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The Estimate of the Maximum Outflow and Soil Erosion Intensity in the Kaludra River Basin

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Abstract: Certain forms of soil erosion were observed in the Kaludra River basin. On the basis of the investigation results obtained in the field by means of computer-graphic methods, maximum outflow and the soil erosion intensity were estimated.
Key words: river basin, erosion, intensity, outflow, computer-graphic methods

Introduction

The Kaludra River basin, covering an area of 77.41 km^2, is the third basin by size in the town of Berane valley, after the Bistrica river (136.13 km^2) and the Dapsic River basins (81.01 km^2) (Spalevic, V., 1999). The basin is a wooded area consisting of sloping grounds of rather big inclines (Average Basin Slope = 44.34%). The following forms of erosion in the basin are most common: simple surface erosion with a uniform washing away of surface soil particles along the basin, mixed erosion with sporadic formation of small furrows and hollows and a_1, b_1 and a_3 forms of regional erosion by water (Kostadinov, 1996) as a result of pluvial erosion. In some parts of the riverbed of the main water stream, mostly in the village of Kaludra - Babica Mala hamlet - by combination of regional erosion supported by the river water flow power, riverbank destruction and meandering occurred.

The appearance of these forms of soil erosion initiated the investigation of the state of erosion in the basin.

Material and Method

The outflow and soil erosion intensity estimation was made for the basin of the Kaludra River, which is the right tributary of the Lim river.

The basin is located in the southeast part of the town of Berane valley. It covers the area from Donja Rzanica mountain (at a height of 688 meters above sea level) to Cmiljevica (1963 meters above seal level), Murgas (1854 m) and Usoviste mountains (1933 m). The districts of D. Rzanice, Zagorje and Kaludra villages are located in the basin as well as a great number of summer pastures along the watershed and the foot of the mentioned mountains.

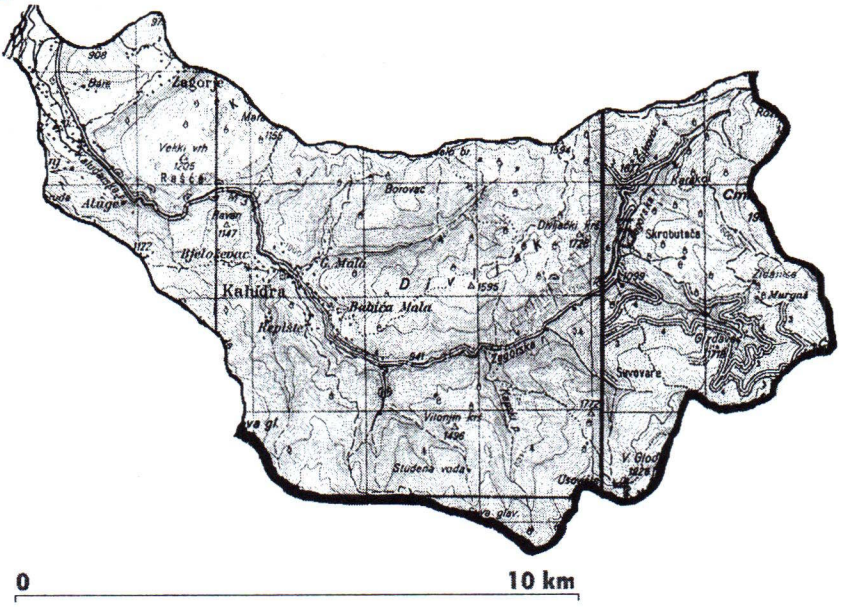

Fig. 1 Situation plan of the Kaludra River basin

The hydrography network of the Kaludra River is well developed. Its right tributaries are the Krcev Brook and the Duboki Brook, the Mala River, the Staso Brook and the Zagorje River. Its left tributaries are the Bjelosevac, Rzani and Kapsi Brooks and the Murgas River. A number of nameless smaller brooks also flow into the Kaludra River.

The methodological approach to the Kaludra River basin research consisted of gathering and processing of data on physico-geographical parameters of the river stream and basin as well as on geological and pedological features of the investigated area. Parallel field and theory researches required specific methodological approaches.

