THE CAUSES OF CATASTROPHIC FLOODS IN THE TRANSCARPATHIAN REGION AND THE SYSTEM OF ECOLOGICAL PROPHYLACTIC MEASURES FOR THEIR PREVENTION

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The greatest floods in the XX-th century occurred on November 4-8, 1998 in the Transcarpathians, in the upper reaches of the Tisa and its tributaries – the Teresva, the Rika, the Borzhava, as well as in the basin of the river Latorytsia. These floods were accompanied by such natural disasters as mud flows, structural and layer shifts, plane and bank erosion and carst processes. All of these increased essentially the material losses. According to official data, 269 villages populated by 40790 people suffered from the floods. There were 1426 houses ruined fully and 1347 houses partly damaged. The 2887 houses needed capital repair and the 187 populated areas were deprived of telephone communication.

In the mountain villages of Tyachiv district there were 241 families that had to leave their dwellings as a result of layer shifts, and about 300-350 houses are still in dangerous zone as to the shifts and under the control of geologists. 100,000 hectares of agricultural lands, including the 70,000 hectares of arable land were flooded in Prytysianska lowland, as well as in the plain villages within the basins of the Teresva, Tereblya, Rika, Borzhava and Latorytsia rivers.

Water chaos damaged 20 big bridges of 876 m lenght and 254 km of highways. 680 special shores were destroyed in the beds of rivers. In the basin of the Teresva, near the villages of Kryve, Neresnytsia, Pidplesha, Krasna and Lopukhovo dozens of km of narrow-gauge railways were damaged, many railway bridges were undermined. The railroad was put out of action for a long time.

During this ecological disaster 17 persons were lost, the general economical losses exceeded 400 million hryvnas, to say nothing of the cost of hundreds of thousand cubic meters of washed out brown-soil grounds and agricultural lands, depreciated by shifts.

The ecological disaster attracted the public attention in many countries of Europe, America and Asia, which rendered the humanitarian and technical assistance to the flood's victims. Ukrainian President and the Head of the Government visited the

Transcarpathian region for several times to speed up the liquidation of flood aftermath and to help the people.

The problem of conquering floods and other natural disasters has an interstate importance. The largest tributary of the Danube – the Tisa flows through the transboundary zone of Ukraine, Romania and Hungary. Its length is 201 km within the Transcarpathian region and totals – 966 km. Transcarpathian rivers such as the Latorytsia and the Uzh flow down into the river Bodrog on the territory of Slovakia. Numerous oil and gas pipelines, the pipes for chemical products and ethylene, high-voltage electrical lines are laid through the Ukrainian Carpathians. There are also the railways and highways of international significance there. Therefore it is important to ensure an ecological balance for normal functioning of these communications in the region.

Comparative ecological research shows that the character and the scale of floods is conditioned by a complex of interacting natural and anthropogenic factors.

Among the natural factors the most important is the unfavourable hydrometeorological situation: the quantity of precipitation exceeds the norm; the duration, intensity and area of rainfall; the sudden melting of snow in early spring or late autumn; the character and density of hydrological net.

It should be noted that the Carpathians are situated in the semi-humid and humid climatic zone. In Chop (102 m above sea level) falls 700 mm of vertical precipitation per year, at the meteorological station Ruska Mokra (640 m a.s.l.) in Gorgan Mts. it reaches 1600 mm. To this quantity we should add about 200 mm of horizontal precipitation from moisture condensation of fog and hoar-frost in the forests [16]. Hydro-net in Transcarpathians includes 9426 rivers and streams 19,793 km long. Here is the highest density of waterways in Ukraine – 1.7 km per km^2.

Flood processes depend also on the characters of water basin surface – steepness of the slopes, dismemberment of the relief, thickness of the pedosphere, depth of geological layers.

Due to such unfavourable ecological situation dangerous floods happened in the Carpathians in the past too, when the anthropogenic impact onto natural landscapes was insignificant. According to contemporary records and historical data, floods were registered in the basins of the Tisa, the Dnister and the Prut in 1700, 1730, 1864, 1887, 1895, 1900, 1911, 1913, 1926, 1927, 1933, 1941 [1,5].

