HYDROLOGICAL RESEARCHES IN SMALL TORRENTIAL WATERSHEDS

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SUMMARY

There are presented the research works carried out during a period of 8...10 year in 7 torrential watersheds with areas between 154 and 713 ha, covered by forests in a percentage of 16...98 %. The mean runoff coefficients for the entire studied period varied between 6.8 % (in the case of one watershed with a sandy-loamy soil) and 22.9 % (in the case of the watersheds with loamy-clayish soils). The maximum runoff coefficients during a highflood were between 0.342 and 0.642 in the respective watersheds. The specific erosion varied between 2.8 and 27.0 cu m/ha/year. The channels and the afferent banks contributed with 88...95 % of the total sediment transport, the rest was due to the slopes. Forests are an excellent means for maximum discharge diminishing and slope erosion controlling.

1. INTRUDUCTION

As the main hydrological parameters of the small torrential watersheds which are going to be managed (maximum discharges and highflood volumes, runoff coefficients, the amount of carried sediment materials, etc.), can be directly established only in a rather small number of cases, there have been organized systematic researchworks by the Romanian Ministries interested in such works; they have been carried out in some main watersheds and the data obtained are to be generalized for similar conditions. Further on we shall briefly summarize the researchworks carried out by the department of Silviculture in seven small watersheds.

2. CHARACTERISTICS OF THE STUDIED WATERSHEDS

The watersheds areas cover between 154 and 713 hectares (Table 1), their mean slope ranging from 22 to 51 %, the highest elevation from 1000 to 1400 m, and the afforestation rate from 16 to 98 %. The mean annual rainfall amount varies between 550 and 800 mm, about 70-80 % of which is under the form of rain. The petrographic underlayer consists of marl, clay and gritstone deposits (4 watersheds) crystaline schists (1 watershed), gritstones and marls (1 watershed), and gravel, boulder and sand deposits (1 watershd). On these sublayers there are brownyellowish soils, middle deep to deep.

These watersheds had, and some of them still have a severe torrential character. Their management consisted of afforestations on severely eroded slope grounds and of small hydrotechnical works (dams and canals) over a part of the channel network highly affected by severe erosions, slope falls and slidings.

For studying the slope runoffs and erosions, 16 plots were delimited in these watersheds, whose characteristics are given in Table 2.

The seven watersheds are included into four watershed groups (I...IV) and into two subgroups (Ia and Ib) with respect to their petrographic sublayers and afforestation rates.

3. RESEARCH METHOD

During the period 1970...1980 there were carried out researches on the liquid precipitations, surface runoff, erosion and sediment yield. The rainfalls were daily measured by means of recording rain gauges and depending on its area each watershed had between 2 and 5 recording raingauges

The surface runoff was measured by means of water - stage recordings and torrent control dam weirs adapted for hydrometric measurements. The sediment transported by high-flood waters were partly retained by the dams and the deposits were periodically measured with topographic devices.The sediment which passed over the dams and thus ran towards the collecting river, were estimated multiplying the water volume by turbidity; the latter was determined through samples.

The water and sediment resulting from slope plots were captured by means of some tin basins. The surface runoff at the slope levels were also studied on microplots or rainfalls caused by aspersion.

4. RESULTS

4.1. Liquid precipitations

On the average, in each month of the warm season (15.IV-15.X) there were recorded 20-25 rainfalls (separated by periods without rainfalls of at least 60 minutes) in the watersheds of groups I and II (i.e. about 105-115 mm mounthly)and 16-17 rainfalls in the watersheds of groups III and IV (i.e. 65-70 mm mounthly). The rainfalls up to 5 mm, unefficient from the hydrological point of view, represented between 19 % (in the group I watersheds) and 30 % (in the group III watersheds) of the total amount of the liquid precipitations. The maximum rainfalls ranged from 72 mm (group III) and 186 mm (group IV). Remarkable rainfalls were registered in the other watershed groups as well (170 mm in group I and 125 mm in group II). The rainfall average intensity was generally low (under 0.1 mm/min). Exceptionally there were rainfalls of intensities 1.0...1.5 mm/min.

4.2. Surface runoff

4.2.1. The surface runoff measured in the downstream control point.

The surface runoff for the entire watershed was characterized by means of rainfall runoff coefficients. The mean value of these coefficients in a period of 8....10 years ranged from 0.068 (in a sandysoil watershed) to 0.229 (in a loamyclayish soil watershed). The highest runoff coefficients registered for only one highflood varied in the seven watersheds between 0.342 and 0.642 (Table 1).

- The peak discharges did not exceed 31 cum/s; the specific peak discharges ranged from 5.1 and 130.8 l/s hectare.

- The average heights (for all highfloods) of the rainfalls during a highflood ranged from about 15 and 32 mm.

- The highflood durations varied, on the average, between 15 and 100 hours; t e longest duration of a highflood was 24 days and corresponded to a succession of rainfalls.