Field researches consisted in the ground recognition with a detailed gathering of data on the soil erosion intensity and forms, on the condition of the plant cover with an estimation on the soil exploitation as well as on the protective measures which contribute to the reduction of the erosion process.

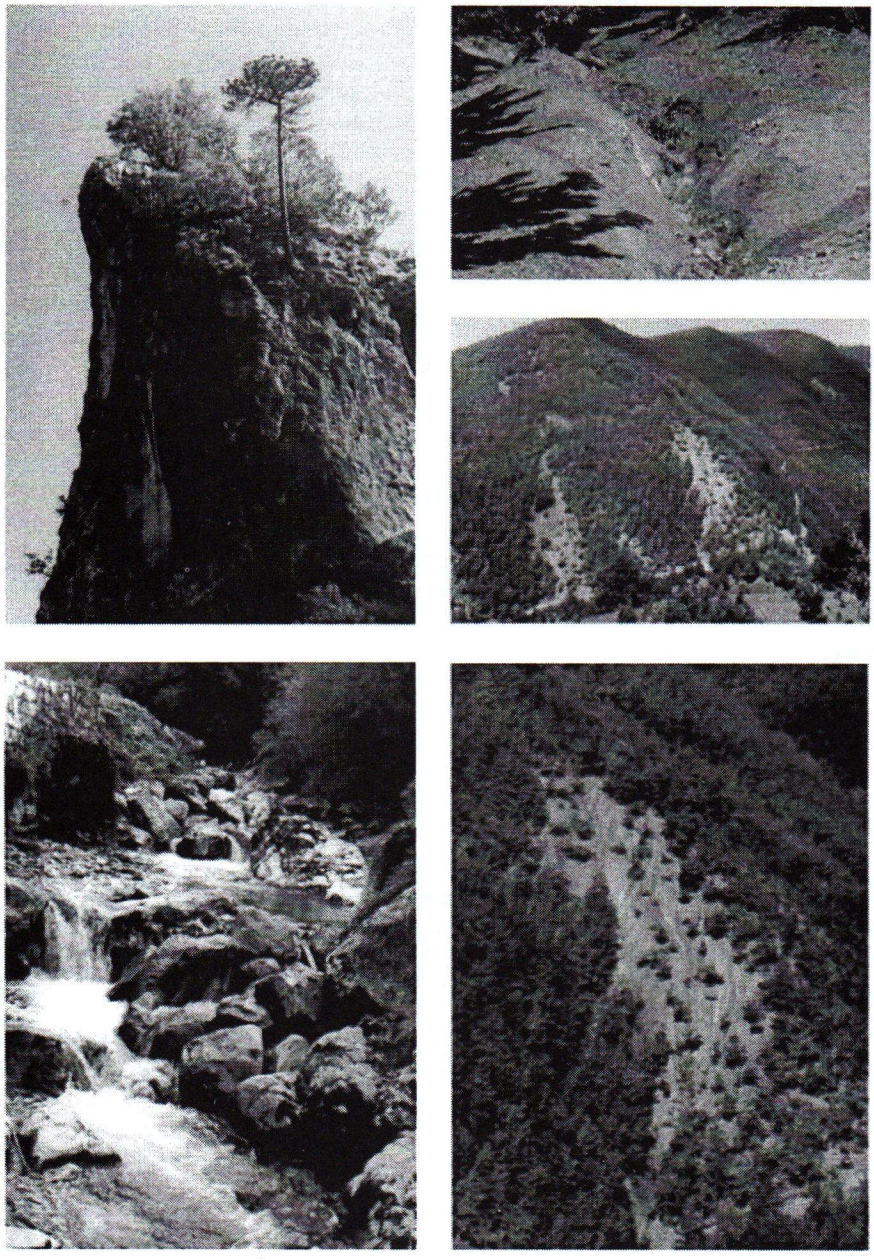

Fig. 2. A view of the Kaludra River basin

The incline, length, exposition and the forms of the slope, the erosion base depth, the depth, density and intensity of erosion furrows, the furrow formation degree, parcelling and other indicators needed for the investigation of the soil erosion process were investigated by means of *morphometric methods.*

During the field research, the most characteristic parts of the basin were *photographed,* and a *video-tape recording* was also made, with an aim to show visually the state of the erosion process and consequences caused by the process.