At the beginning of the XXth century an especially dangerous flood took place in Transcarpathians on the Tisa on July 10-11 1913, when the water level in the centre of Tyachiv reached 120 cm (it is marked on the monument of L. Kossuth). In 1914, despite of the war, Hungary built a strong dike on the right bank of the Tisa to protect populated areas.

In the 1930-ies the village Vylok in Berehovo district suffered from the flood and the Czechoslovakian government built a similar dike.

Ecological stability in the basins of mountain rivers and their normal hydrological regime depend greatly on the index of forestation, the character of vegetation cover and anthropogenic changes in its structure. From all types of vegetation, forest ecosystems, due to the multi-layer structure of its over- and underground parts and high productivity, have the highest ecostabilizing importance. The efficiency of water-protective function of forest ecosystems depends on the index of afforestation within the water basin, the age, the dendrological composition, the vertical structure, productivity, sanitary condition of phytocoenosis, character of the layer and physical properties of forest soils.

According to the data of long-time research of O.V.Chubaty [13] at the forest hydrological station in Svalyava (219 m a.s.l.), with annual precipitation of 965 mm, the ripe beech forest holds 25.1% of precipitation during the year, and the rest of 74.9% gets under its floor. On the northern macro-slope of the Carpathians at the station Khrypeliv (850 m a.s.l., 1094 mm of precipitation) spruce forest hold 36.9% of precipitation, and 63.1% of it goes under the floor. With the increase of afforestation index on 1% of the area, an average river flow is increasing by 9.4 – 11.9 mm.

During the last centuries undesirable quantitative and qualitative changes took place in the forest formations in the Carpathians and then influenced essentially the ecological stability of the natural environment. The area of oak forests has decreased by 64,000 ha, the beech forests by 93,000 ha, and the fir forests by 36,200 ha. On the other hand, the area of spruce forests (mostly monocultures) has increased by 298,300 ha [3,7,8]. The area of post-forest pastures has increased by 331,000 ha and the area of post-forest hayfields by 213,000 ha [4]. There are about 60,000 ha of anthropogenic bushes and 113,000 ha of badlands in the Ukrainian Carpathians. The general afforestation degree in four Carpathian regions in 1973 was 20.16% in the plains and 53.52% in the mountain parts [9].

Essential changes in the forest stock of the Carpathians had taken place in economically difficult post-war years. During 1947-1957 73 million m^3 of wood was cut there and 20% of the forest covered lands was bared. Fig.1 and 2 show the dynamics of the main use and afforestation in Transcarpathians in the post-war times. These significant territorial changes in ripe forests had negative impact on the hydrological condition of mountain rivers too, and disastrous floods became more frequent. They were marked in 1947, 1948, 1955, 1957, 1959, 1964, 1969, 1970, 1974, 1977, 1980, 1982, 1992, 1993, 1997 and 1998 [5,9,10,12].

Especially unfavourable hydrological situation was in the Transcarpathians in the autumn of 1998. It caused immense floods, ground shifts and mud flows. During August – October the precipitation at the meteorological stations in Transcarpathians reached 1.2 – 2 monthly quotas and the over-wetted ground did not hold the excessive moisture (Fig.3). At the beginning of November 1998 an atmospheric front passed through the Carpathians causing the formation of micro-cyclons in the Ukrainian Carpathians. As a result, the total quantity of precipitation was 45-75 mm on November 4-5 in the basins of the Latorytsia, the Borzhava and the Teresva; in the upper basin of the Tisa it was 90-120 mm, and in the upper waters of the Rika 207 mm (Fig.4). Daily amount of precipitation reached monthly norm and in some places 1.5 of norm.

