ГЛАСНИК СРПСКОГ ГЕОГРАФСКОГ ДРУШТВА
BULLETIN OF THE SERBIAN GEOGRAPHICAL SOCIETY
ГОДИНА 2009. СВЕСКА LXXXIX- Бр. 4
YEAR 2009 TOME LXXXIX- N^{o} 4

Original Scientific Paper UDC 911.2:551.053(497.17)

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EXCESS EROSION AND DEPOSITION IN THE CATCHMENTS OF KAMENICHKA AND RADANJSKA RIVER-REPUBLIC OF MACEDONIA

Abstract: One of the greatest environmental problems in the Republic of Macedonia is accelerated soil erosion caused by high human impact during last centuries on to the susceptible landscape. Natural factors itself are very suitable for development of such erosion: from mostly erodible rocks and soils on the mountainous slopes around the depressions, to the generally continental, semi-arid climate and slight vegetation cover. Because of that, there are sites with severe erosion and deposition like those in the catchments of Kamenichka River and Radanjska River, two torrential tributaries of Bregalnica. In these catchments there are varieties of erosion-related landforms: rills, gullies, badlands, landslides, as well as valley-type alluvial fans and huge alluvial plains. Such devastating accelerated erosion and deposition largely transformed original landscape, and represent significant environmental, social, and economic problem in local areas. Because of that, some measures of protection and conservation were taken from 1950-ties in both catchments. But it is obvious that the final effect of these measures is far of enough, so new efforts must be implemented to revitalizing these abandoned lands.

Key words: excess erosion, deposition, human impact

Извод: Један од највећих еколошких проблема у Републици Македонији је интензивна ерозија тла изазвана антропогеним фактором у прошлом веку. Природни фактори су врло погодни за развој такве ерозије: почев од стена и тла на планинским падинама, до континенталне и полупустињске климе, као и вегетационог покривача. Услед тога, издвајају се области интензивних процеса ерозије и акумулације у сливовима Каменичке и Радањске реке, двеју бујичних притока Брегалнице. У овим сливовима налазе се различити ерозвни облици рељефа, као што су: јаруге, вододерине, бедлендс, клизишта као и речне долине и алувијалне равни. Интензивни процеси ерозије и акумулације у великој мери трансформисали су оригинални рељеф, и представљају значајан физички, социјални и економски проблем у овој области. Услед тога, 1950-их година спроведене су мере заштите у оба истраживана сливас. Ипак, очигледно је да коначни ефекат ових мера је далеко од потребног, тако да нови напори морају бити реализован у ревитализацији ових напуштених простора.

Кључне речи: ексцесивна ерозија, акумулација, антропогени фактор

Introduction

Accelerated erosion becomes one of the leading agricultural, social, economic and environmental problems in the world today. In that aspect, some regions, especially those with temperate semi-arid climate and high human impact on the landscape are indeed heavily affected. Among the others in Mediterranean region, Republic of Macedonia is one of the countries with high intensity of soil erosion (Gjorgjevic et al., 1993). Very suitable natural factors as large mountainous areas covered by erodible rocks and soils, domination

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of south-inclined steep slopes, semi-arid climate with stormy rains occurrences, weak vegetation cover etc., are predispositions for that (Milevski, 2007). But the main trigger is long lasting anthropogenic influence in this area during centuries, especially in regard to deforestation. For that reasons, there are numerous sites through the country characterised with severe erosion and deposition. Two of such notable sites elaborated in this paper are catchments of Kamenichka River and Radanjska River. The catchment of Kamenichka River is already known as one of most severe eroded catchments greater than 100 km^2 in the Republic of Macedonia (Blinkov, 1998; Milevski, 2006; Blinkov et al., 2007). In other hand, Radanjska River catchment is not well surveyed until recently, when entire complex of alluvial fans is found along the valley bottom (Milevski, 2008). Thus, both rivers are typical torrential tributaries of Bregalnica with comparable size, but with different physical and socio-geographic features. No matter, their catchments have similar landscape heavily damaged by excess erosion and deposition, particularly in lower downstream parts where anthropogenic influence was highest. Although some protection measures were undertaken after 1960-ties (afforestation, retention walls etc.), the results are far of enough. Today, these areas are poor, depopulated, devastated and represent significant environmental, economic and social problem.