- The highflood hydrographs were generally complex. The singular hydrographs (at watersheds of group I) can be represented by two arcs of an upper concavity parabola, the increasing arc being the shorter.

- The direct runoff (h_n)was expressed with respect to the rainfall storm (h) and the antecedent precipitation index (I_{15}) (t = 1...15 days) in regression equations such as:

$$h_n = a \cdot h^m \quad I_{15}^n$$

$$I_{15} = \sum_{t=1}^{15} 0.9^t \cdot h_t$$

- The specific maximum discharges were smaller in the smaller watersheds with a greater amount of afforestations, the highflood durations generally being greater in these watersheds.

- The rainfall structures, determined through rainfall storm variations in time, had a more important effect upon the discharge hydrographs than the watershed shapes, drainage network densities and vegetation distributions in the watersheds.

4.2.2. Surface runoff on plane slopes.

The runoff coefficients (C) established on plots of 0.5 sq.m at rainfalls caused by aspersion, on grazing field with loamy to loamy-clayish profound soils varied with respect to the rainfall intensity (i) whose duration was 120 minutes; thus:

i = 0.50 mm/min.......C = 0.50
i = 1.00 mm/min.......C = 0.67
i = 2.00 mm/min.......C = 0.74

The results of the research works on the surface runoffs at natural rainfalls on slope plots are given in Table 2. The runoff was the lowest on the forest soils formed on disaggregated crystaline schists (the runoff coefficients under 2 %) and the highest on soils without vegetation, eroded, formed on marlclayish deposits (the runoff coefficients over 40 %).

4.3. Erosion and sediment yield

4.3.1. Erosion and sediment yield on plane slopes (sheet erosion).

Owing to the extremely reduced runoff in the case of sandy soils covered by forests or grazing fields, the sediment production rate was between 0.050 and 0.300 t/ha/year. In the case of loamy-clayish soils the erosion was severer where the forest cover was the poorest and the soil upper layers the most eroded. Thus, the sediment production rate had the following values: 0.200 t/ha/year on the moderately, eroded forest lands; 0.150...0.280 t/ha/year on meadows and hayfields with moderately eroded soils; 2.90 t/ha/year on meadows with severaly eroded soils; 25.6...28.9 t/ha/year on debris without vegetation; 29.18 t/ha/year on degraded meadows with excessively eroded soils; 76.40 t/ha/year on sliding bare grounds (Table 2).

4.3.2. Channel erosion

According to our previous research works (Gaspar-Apostol, 1964 (1), Gaspar-Untaru, 1978 (2), it resulted that in the torrential watersheds mostly convered by forests and grazing fields of the mountains and high hill zones, the greatest alluvia amounts came from the beds. Thus, in the studied watersheds, although the areas of the channels and their afferent banks (including the gullies on the slopes) represented only 2...5 % of the respective watersheds, the volumes of the sediment supplied by channels were 88...95 % of the total transported sediment amount. On the average, about 600.. ..800 cum/km/year were transported from the channels and afferent banks network into watersheds 1...4 (Tabls 1), about 360 cum/km/year into watershed 5 and about 90 cum/km/year watershed 6.

4.3.3. Total sediment yields from watersheds

The highflood water loading with alluvial materials (in suspension and bed load) in the studied watersheds was annually between 6 and 37 kg/cum on the average. The loading mainly varied with respect to the discharge, i.e. the current speed. The maximum highflood water loading value exceeded 150 kg/cum and corresponded to a discharge of 31 cum/s (in watershed 3). The total sediment yield amounts during the studied period, conventionally distributed over the entire watershed area, led to the following sediment production rate (Table 1).

- in the watersheds of group I: between 17.5 and 27.0 cum/ha/year
- in the watersheds of group II: 8.8 cum/ha/year
- in the watersheds of group III: 2.8 cum/ha/year.

CONCLUSION

- Under relatively similar relief conditions, the rainfall structures and petrographic sublayers were the main factors determining the surface runoff.

- The runoff amount during a highflood varied especially with respect to the storm precipitation and to the antecedent precipitation index.

- The greater the channel network area (and afferent banks) affected by degrading processes (severe erosions, slidings, fallings) , direct runoff and highflood discharges were, the more important the sediment yield was.

- In the torrential watersheds covered by forests and grazing fields the channel network affected by degradation supplied 88...95 % of the total sediment yield.

ZUSAMMENFASSUNG

Es werden Forschungsarbeiten dargestellt die in Perioden von 8...10 Jahren in 7 Wildbach-Einzugsgebieten mit Flächen zwischen 154 und 713 ha und Bewaldungsprozenten von 16...98 % ausgeführt wurden. Der mittlere Abfluß-Koeffizient für die gesamte betrachtete Periode variiert zwischen 6.8 % (des Einzugsgebietes mit sandig-lehmigen Böden) und 22.9 % (der Einzugsgebiete mit lehmig-tonigen Böden). Der maximale Abflußkoeffizient während eines Hochwassers betrug zwischen 0,342 und 0,642 in den jeweiligen Einzugsgebieten. Die spezifische Erosion variierte zwischen 2.8 und 27.0 m3/ha und Jahr. Die Bachbette und die angegriffenen Ufer trugen zu 88...95 % zum Feststoff-Transport bei, der Rest stammte von den Hängen. Forste sind ein ausgezeichnetes Mittel um die maximalen Abflüsse zu vermindern und die Erosion der Hänge unter Kontrolle zu bringen.