The input data necessary for the outflow and soil erosion intensity estimation (geometric, topographic and hydrological features) in the Kaludra River basin were processed in a new, "modern« way, by applying computer-graphic methods on all the data processing levels. By the «Surface and Distance« program (Spalevic, V. et al., 2000) quantitative and qualitative indicators were obained and they were represented in the form of a number of equivalents. They were used as input data for the «River Basins« program (Spalevic, V. et al., 2000a), by means of which final values of the outflow and soil erosion intensity were obtained.

Results and Discussion

Climatic features of the region, geometric, topographic, hydrological as well as the geologic features of the basin, soil types and the way of soil exploitation were analyzed for the estimation of the maximum outflow and soil erosion intensity.

As far as climatic factors are concerned, air temperatures and precipitations were analyzed. The data obtained by the Republic Hydrometeorological Bureau of Montenegro were used for the Berane station. The data on average monthly air temperature, monthly precipitation sums and maximum daily precipitation amounts, necessary for the «River Basins« program, are shown in tables 1, 2 and 3.

Tab. 1. Average monthly air temperatures in ^{0}C in Berane

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MAX	6.5	6.9	10.0	18.8	18.8	23.6	25.0	26.5	21.2	17.0	13.2	9.4
MIN	-6.5	-6.6	-0.7	0.6	9.8	8.3	16.2	14.2	10.0	5.4	-1.0	-4.6
Average Value	-1.5	0.6	4.5	8.8	13.6	16.5	18.7	18.2	14.4	9.5	4.6	0.2
ST. D.	2.6	3.0	2.4	2.7	1.7	2.0	1.6	1.9	2.0	2.0	2.6	2.7

Average annual temp. = 9.0

Tab.2. Monthly precipitation sums in mm - Berane

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MAX	187.8	179.0	226.0	193.0	298.0	211.0	179.0	158.1	219.0	254.0	370.6	222.0
Average Value	82.7	73.5	61.9	74.6	82.2	72.0	58.3	56.1	72.5	93.0	118.3	99.2
ST.D.	53.0	45.7	38.1	43.5	47.2	44.6	42.0	37.5	53.2	61.1	68.8	55.3

Annual precipitation sum = 944.3

Tab.3. Maximum daily precipitation amounts in mm - Berane

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MAX	54.0	87.0	61.3	77.4	80.5	47.5	43.0	65.4	115.0	96.0	73.4	62.6
Average Value	25.5	23.0	21.1	23.8	22.4	19.6	17.6	20.3	28.5	30.0	29.7	25.9
ST.D.	15.9	15.3	12.2	16.2	13.5	10.1	9.0	13.8	18.7	18.8	15.7	14.6

The Kaludra River basin is elongated and assymetrical in shape. The Mala River, Rzani and Kapsi Brook and the Murgas River are characterized by very steep sloping grounds, which may cause the development of an erosion process.

The Kaludra River basin is located in the mountainous region. The relief is divided by numerous river streams. Some mountains are very steep and they raise almost vertically from the riverbed in gorges. The relief dynamics can be best seen by comparing the lowest (680 m at the mouth to 1100 m at the Zagorska and Murgas rivers juncture) and the highest peak elevations (1200 - 1963 m at the watershed of the adjoining basins). Based on this, it can be concluded that great height differences provide the relief with a great energy which helps erosion processes and erosion in all forms ranging from the surface washing away process to torrents.

The geological stock of the Kaludra river basin mostly consists of sandstones, slates and eruptives of diabase and metamorphic rock formation, sandstones, slates, argyloschists and metamorphic rocks of the Jurassic and Triassic age. Limestones with the metamorphic rocks of the Triassic age and marl limestones with the metamorphic rocks of the Jurassic age can be found to a lesser degree. All the silicate rocks are susceptible to the washing-away process and hollow and watershed formation, which was observed particularly in the Mala River basin (eastern slope of Glavica, Brotni Do), in the slopes of Divljak, Goles and Musa Hill), facing south, southeast or southwest.

Based on the basic geological map of SFRY, 1:100 000 (Zivaljevic et al., 1982), areas are grouped in the basin according to the water permeability of rocks (stock) and a map of water permeability of the region was made with the fp, fpp and fo elements, necessary for the water permeability coefficient (S_1) calculation and they denote: fp - part of the basin area which consists of rocks of great water permeability, fpp - part of the basin area consisiting of rocks of medium water permeability, fo - part of the basin area consisting of low water permeable rocks, which form a separate group in geology.