Methodological approach

For research of excess erosion and deposition processes and landforms in Kamenichka and Radanjska River, complex methodology is used. First of all, several field researches were carried-out with GPS surveying, from which landscape morphology and extent of erosion is identified. Field researches were accompanied by analyses of geologic and topographic maps, digital elevation models (from 3"SRTM DEM), satellite imagery (Landsat ETM+), vegetation maps and Corine Landcover 2000 data's. These tools showed as very useful in determination of erosion factors and GIS implemented estimation of erosion intensity. Moreover, fine-resolution satellite imagery (Google Earth; 0.6 m QuickBird) enable even detailed morphology analyses of gullies and alluvial fans. For estimation of human impact in the catchments, some historical sources were used and field information's from local peoples, as well as official census data's from state statistical agency. Because of the subject, comparative method is utilized not only between two catchments, but also for landforms variability in same catchment.

Study area overview

Kamenichka and Radanjska River are located in east part of the Republic of Macedonia (fig. 1). They are average-size tributaries of Bregalnica, which is in turn largest arm (225 km long) of the major river in the country-Vardar. Kamenichka River (which mean "Stones River") is average in size (length: 22.2 km; catchment area: 118.3 km^2), right tributary of Bregalnica, extending near the border with Bulgaria. The source area of Kamnichka River is highly in Osogovo Mountain (Ruen, 2252 m) on 2000 m a.s.l., while the inflow is in Kalimanci Reservoir on 510 m a.s.l. Because of fault-tectonic predisposition, river course is almost linear, lengthened in NW-SE direction (along the Saso-Toranica dislocation), and longitudal gradient is high (6.7%), especially in the first several kilometres.

As a result of fault activity, then permanent tectonic uplift of Osogovo Mountain and intensive, generally vertical fluvial erosion, the catchment of Kamenichka River is narrow and deeply incised in erodible crystalline rocks. The catchment is characterised with steep slopes mostly inclined toward SW direction, and with considerable vertical relief, showing high erosion potential (Milevski, 2006). Climate in the area is continental to mountainous with long direct solar radiation, high daily and seasonal temperature amplitudes, and with mean precipitations of 700-800 mm/y. Drainage network is dense, but because of weak vegetation cover, most of the rivers in lower parts have very variable discharge and typical torrential character. The main cause for weak vegetation and forest cover is human impact. Since this area is rich in ore deposits, it very early attract settlers and miners, largely devastating the forests for mining activities (Blinkov et al., 2007). Today, there are 6 settlements with 34 groups of houses ("maala"), and about 8100 inhabitants in the catchment.