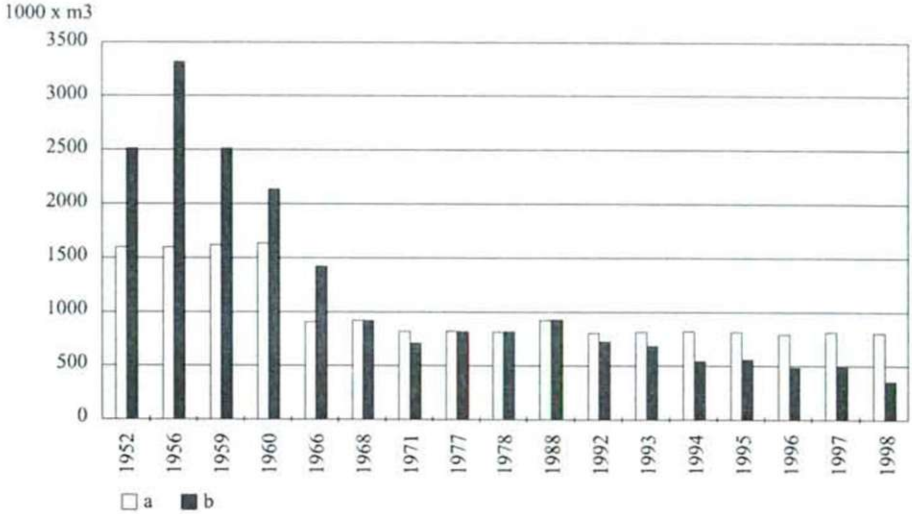

Fig. 1. The dynamics of real clear cutting in forestry in the comparison with ecological grounding cutting (1952-1998) (here and on the fig. 2 – according the date of Forestry direction). Symbols indicate: *a* – ecological grounded clear cutting, *b* – real cutting

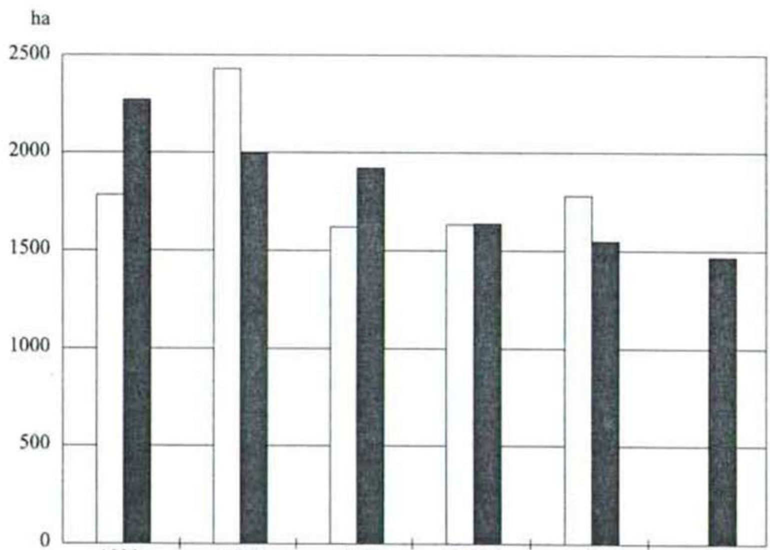

Fig. 2. The dynamics of forestation in comparison with area of clear cutting in forestry in the 1993-1998 period. Symbols indicate: *a* - the area of clear cutting, *b* - the area of forestasion.

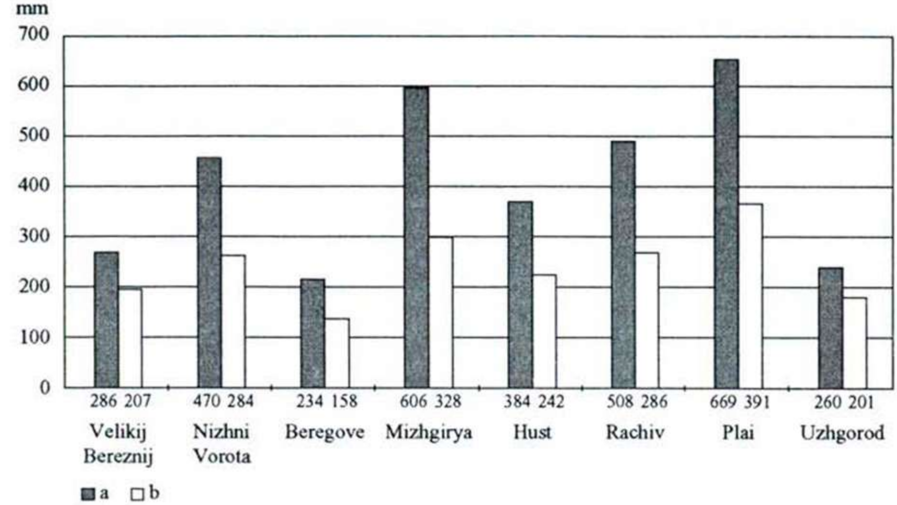

Fig. 3. The precipitation in August–October 1998 on meteorological stations of Transcarpathian region (here and on the fig. 3, 4 – according the date State hydrometeorological station). Symbols indicate: *a* – factual precipitation, *b* – average precipitation