Based on the water permeability of rocks of the Kaludra River basin (figure 3), values for fp - 0.528, fpp - 0.314 and fo - 0.158, were obtained and are shown in tab. 4.

Tab. 4. Values of fp, fpp and fo elements of the Kaludra River basin

Area	fp		fpp		fo		Σ	
	km^2	%	km^2	%	km^2	%	km^2	%
1.	2.51	3.24 %			2.74	3.54 %		
2.	1.90	2.45 %			0.16	0.21 %		
3.	36.47	47.11 %			2.74	3.54 %		
4.	-	-			2.13	2.75 %		
5.	-	-			4.46	5.76 %		
Total	40.88	52.80	24.30*	31.39 %	12.23	15.80	77.41	100 %

** fpp = Σ - (fo + fp)*

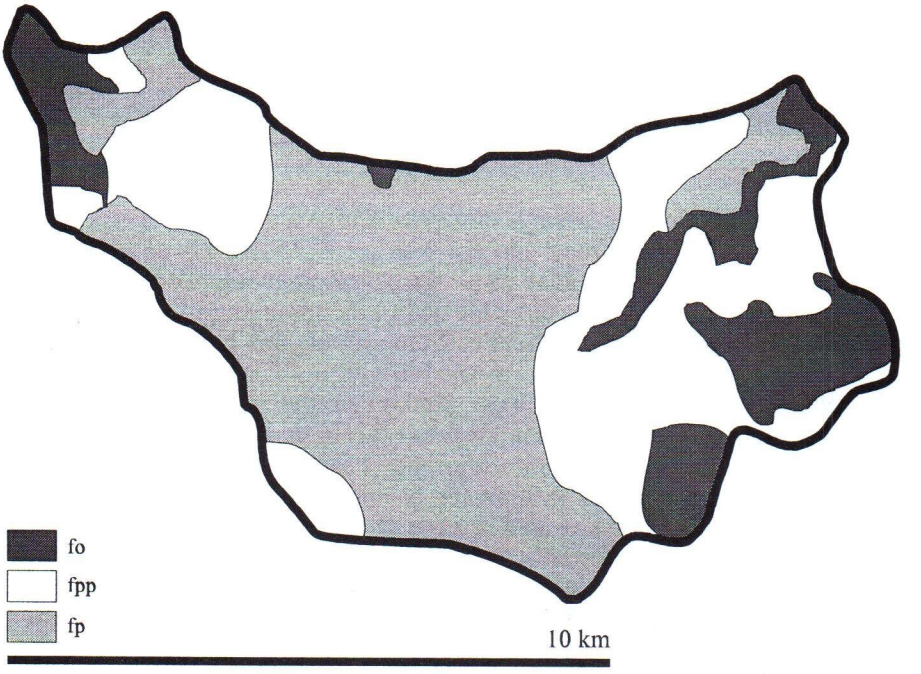

Fig. 3. Map of rocks distribution according to their water permeability

The following soils can be found in the Kaludra River basin by Fustic and Djuretic (2000):

- eutric cambisol on gravel, medium deep;
- cambisol on calcareous-silicate rocks, forest type;
- district cambisol on sandstones, medium deep;
- distric cambisol on sandstones, forest type and
- eutric cambisol on basic eruptive, forest type.

The vegetation in the Kaludra River basin consists mostly of forests and natural meadows and pastures. There are very few cultivated fields and orchards and they are located in the districts of the Kaludra, Zagorje and Donje Rzanice villages. The forests are dense and they protect the soil from erosion in higher and less accessible areas. Stands of mixed deciduous-conifer trees and deciduous and conifer trees can be found. Due to exploitation and devastation, forests are sparse or stunted in areas closer to settlements and summer pastures, and hollows and other forms of erosion, therefore, can very often be found.

Natural pastures are most often well overgrown with grass, which is also the case with the pastures of more flattened grounds, and erosion is of lower intensity. However, pastures with sparse grass are overgrown with weeds or bushes and are more susceptible to erosion. Numerous livestock paths, watering holes, where livestock often stop and stay for some time, newly built roads, etc. - contribute to this. A great number of ravines are formed on these pastures, they

stretch through forests and spread depending on the amount of the concentrated water, the soil and stock resistance, the incline and other conditions.