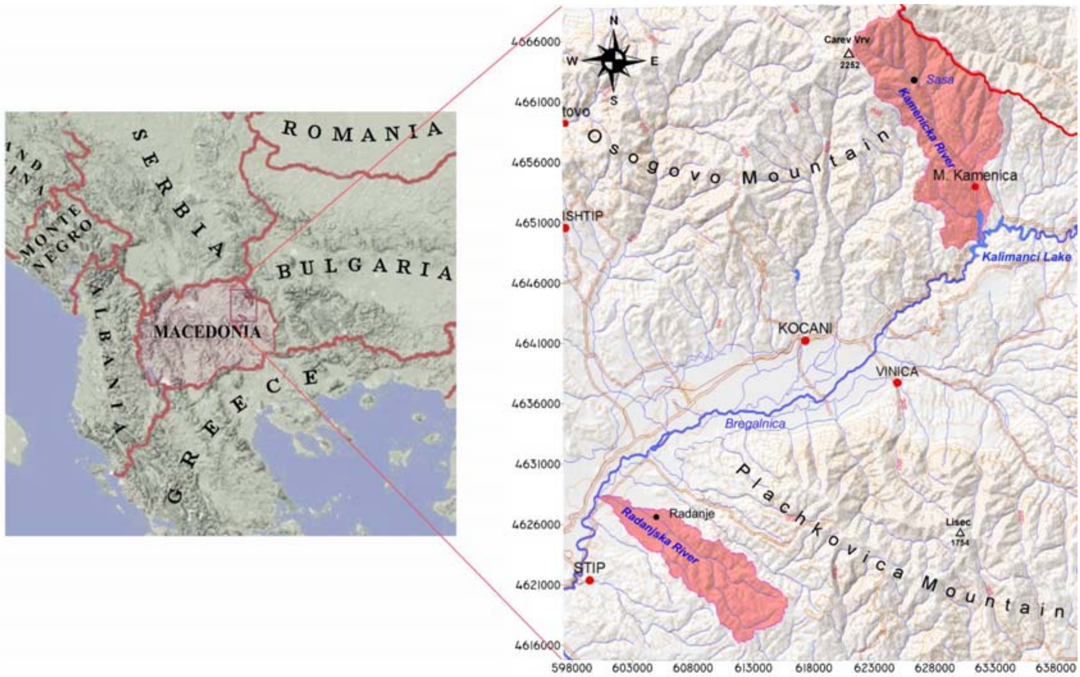

Figure 1. Geographic location of Kamenicka and Radanjska catchments.

Radanjska River, also known as Suva Reka (Dry River) is smaller (length: 19.8 km; catchment area: 62.8 km) left tributary of Bregalnica some 50 km downstream of Kamenichka River. The source area of Radanjska River is in the west hilly part of Plachkovica Mountain (Lisec, 1754 m) on 960 m, while the inflow is on 276 m a.s.l. Thus, longitudal river gradient is 3.5%, nearly half of Kamenichka River. The river course generally has linear SE-NW direction which is predisposed by faults and geological formations. Because of neotectonic uplift and vertical river incision in crystalline rocks and Eocene sediments, valley profile has V shape with convex sides, similar like Kamenichka River. The catchment is generally bellow 1000 m, elongated and inclined toward NW; with smaller slopes and lower vertical relief. Climate is temperate-continental with long insolation (more than 2500 h/y), high mean annual temperature of about 12°C, and low precipitations of 500 mm/y. Although this is semi-arid area, there are heavy rain occurrences with more than 20 mm/h almost each year (Lazarevski, 1993; Skoklevski and Todorovski, 1993). Because of aridity and of insignificant forest areas, drainage network has notable torrential character with very high amplitudes in water discharge. Vegetation in the catchment is almost totally degraded by long-lasting human impact especially in regard to deforestation. Namely, this area for long time is known as livestock region of extensive pasturing and overgrazing, followed by devastation of natural vegetation. For that reason, almost entire catchment is under excess rill, gully, landslide erosion and overall denudation.

Previous table (Table 1) show significant differences between two catchments especially in regard to the topography. But forest areas (derived from Landsat ETM+) are similar and very small in contrast to total road (and path) network which is rather high, indicating high human impact.

Table 1. some physical-geographic and socio-geographic parameters for Kamenichka and Radanjska River catchments.

Parameter	Kamenichka River	Radanjska River	difference K-R
Length km	**22.9**	**20.6**	**2.3**
Divide km	**58.4**	**47.9**	**10.5**
Area km^2	**118.3**	**62.8**	**55.5**
Drainage network km	**194.8**	**95.2**	**99.6**
Drainage density index	**1.65**	**1.52**	**0.13**
Highest alt. m	**2205**	**1036**	**1169**
Lowest alt. m	**510**	**276**	**234**
Altitude diff. m	**1695**	**760**	**935**
Mean alt. m	**1119**	**660**	**459**
Mean slope	**24.0**	**11.0**	**13**
Mean relief dissection m/km^2	**292**	**141**	**151**
Solid rock areas %	**12.7**	**13.5**	**-0.8**
Erodible rock areas %	**87.3**	**86.5**	**0.8**
Average interpol. temp. °C	**8.2**	**11.0**	**-2.8**
Average interp. precip. mm	**787**	**620**	**167**
Forest area %	**34.5**	**23.2**	**11.3**
Settlements/”maala”	**6/34**	**6/6**	**28**
Population 1953	**4749**	**1739**	**3010**
Population density 1953	**40.3**	**27.7**	**12.6**
Population 2002	**8100**	**778**	**7322**
Road network m/km^2	**1.05**	**0.95**	**0.05**

