excellent run-off conditions, however, the area is small and far from the recipient area. Therefore, their influence on the emerging of floods is considered as insignificant.

9. Since 1990s there have been significant changes in Transcarpathia's economy. The importance of the service sphere has grown, the negative processes in the economy have brought about the change of the economic system. Many people have lost their jobs and looked for work abroad. The economic setback is present in Transcarpathia as well. Plants and factories were closed down, agricultural societies were terminated. Transcarpathia is still trying to gradually increase industrial production and improve the neglected ecological situation.

The environmentally-damaging functioning of chemical factories, storage of military vehicles, the excessive and inappropriate use of chemicals in agriculture, the allocation of industrial, agricultural and household waste, the drastic decrease of forest-covered areas pose serious problems for the partially governmentally subsidized economy.

Transcarpathia is an agricultural region specializing in wood supply and processing, food, light industry, machine-building, spa-treatment services, tourism and agricultural production. The agricultural industry complex plays an important part in the region's economy. Among the region's economic activity agriculture (together with game husbandry and sylviculture) is the most efficient branch. 26.4% of the able-bodied population work here. 35.5% of Transcarpathia's territory is cultivated.

The influence of anthropogenic factors causing floods is the strongest (medium) in the south-western part of the north-eastern Carpathians which is predominantly used as plough-land in the foothills (*map 2*).



Map 2: The allocation of the anthropogenic factors causing high water in Transcarpathia. Edited by Izsák T.

Legend:

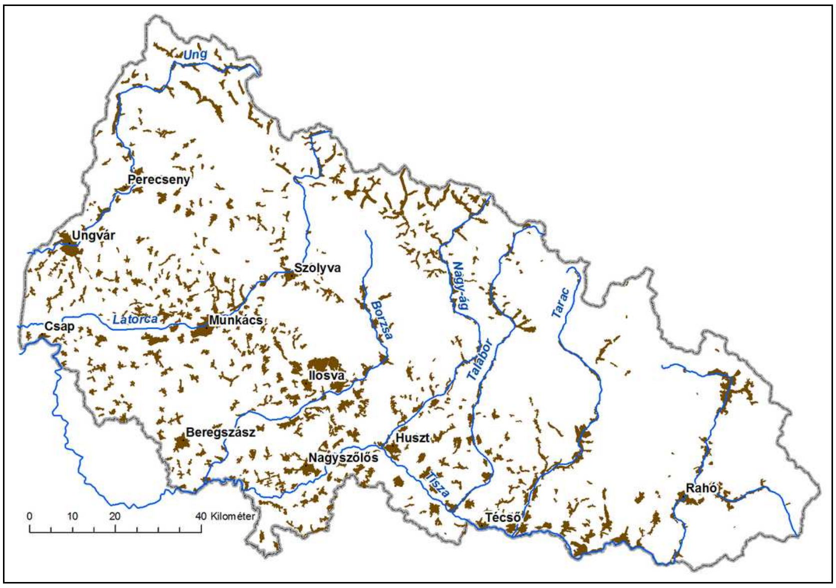
1. Medium influence –south-western foothill slopes in the north-eastern Carpathians are often characterized by windy ridges and plains with wide meadows and pastures. The surface run-off caused by precipitation flows directly into the recipient area.
2. Weak influence – predominantly arable cultivated area up to 200 m above the sea level. The surface run-off has significant evaporation and permeation loss due to frequent loosening of the soil. The surface run-off caused by precipitation flows directly into the recipient area.
3. Very weak influence – two types can be distinguished in the catchment area. Most often these are arable cultivated areas providing food for the numerous population living in the highland plains near big settlements. The surface run-off is relatively good, the water flows directly into the recipient area. Due to the smallness of this type its water accumulation influence is considered to be quite low.

The territorial structure of the natural and anthropogenic factors (*maps 1 and 2*) testifies to the moderation of the hydrological influence of geographical (natural and social) environment depending on the height above the sea level.