There are also some minor erosion processes in the major part of the Kaludra River basin. However, each river basin (Kostadinov, 1996) is exposed to natural dialectic relationships of eternal struggle between active erosion forces and the resistance by soil structures, the vegetation cover and other positive influences in the basin. The washing-away process and other forms of erosion are of lower intensity in those parts of the investigated basin where the vegetation cover (forests and grass) is preserved. A specific attention should be paid to river erosion, where erosion processes appear mostly as a result of the force of the river water flow in the form of rockslides and riverbank destruction and meandering (figure 4).

These forms of erosion are intensified by sudden (torrential) risings of occasionl and permanent water currents, non-resistant soil and stock, the pulling out of trees, freezing and melting of soil, etc.

Erosion processes were most highly pronounced in a thinned-out and devastated forest and in pastures as well as in those parts of gorges where salifluctuating and delluvial deposits, susceptible to erosion, are often found.

The Kaludra River basin is mostly (around 70%) situated in the region of a height of 1100-1800 meters above sea level. Areas of lamella between adjacent isohips of the Kaludra River basin are presented in table 5.

Tab. 5. Areas of lamellas between adjacent isohips of the Kaludra River basin

	Lamella (m above sea level)	Area (km^2)	Percentage of the Total Area
1.	(681) 700-800 m	0.95 km^2	1.23 %
2.	800-900 m	2.53 km^2	3.27 %
3.	900-1000 m	4.20 km^2	5.42 %
4.	1000-1100 m	4.82 km^2	6.23 %
5.	1100-1200 m	7.64 km^2	9.87 %
6.	1200-1300 m	8.88 km^2	11.47 %
7.	1300-1400 m	7.95 km^2	10.27 %
8.	1400-1500 m	7.99 km^2	10.32 %
9.	1500-1600 m	7.95 km^2	10.27 %
10.	1600-1700 m	9.31 km^2	12.03 %
11.	1700-1800 m	7.97 km^2	10.29 %
12.	1800-1900 m	5.68 km^2	7.34 %
13.	1900-1963 m	1.55 km^2	2.00 %
		77.42 km^2	100.00 %

The results of the «River Basins« program for the Kaludra River basin are presented in table 6. According to the investigation results, maximum outflow is 371.05 m^3/s. The erosion material production is 37692 m^3/year, and actual losses of soil from the basin are 13405 m^3/year or 173 m^3/km^2year.

The Kaludra River basin is, according to erosion processes by Gavrilovic (1972), classified into the IV category of destructiveness (Z=0,300) and it is a weak mixed erosion. According to the erosion intensity classification (Kostadinov, 1996 by Gavrilovic 1972), the Kaludra River basin belongs to the regions of very weak mixed-type erosion.

Fig. 1 Miodrag Babic (Babica Mala hamlet) pointing out the damages caused by the rising of water current, which has, moving its riverbed, almost halved a part of the parcel by the riverbed

Tab. 6. Results of the «River Basins« program for the Kaludra River basin

Naziv sliva: Kaludarska rijeka			
Ulazni podaci:			Izlazni podaci:
F = 77.41km2		h0 = 700m	A = 0.46
O = 44.90km		dh = 100m	m = 0.61
Lv = 19.06km		Hmin = 681.0m	B = 4.62km
Lb = 16.74km		Hmax = 1963.0m	a = 0.33
Fv = 45.12km2		Suma L = 62.20km	Hsr = 1275.79m
Fm = 32.29km2		Lm = 12.97km	D = 594.79m
		fp = 0.155	Isr = 44.34%
Liz :	f :	fpp = 0.530	Hleb = 1282.00m
2.95km	0.93km2	fo = 0.315	Er = 137.57
8.28km	2.47km2	fs = 0.469	G = 0.80
18.67km	4.06km2	ft = 0.453	K = 1.47
30.71km	4.68km2	fg = 0.078	S1 = 0.75
41.30km	7.38km2	hb = 115.0mm	S2 = 0.72
35.95km	8.55km2	to = 9.00°C	W = 1.5741m
38.09km	7.67km2	Hgod = 944.30mm	2gDF^(1/2) = 950.45mkm/s
37.15km	7.81km2	Y = 0.72	Qmax = 371.05m3/s
36.04km	7.53km2	Xa = 0.47	T = 1.00
69.73km	9.08km2	Fi = 0.22	Z = 0.300
18.56km	7.88km2		Wgod = 37692.5525m3/god
5.79km	5.60km2		Ru = 0.356
	1.52km2		Ggod = 13405.82m3/god
			Ggod/km2 = 173.18m3/km2god