Excess erosion processes and landforms

As already seen, natural and anthropogenic factors in Kamenichka and Radanjska River catchments are very appropriate for processes of accelerated soil erosion. That resulted in waste variety of erosion and deposition landforms, while the landscape is heavily transformed and destructed.

Kamenichka River catchment is especially characterised by excess linear rill and gully erosion in crystalline rocks as well as in soft Pliocene sands and sandstones in south-eastern part. These processes and landforms generally found on the left (east) catchment side which is larger and south-west inclined (sun-sided). Rills frequently occur in cultivated, sloped land areas below 1000 m of altitude, with downslope tillage and irrigation, or on uncover, erodible hilly terrain with concentrated overland flow. Severe rill erosion is present in highly dissected south part of the catchment (near Kosevica village), where significant amount of deposits is produced. Depending on land cover, soil erodibility, slope angle and slope length, rills often extend in more permanent gullies. Moreover, because of suitable natural and anthropogenic influence, large areas have gully erosion. It is extremely severe on the valley sides of Kamenichka River and its tributaries, where mining activities, deforestation and landscape destruction have long lasting history. Here, gullies are deeply incised, V-shaped, developed in highly erodible, tectonically cracked and disintegrated Palaeosoic chists, except in south part near Kosevica village, were created in soft Pliocene sands and sandstones. There are regions downstream from Sasa village with more than 15 gullies on km^2, or with gully density of 500 m/km^2. The size of gullies largely differs; from tenth meters to several hundred meters. Sometimes because of the size is difficult to distinct large gullies from small torrential valleys. Because of huge quantities of eroded material during rainstorms, most of these gullies have alluvial fans in the bottoms of which size usually corresponds to their catchment area.

Landslides are also very common in this area, especially in the lower parts of the catchment, below 1200 m altitude. Their formation is enabled with soft sediment rocks (sands, sandstones) covering inclined Pliocene clay layer. However, the main trigger is large anthropogenic influence which changed overland flow, increased slopes etc. Numerous landslides are recorded downstream from the village Sasa. This part of the valley is composed by soft erodible schists and clastic sediments, mostly uncovered, eroded and with steep slope. Because of that, soils and decomposed rocks on the valley sides almost entirely slide-down toward the valley bottom, making and enormous system of landslides with total estimated volume of 5 millions m^3. That is particularly evident near the village Kosevica where the village itself is in danger (fig. 2). Aside of that, several landslides are registered on the coastal region around Kalimanci Lake (Milevski, 2006). All of them highly influence the rate of soil loss and the rate of sediment load from the Bregalnica River to the Kalimanci reservoir. It is worth to stress that some landslides were activated recently with direct human impact, mostly by road incision in unstable terrain.

Figure 2. Large landslide in Kosevica village, endangering near houses and roads.

In the vicinity of Sasa village, valley sides of Kamenichka River are so much destructed by gullies, torrents and badlands, that this area resembles typical badlands in length of 2-3 km. Large quantity of deposits in Kamenichka River originate exactly from this badlands area. Badlands-like is torrential catchment of Kosevica River (6.8 km^2), left tributary of Kamenichka River. This catchment is incised in very erodible Pliocene sands and sandstones totally uncovered by past deforestation. Accompanied by long-lasting human impact, this area is heavily damaged by sheet erosion, rills, large gullies, and landslides, some of them recently activated. Our estimations show that average erosion intensity in Kosevica catchment is 1380 $m^3/km^2/y$ or near 1.4 mm/y.