10. The increase in the number of settlements and their territory augments the procession of the surface water. The roofs of the houses, the hard surface roads and road systems in the settlements, the railway, the drain- and pipelines, the power-lines reduce the amount of precipitation getting into the soil as well as permeation, thus increasing the surface run-off.

In Transcarpathia after World War II the population has almost doubled. In the populated areas and along the transport roads the ecological situation is becoming worse, the natural vegetation and forests are being reduced, negative natural phenomena and processes are emerging.

The number of settlements in early XX century was 492, now there are 609 settlements in the region. The greater the number of settlements the more extensive is the territory they occupy (*map 3*).



Map 3: The territory occupied by Transcarpathian settlements (brown colour – settlements). Source: Transcarpathian Atlas 1991; Edited by Molnár D.I. – Izsák T.

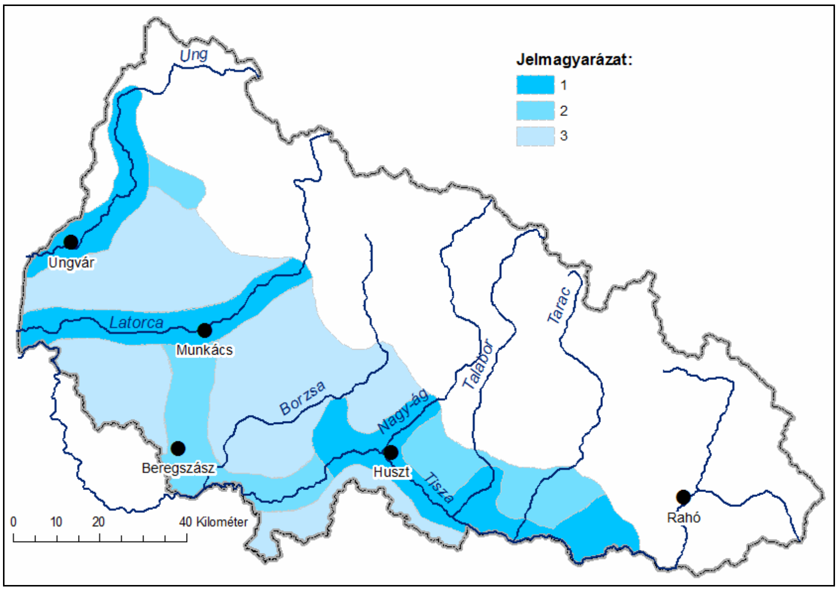
Before the Tisza's flow was taken under control the settlements were built in the areas threatened by floods. The erection of flood preventing protective lines and dams led people to build houses in the plains where the river formerly flowed.

The length of the hard surface roads reaches 3.3 thousand kilometres, which is over 261 km per 1000 km² area. The width of transport roads is generally 16 meters. They occupy 52.8 km^2 (5280 ha), i.e. 0.4% of the region. The length of unsurfaced roads (in forests, meadows, mountains, etc.) is about the same.

The length of the railway lines has not changed much since 1960s and they occupy 6.5 km^2 in Transcarpathia (together with the protected stretch of land belonging to it), thus taking 0.05% of the region's territory.

The pipelines, the high voltage power lines together with the artefacts and the protected stretch of land related to them occupy about 4 thousand hectares, i.e. about 0.3% of the region's territory.

The hydrological influence of technological factors (the hard surface in the settlements: roofs, roads, pavements, etc.) cannot be obviously compared to the natural and anthropogenic factors for they emerged as a complex and interrelated territory, however, the technological factors stand far from each other. The latter are most characteristic in the lowest lying parts of the catchment area near the biggest run-offs (*map 4*).



Map 4: The allocation of the technological factors in Transcarpathia.
Edited by Izsák T.

Legend:

1. Medium influence – the part of the catchment area with settlements populated by 5000 or more people. These have developed a relatively well determined territory with hard surfaces (roofs of houses, roads, pavements, etc.) exceeding 50%. These settlements are predominantly situated along the water flow, thus, the evaporation and infiltration runs off with minimum loss to the river bed.