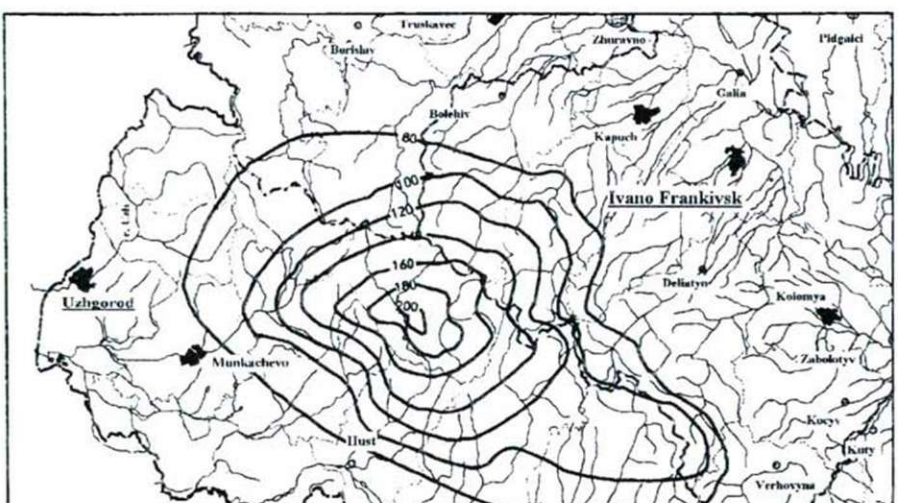

Fig. 4. The map of isolines of precipitation in the Carpathians in 3–5 November 1998 (scale 1:1000000)

Table. Characteristics of water levels during the flood of 5-8 November 1998 in the Transcarpathians.

River	Meteo-post	Zero of post, alt. asl	Historical maximum		Data on the flood in 5-8 November, 1998					
			water level, cm	date	H (during observa-tion) average annual, cm	H lowest water level in the river, average, cm	H max of the flood, cm	date / duration of observa-tion, min.	+ H* (during observa tion), annual, cm	- H* (during observa-tion) of lowest level in 1998, cm
1	2	3	4	5	6	7	8	9	10	11
Tisa	Rakhiv	429,73	499	08.06.69	248	158	500	05.11/00	252	90
	V.Bych-kiv	294,78	598	13.05.70	208	58	552	05.11/04	344	150
	Tyachiv	208,97	674	30.12.47	199	-5	726	05.11/10	527	204
	Khust	162,91	426	13.05.70	180	-1	428	05.11/16	248	181
	Vylok	115,15	696	14.05.70	50	-157	660	06.11/03	610	207
	Chop	92,35	1322	18.05.70	576	398	1328	08.11/18	752	178
Chorna Tisa	Yasynya	646,50	464	23.02.64	164	134	340	05.11/00	176	30
Teres-va	Ust-Chorna	523,86	301	14.12.57	96	47	363	05.11/00	267	49
	Neres-nytsia	298,38	349	01.04.62	10	-86	305	05.11/00	295	96
Mok-rianka	Ruska-Mokra	549,04	255	14.12.57	80	40	312	05.11/00	232	40
Tereb-lya	Kolocha-va	531,17	270	29.10.92	112	67	360	05.11/03	248	45
Rika	Mizhhir-ya	434,22	478	14.12.57	113	69	378	05.11/04	265	44
	Khust	156,41	685	30.12.47	339	234	620	05.11/06	281	105
Bor-zhava	Dovhe	168,35	514	14.12.57	189	134	536	05.11/00	347	55
	Shalanky	114,32	822	26.07.80	249	117	890	06.11/00	641	132
Latory-tsia	Pidpolo-zzya	356,54	388	14.12.57	109	64	320	05.11/00	211	45
	Svalyava	190,00	416	01.03.67	120	96	304	05.11/04	184	24
	Muka-cheve	115,60	650	23.07.80	274	217	687	05.11/06	413	57
	Chop	96,58	744	26.07.80	453	252	746	07.11/00	293	201
Stara	Znyatse-ve	104,92	499	23.07.80	321	85	494	05.11/16	173	236
Uzh	Zhorna-va	328,29	296	14.12.57	53	14	246	05.11/02	193	39
	Vel. Bereznyi	196,26	527	14.12.57	228	196	433	05.11/01	205	32
	Zariche-ve	154,56	446	29.01.79	161	84	442	05.11/06	281	77
	Uzhgo-rod	112,38	350	17.1192	-70	-152	295	05.11/10	365	82
Turya	Simer	151,23	332	23.07.80	66	24	320	05.11/04	254	42