Although something different in natural and anthropogenic factors, Radanjska River catchment is characterized by almost the same types of erosion processes and landforms as Kamenichka River. Generally there is remarkable rill and gully erosion accompanied with smaller landslides and badlands. These landforms are located mostly on the east (right) sunny (SW-inclined) catchment side (Tiken Bair hill) composed by erodible schist's (gneiss, mica-schist) and Eocene sandstones. Rills usually are created in mica-schist on the gully heads near divide and on gully sides with concentrated overland flow. Some of them are ephemeral, easily changing or destructing during next rainstorm event. But there are more permanent rills as a first stage of gully formation downslope. However, with rill and interrill erosion huge quantity of deposits is produced. These deposits are transported with flowing waters through the gullies and torrents toward the Radanjska valley bottom, contributing in increase of the alluvial fans and plains. Because this area is rarely populated and agriculture land is almost lost, rills resulted from agriculture activities: irrigation, tillage etc., actually do not exist.

Gullies are the most notable and destructive landforms in the Radanjska River catchment, usually found on the right valley side (Tiken Bair hill). Because the soil layer is already removed, gullies were incised in parent rocks: Precambrian mica-schist, gneiss and Eocene complex (sandstone, limestone etc.). Depending of rock erodibility, they have more or less deepened V-shape with straight or convex sides and with steep, stair-like longitudinal profile. Transversal and longitudinal profile show relatively young, active stage of gully development. Frequently there are smaller gullies on the side of larger ones, which in turn can be really large: up to several hundred meters in length, so it is difficult to distinct them from small torrential catchments.

Figure 3. Rill and gully erosion with alluvial fans on the right (east) valley side of Radanjska River.

Morphologically, gullies on stepper slope have almost linear direction, while on lower slope or where rocks changed, they have meandered route. Some gullies mutually approach and connect downslope forming an amphitheatric head, while those on the valley side in bottom are parallel one after other, giving the rubber-like shape of the landscape (Fig. 3). However, gullies produce huge quantity of deposits during torrential events, supplying near accumulative landforms or Radanjska River with sediments.

Landslides are not so common in Radanjska catchment, generally due to not very suitable lithology and lack of soil layer. With field research two typical landslides were identified, caused by instability of left valley side with permanent lateral incision of Radanjska River. Actually, large part of left (west) valley side is instable because of lateral pushing of the river by his right-side torrential tributaries. The landslides have average size of about 150 m in length, 80 m wide and up to 8 m deep. Several other shallow landslides are recorded on river terraces from both sides, but they were not researched in detail.

It is worth to stress that on the right valley side there are interesting occurrences of denudation landforms in less erodible gneiss and Eocene sediments. Due to higher resistance of weathering, these rocks left uneroded and shaped like different stone formations: towers, needles, pseudo caves etc.

Because of numerous gullies, rills, weathering landforms, landslides and excess deposition, the Radanjska River valley downstream of Odzalija village (in length of 5 km) is badlands-like. This is totally devastated landscape impossible for any kind of human use. There are several smaller badlands up to 200-300 m in length upstream of Radanje village.

Excess deposition landforms

As a result of severe erosion in Kamenichka and Radanjska River catchments, large amount of eroded material is produced. By energy of flowing waters and gravitationally, this material is moving toward lowest point in the catchment (local erosion basis). On this path, transport energy or capacity of flowing waters significantly decrease with decreasing of slope, enabling formation of deposition landforms. These landforms correlate with erosion intensity, so largest deposition landforms were created in the regions of most severe erosion, because running waters cannot carried-out such high amount of material. Generally, there is huge deposition landforms in both catchments represented by alluvial fans and alluvial plains created along the valley bottom of main rivers.