F - površina sliva, **O** - dužina vododjelnice, **Lv** - prirodna dužina glavnog vodotoka, **Lb** - dužina sliva mjerena serijom paralelnih linija, **Fv** - površina većeg dijela sliva, **Fm** - površina manjeg dijela sliva, **Liz** - dužina izohipsi, **f** - površina između dvije susjedne izohipse, **ho** - nadmorska visina početne izohipse, **dh** - ekvidistanca, **Hmin** - najniža kota u slivu, **Hmax** - najviša kota sliva, **Suma L** (ΣL) - ukupna dužina glavnog vodotoka sa pritokama I i II reda, **Lm** - najkraće rastojanje između izvorišta i ušća, **fp** - dio površine sliva koji je sastavljen od jako vodopropustljivih tvorevina iz stijena (krečnjak, pijesak, šljunak), **fpp** - dio površine sliva koji je sastavljen od stijena srednje vodopropustljivosti (škriljci, laporci, pješčari), **fo** - dio površine sliva koji je sastavljen od stijena slabe vodopropustljivosti (teška glina, jedri eruptivi), **fš** - dio površine sliva pod šumom, **ft** - dio površine sliva koji se nalazi pod travama, livadama, pašnjacima i voćnjacima, **fg** - dio površine sliva koji je pod goletima, oranicama i zemljištima bez travne vegetacije, **hb** - visina bujične kiše, **to** - srednja godišnja temperatura vazduha, **Hgod** - srednja godišnja količina padavina, **Y** - tipovi zemljišnih tvorevina i srodne vrste, **Xa** - Uređenje sliva, koeficijent uređenja sliva, **Fi** (φ) - brojni ekvivalent vidljivih i jasno izraženih procesa erozije zemljišta.
A - koeficijent oblika sliva, **m** - koeficijent razvijenosti vododelnice, **B** - srednja širina sliva, **a** - (a)simetričnost sliva, **Hsr** - srednja nadmorska visina sliva, **D** - srednja visinska razlika sliva, **Isr** - srednji pad sliva, **Hleb** - visina lokalne erozione baze sliva, **Er** - koeficijent erozione energije reljefa sliva, **G** - gustina rečne mreže sliva, **K** - koeficijent vijugavosti toka, **S1** - koeficijent vodopropusnosti područja, **S2** - koeficijent vegetacionog pokrivača, **W** - analitički izraz retencije vode u doticaju, **2gDF^(1/2)** - energetski potencijal slivanja vode za vrijeme bujičnih kiša, **Qmax** - maksimalno oticanje iz sliva, **T** - temperaturni koeficijent područja, **Z** - koeficijent erozije sliva, **Wgod** - produkcija erozionog materijala u slivu, **Ru** - koeficijent retencije nanosa, **Ggod** - stvarni gubici zemljišta, **Ggod/km2** - stvarni gubici zemljišta po km^2.

Conclusion

Certain forms of soil erosion were observed in the Kaludra river basin. On the basis of the investigation results obtained in the field by means of computer-graphic methods, maximum outflow and the soil erosion intensity were estimated.

The input data necessary for the outflow and soil erosion intensity estimation (geometric, topographic and hydrological features) in the Kaludra river basin were processed in a new, «modern« way, by applying computer-graphic methods on all the data processing levels. By the «Surface and Distance« program, quantitative and qualitative indicators were obained and they were represented in the form of numerous equivalents. They were used as input data for the «River Basins« program, by means of which final values of the outflow and soil erosion intensity were obtained.

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The Kaludra River basin is, according to erosion processes, classified into the IV category of destructiveness and it is a weak mixed erosion. According to the erosion intensity classification, the Kaludra River basin belongs to the regions of very weak mixed-type erosion.

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