Designated *: + H = estimation (6) – (7); - H = estimation (8) – (6)

Heavy showers caused sudden rise of water levels in the Tisa near Tyachiv and Vylok and in the Latorytsia below Mukachiv. They were 4.1-6.1 m. At the 10 water-measuring stations the highest water level reached or exceeded a historical maximum. The data from hydro-meteorological stations are shown in the table.

It is well known from the special forestry references that forest ecosystems can, to a certain extent, hold the precipitation and regulate the surface flow of water. For the ripe forests of the Carpathians the daily precipitation is up to 175 mm [2]. At the beginning of November 1998 these indices were much higher, the soil was overmoistured, and all of these resulted in disastrous floods. Over-cutting of the mountain forests that had taken place in the past had intensified the activity of floods and other natural disasters.

The problem of floods has many aspects, therefore the system of measures for their prevention is differentiated and diverse. Water basin of a mountain river with characteristic net of water arteries should be considered as half-open eco-hydrological system. Depending on the structure of landscape where the basin is formed, on the character of hydro-net and hydrological conditions, it is possible to define four functionally connected zones in this system (Fig.5).

There is a large mountain zone accumulating water resources in the upper part in the river basin (zone "A"). It includes a wide net of streams with swift water flow, that is why there is no flood danger, but the danger of mud flow exists. It is adjacent to the piedmont transit zone (zone "B") covering foothills and mountain landscapes with possibility of bank erosion. The most dangerous as to the water chaos is the plain zone of potential decumulation of water resources (zone "C", or flood zone). It covers wide terraces and adjoining plain landscapes, dangerous to the flood of water masses. Farther this zone turns into a usual plain transit river-bed zone (zone "D"). Each of these zones demands differentiated anti-flood measures depending on their ecological and hydrological specific features.

As it was stated, floods are conditioned by both natural hydrological and anthropogenic factors. They may be different depending on the forms and scale of anthropogenic influence on the habitat.

Considering the ecological condition of mountain river basins, the character of landscapes and the structure of water net, we chose six subsystems of anti-flood measures: hydro-technical, forestry, nature conserving, agricultural, organizational and ecology-educational.

The subsystem of hydrotechnical measures. These measures are of paramount importance for normalization of hydrological regime of mountain rivers and are to be taken in all zones of water basins. In upper waters of rivers, dangerous as to the floods for the lower basin parts (zone "A"), it is necessary to build anti-flood reservoirs. A net of special reservoirs for rafting timber (dams, "clausura") was built at the end of XIXth and the beginning of XXth century within the basins of the Bila Tisa (village Luhy), the Chorna Tisa (v. Lazeshchyna, 3 dams; v.Chorna Tisa, site Apshynets; v.Dovzhana, river Dovzhana), in upper waters of the Tereblya (the Chorna Rika, rivers Pessya, Lubelyanka, Chernyanka). In the Ivano-Frankivsk region some reservoirs were on the river Cheremosh. Mountain water reservoirs also performed an important anti-flood function. After the times of floating of the timber had ceased, they fell into decay. But we should say that new-built mountain reservoirs could have also recreational - and the larger of them – hydro-energetic significance.

In the "B" zone, especially on the sharp turns of rivers, concrete fortifications should be built, and stone dams on the turns of small rivers.

In the "B" zone the most reliable measure against flooding is the construction of powerful dikes. On the right bank of the Tisa near Tyachiv, Vylok and other populated areas such dikes have been functioning for 80-90 years quite successfully.