2. Weak influence – the part of the catchment area with settlements populated by 2000–5000 people. These are characterized by numerous gardens, while the hard surface amounts to 25–50%.

3. Very weak influence – the part of the densely populated catchment area where the settlements are very close to each other (2.5–3 km) and the population of the tiny villages is below 500 people. In the rural areas the proportion of hard surfaces is usually below 25% and the surface water flow can be seen for kilometres.

After analysing the causes of floods I have come to the conclusion that they emerge, run-off and have become disastrous in size mainly due to the excessive amount of precipitation. The 1998 and 2001 floods in Transcarpathia were caused by the huge amount of precipitation in a short period of time. Besides, human economic activity should also be mentioned, namely the drastic reduction of the forest-covered areas after World War II (especially between 1950 and 1980) as well as timbering in recent years which is often claimed to be performed to protect the forest.

As a result of the growth of settlements forests have been destroyed, the surface vegetation has been changed, thus increasing the influence of the flood-causing factors.

Of great significance is the realization of investments into flood-prevention measures. The Ukrainian state has not yet found the mainstream tendency in flood prevention legislation and has failed to properly finance the flood preventing measures. Besides the positive achievements there are still deficiencies, drawbacks and failures that are often solved only after the natural disaster.

CONCLUSIONS, SUGGESTIONS AND THE FURTHER DIRECTION OF THE RESEARCH

Having conducted the research we can make the following conclusions and suggestions:

1. The disastrous floods of 1947, 1957, 1970, 1998, 2001 were due to intensive melting of snow and abundant precipitation at the same time.
2. In the recent decades in Transcarpathia there has been a small increase of annual average temperature and precipitation; in the years with above-the-average amount of precipitation the rivers overflew into the catchment area, however, the average increase of precipitation is not directly connected to the rise of the frequency of floods.
3. All the natural (precipitation, relief, forest coverage) and anthropogenic (timbering after World War II, growth of settlements, the state of hydrotechnological artefacts) factors alike played their role in the emerging of disastrous floods.
4. Most influential for the increase of high water is the change of climatic components, including the rise of the amount of precipitation, the accidental abundant daily precipitation which has been gradually increasing in frequency in recent years.
5. Another important factor is the forest coverage. The forest controls water supply, significantly reduces extreme conditions, extends precipitation in time, holds it back, stores the falling and melting precipitation, thus delaying run-off.
6. The present frequency of high water can be accounted for by agricultural production in the mountainous areas, especially by husbandry in the Soviet times. The grazing of sheep in the subalpine region brought about the lowering of the upper limit of forests and as a result of the melting snow in spring more water gets into the river bed.
7. The floods will occur in the future as well, however, in the prevention of their destructive character hydrological constructions will still play a significant role (dams, reservoirs, by-passes, etc.).
8. We cannot make “positive” changes of the climate, therefore, we have to perform complex flood-prevention measures to avoid disastrous high water and floods in the future.

To forecast floods, to determine flood levels, to avoid their disastrous character we have to make a detailed analysis of each risk factor for the causes of floods do not depend on one factor, but on a complex of factors together with the natural and anthropogenic elements influencing them. Therefore, further researches have to be focussed on:

- climate elements and the system of relations between them, especially the formation and change of precipitation and temperature indices in the Upper-Tisza catchment area on the whole territory of the Carpathian basin;

- the research and detailed analysis of the change of forest-covered areas in certain parts of the Tisza catchment area, determining the continuous reduction, increase of forests and its influence on the run-off;
- the study of the floodplain's becoming covered with warp as well as a cartographic analysis of these territories;
- further and more extensive flood-prevention across-the-border cooperation together with specialists in the field (hydrologists, meteorologists, geomorphologists, politicians), together with the leading specialists from adjacent branches (engineers, builders, maintenance staff);
- the influence of human actions (industrial, agricultural, transport) on the Tisza catchment basin in general and its particular parts which still need further research.

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