BIBLIOGRAPHIE

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2. GASPAR, R., UNTARU, E., 1978: Cercetări privind scurgerea de suprafaţă si transportui de aluviuni în bazine hidrografice mici, torenţiale, partial împădurite, Institutul de Cercetări si Amenajari Silvice, Bucuresti, 68.p.

TABLE 1

The watersheds studied. Liquid precipitations, Surface runofr. Sediment yield

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Watershed number	Watershed group	Watershed name	Watershed area 1)	Average slope	Afforestation rate	Petrographic sublayer	Soil texture	Measurements duration	Mean rainfalls at a highflood	Direct runoff at a highflood	Maximum discharge rate 2)	Runoff coefficient during rainfalls: mean 3)	Runoff coefficient during rainfalls: maximum 4)	Mean concentration	Mean annual specific alluvia transport: Retained by dams	Mean annual specific alluvia transport: Transport over dams 5)	Mean annual specific alluvia transport: Total
-	-	-	ha	%	%	-	-	months	mm	mm	l/s/ha	-	-	kg/m³	m³/ha/year		
1	Ia	Hanganu	272	22	16	marls, clays, gritstones	loamy-clayish	43.6	29.5	7.01	68.5	0.194	0.609	22.2	4.7	12.8	17.5
2	Ia	Hurjui	154	24	21	"	"	34.8	30.5	8.65	130.8	0.227	0.642	36.7	12.2	14.8	27.0
3	Ib	Monteoru	713	27	88	"	"	48.9	30.8	8.78	42.5	0.229	0.642	21.7	9.3	14.9	24.2
4	Ib	Cremenea	257	31	86	"	"	26.9	32.5	9.20	62.6	0.227	0.615	31.3	8.8	13.4	22.2
5	II	Sărăcineşti	707	51	63	mica and gneic schists	sandy-clayish	60.3	17.6	1.49	5.1	0.068	0.342	18.2	5.3	3.5	8.8 6)
6	III	Călugăreni	133	30	68	gritstones marls	clayish	36.2	15.4	1.62	9.2	0.085	0.500	6.0	1.9	0.9	2.8
7	IV	Pietroasa 7)	536	35	98	sands gravels	sandy-clayish	30.1	85.9	65.06	28.7	0.026	0.350	3.0	3.9	-	-

NOTE: 1) Uphill of water stage recording. 2) The recorded maximum liquid discharge dividid by watershed a rea. 3) The average for the entire measurement period. 4) Maximum, at the greatest highflood. 5) It was reckoned the density of 1.75 t f/m³. 6) After 5...13 years since the work corrying ont; previonsly the transport was bigger. 7) All the data refer to onlyone highflood (without measuring the passed alluvia).

TABLE 2

Characteristic data of the studied plots with respect to the runoff and erosion on plane slopes

0	1	2	3	4	5	6	7	8	9	1o	11	12
Nr.	Watershed group	Number of plots	Plot area (approx)	Plot slope	Petrographic sublayer	Soil texture	Land utilization (vegetation)	Land degradation phenomena (E=erosion)	Years of study	Runoff coefficient (approx) average (for all the rains)	Runoff coefficient (approx) maximum (for one rain)	Sediment production rate
-	-	-	sq m	%	-	-	-	-	years	%	%	t/ha/year
1	I	1	1.1oo	6o	marls, clays, gritstones	loamy-clayish	forest	slight-moderate E	3	0-6	1.5	0.20
2	I	5,8,9,1o	33o...127o	4o-6o	"	loamy and loamy-clayish	hayfield	"	3	0.4-1.5	1.6-3.7	o.15-o.28
3	I	7	39o	4o	"	loamy-clayish	grozing field	very severe E	3	3.4	24.5	2.92
4	I	2,3	7o..1oo	6o	"	"	unstable bare land	unstable debris	3	3,7	12.2	25.6-28.9
5	I	6	1oo	6o	"	"	degraded grazing field	Excessive E	3	8.6	42.0	29.2o
6	I	4	37o	4o	"	clayish-loamy	"	Sliding	3	12.8	31.8	76.4o
7	II	S_1,S_2 S_3	5oo..25oo	5o - 1oo	mica schists gneis	sandy-loamy	forest	Slight-moderate E	6	0.5	1.0	0.05-0.30
8	II	S_4,S_5	6oo..7oo	5o-6o	"	"	grazing-hayfields	"	5	0.7	1.3	0.15-0.38