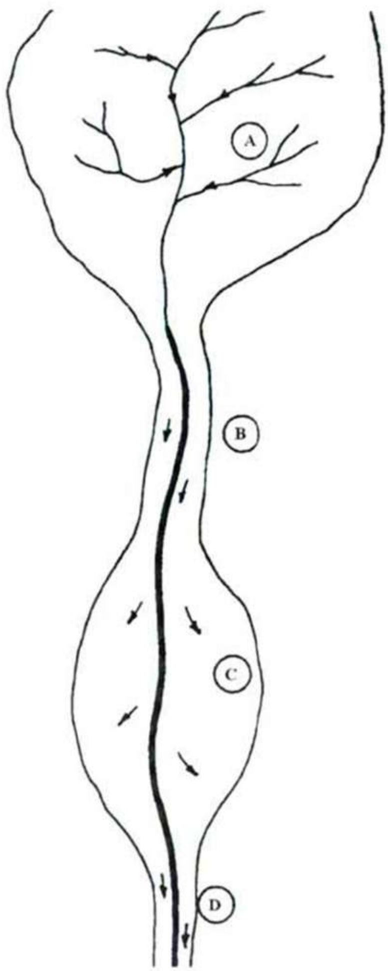

Fig.5. The water basin as an eco-hydrological system.

The main cause of bank erosion is the rapid water current. To slow it down it is necessary to create a system of water trestles in certain places. In these places waters become rich in oxygen, useful for fish-breeding, especially for trout breeding.

A chaotic extraction of gravel, sand and river stones harms the beds of a river, deepening them and creating the bank erosion. Such exploitation ought to be controlled and permitted only in proper places.

In order to estimate the existing ecological condition of large basins of water arteries and to forecast their functioning, it is recommended to increase the net of water-measuring stations and on their basis to organize a system of hydrological monitoring.

The subsystem of forestry measures. The efficiency of hydrotechnical measures in humid regions can be secured only in parallel with forestry ones. The research carried out in the Carpathians showed that the forest cover, in comparison to the non-forest one, decreases the river flow two times and the destructive maximum flow four times.

The most favourable hydrological regime in river water basins is where the forests over 40 years of age cover 65-75% area [2]. Such forest coverage should be provided in zones "A" and "B". The system of forest management in these zones is to be based on the principle of forest stability (*Dauerwald*), substantiated for the Austrian Alps the in XIXth century. The stability of forest and forest environment ensures the stability of water protective function performed by forest ecosystems. Therefore clear-cutting areas should be limited as much as possible in zones "A" and "B".

As it was noted, water basins of mountain rivers should be considered as a half-open hydrological system. To ensure the ecological balance in such systems, the forestry should be managed by the method of water basins, which is grounded for the Carpathians by O.V.Chubaty [14], V.S.Oliynyk with co-authors [6] and V.I.Parpan [7]. However, for use of this method it is necessary to consider the specific ecological features of each basin: climate (the quantity of precipitation), orography and hydrology (divided relief, hydronet character), phytocoenotic (afforestation percentage, forest age structure). Only after such integral evaluation of ecological situation it is possible to determine the volume and methods for exploiting mountain forests in the basins of corresponding rivers.

During a long pastoral period in the high mountain range of the Carpathians, the upper border of forests which hold melted waters from alpine meadows was essentially lowered. The water-protective function of these subalpine forests is several times higher than that of phytocoenoses located lower. The renewal of ecologically grounded upper forest border on high-mountain meadows of Yavirnyk, Rivna, Borzhava, Apetska, Krasna, Svydovets, Kvasivsky Menchul will improve the hydrological regime of the rivers rising there.

In Transcarpathians the forest area belonging to the agricultural economic complex makes now 136,800 ha. These formerly collective and state-farm forests situated near the mountain river beds are of importance for water protection. Unfortunately their ecological condition is unsatisfactory. It would be reasonable to pass them to the State Forest Fund to ensure forest naturalization and improvement of water-protective functions.

Now, in hard economic situation the cutting without permission increased, thus reducing the protective role of forests. In 1998 there were 3,500 m^3 of such cuttings in the forests of State Forest Fund and 30,100 m^3 in the forests of agricultural-economic complex. It is necessary to keep stronger the regime of mountain forests protection and provide local people with gas.

For mountain villages situated in potentially dangerous localities as to the structural and layer shifts it is necessary to create plans of their ecological safety (the safety of existing and planned houses, bridges, railways and highways, electric transmission lines, gas and oil pipes). Such plans must be based on special geological and landscape-ecological research.

The subsystem of nature-protecting measures has to be aimed to the improving of water- and soil-protective function of forest ecosystems and other types of vegetation. For this purpose it is proposed to create a net of water-protective partial reserves with special regime of forestry and agriculture in zone "A". Such plots are not withdrawals from the land fund of land users, but the latter have to use natural resources in such a way as not to violate the protective functions of ecosystems.

In flood-dangerous zones it is essentially to widen the stripes of riverside water-protective forests or in case of their absence to create them by means of cultures.

The subsystem of agricultural measures. A large area in mountain river basins is covered with agricultural lots which appeared in places of cut down forests. In zone "A" the main anti-flood measures should be directed to the improvement of water- and soil-protective functions of post-forest mountain meadows and pastures. Therefore eroded pastures must be afforested and turfed. The cutting down of bushes on steep slopes for increasing arable land must be forbidden. Measures must be taken against ravine (channel) and plain erosion on mountain slopes. It is desirable to reconstitute the traditional "terrace crop-growing" used before in mountain regions. It is inexpedient to use 50 m riverside zone for tilled crops.

The subsystem of organizational measures. Now mountain streams do not have a single manager responsible for their regulation, maintaining normal hydrological regime and protection. Since they run on the lands of State Forest Fund it would be reasonable to create a structural sub-department for protection and regulation of mountain rivers and streams.

The subsystem of ecology-educational measures. Forestry, agriculture and water economy in the Carpathians have their own mountain characteristic feature which is not always taken into consideration by specialists and land users. Therefore proper attention must be paid to rise the level of nature-protection knowledge as to the rational use and resumption of natural resources and preservation of ecological balance in the region.

It is desirable to exchange experience with specialists from Slovakia, Hungary and Romania in the struggle against disastrous natural phenomena.

Conclusion

The forecast of the probability of future floods in the Transcarpathians is disastrous. The region is situated on the south-western macro-slope of the Carpathians which gets more precipitation than the north-eastern one. Transcarpathians is the zone of warmer climate, hence the process of snow melting is more rapid. There are mainly oak and beech forests under which snow melts two-three times quicker, than under evergreen dark-needle forests. There are more than 60,000 ha of treeless high-mountain meadows where tremendous snow masses are accumulated. On the Volcanic Ridge andesits and trahits prevail, that are hard waterproof rocks. The hydronet in Transcarpathians is much denser than in other Carpathian regions. The Prytysianska lowland lies 200-250 m below the plain landscapes of the Dnister. The region is a seismic zone were little earthshakers often happen, what in its turn can cause the activity of slope processes and layer shifts.

According to genetic classification of mud flows, within the Transcarpathians one can distinguish the south-western dangerous region, covering the basins of right-hand tributaries of the Tisa. There is a ridge of Pienin limestones extending from Perechyn to Dilove, where dangerous carst processes are potentially possible.

During the last decades in the Carpathians, as well as in other regions of northern hemisphere, we observe global warming of the climate under the greenhouse effect. From the 90-ies of the last century the waters in river basins of Europe rise and the same is observed in the Carpathians. All of these may cause further floods and other dangerous ecological processes. Therefore Transcarpathians should be classified as an ecologically critical region which needs a special management for forestry, agriculture and water economy. It needs changes in the orientation of economy, directing it onto decreasing forest exploitation, increasing forest coverage and rising protective functions of forest and meadow ecosystems.

Due to warm climate, different balneological resources, high recreational potential and easy accessibility of picturesque mountain landscapes, the Transcarpathians should pay more attention to recreation and tourism industry.

It is necessary that the Western Scientific Centre of National Academy of Sciences of Ukraine should substantiate a complex program for research of the flood problems and other natural phenomena for the nearest future and the perspective by drawing scientific and production potential of the region.

The Ukrainian Carpathians border with four countries having mountain systems. To solve ecological, economic and nature protecting problems successfully in the transbordered regions it would be expedient to create The Carpathian Ecological Comission.

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