In Kamenichka River most of deposition landforms are along the valley bottom of the Kamenichka River, downstream of the village of Sasa. As a result of excess erosion in the catchment, these parts of valley bottom represent alluvial plain with huge amount of fresh deposits from near torrents and gullies. Along the bottom of the left (east) valley side, these torrents and gullies formed 7 typical alluvial fans which are usually about 200 m wide and 200-250 m long. Each alluvial fan is morphologically well developed with incision channel, intersection point and unstable lateral channels. Deposed material is very coarse, showing short path from the source of origin. Because of permanent rising of the fans from the east, the Kamenichka River itself is moving to west direction, cutting the right valley side (Fig. 4). With regard to the catchment asymmetry, there are few smaller alluvial fans on the right (west) valley side of the Kamenichka River.

Aside of alluvial fans, the Kamenichka valley bottom is permanently filled-up with large quantities of eroded material from the near gullies and torrents, forming characteristic alluvial plain. This is site with excess deposition, which is 13 km long, 20-100 m wide, and 5-15 m deep. In total, a quantity of 5.2 millions m^3 of deposed material is estimated from which 3.7 millions m^3 in the alluvial plain, and 1.5 million m^3 in the alluvial fans. Because of torrential protection, in the 1960s, a system of 25 barrages is constructed across the valley bottom of the Kamenicka River and further 26 barrages on hers tributaries. They are fulfilled behind with geodetically measured 976000 m^3 of sediments in the last 50 years

(Blinkov & Trendafilov 2004). Other sites with excess deposition are in their right torrential tributaries: the Kosevica River and the Mosticka River.

Figure 4. Large valley-type alluvial fan in Kamenichka valley from one left torrential tributary.

Because of severe erosion, there are numerous deposition landforms in Radanjska River catchment also, represented by more than 30 valley-type alluvial fans and one large alluvial plain with fresh coarse deposits.

Figure 5. Numerous alluvial fans on the right side and large alluvial plain in the valley bottom of Radanjska River.

Along a right (east) side of Radanjska valley bottom, torrential tributaries and gullies formed a 6 km long series of relatively small alluvial fans. These alluvial fans have typical conic-fan structure, and were created where torrents sharply change longitudinal slope: from steep upstream slope into flat valley bottom. From more than 30 registered alluvial fans, near 20 has area greater of 500 m^2, with the largest of about 35.000 m^2.

Dimensions of the individual fans are from 30x30 m, to 240x230 m up to the fan apex. Most of the fans (ranged from 550 m a.s.l. to 410 m a.s.l.) are close and linked together in one longer belt ("bajada"), with total volume of 1-2 millions m^3 deposed material. This is indeed great quantity, keep in mind a small catchment area (62.8 km^2). Aside of relatively small area, alluvial fans have interesting morphology with all structural morphologic elements: drainage basin, fan apex, fan area, incision channel, intersection point, distributive channels and fan bottom. Most of the "free-side" fans are quite symmetrical, but those which coalesce together, have asymmetric profile. However, there is proportional relation of fan area and fan slope with their drainage basins, coincide with well known Bull (1962, 1964) equation. Longitude profile of the fans is generally concave, and in correlation of fan area and granulometry of deposed material. Deposed material is very coarse because of the vicinity of their origin, and with irregular sorting through the fans. Although fans constantly tend to frontally rise-up even pushing the main river, in same time the main river cut-off and detaches frontal parts slowing down their rising (Milevski, 2008).

Aside of alluvial fans which are mostly connected, middle part of valley bottom of the Radanjska River itself in length of 5 km is entirely fulfilled with enormous amount of deposits estimated of about 2-3 millions m^3. These deposits originated generally from near torrents, gullies and removed material from alluvial fans. Because of such erosion and deposition, in 1960-ties 3 large retention walls up to 10 m high were built upstream of Radanje village. Today these retentions are totally filled-up, which show that entire valley bottom upstream of the walls is raised-up for about 10 m.

Table 3. Morphometric characteristics of alluvial fans in Kamenichka and Radanjska River catchments, with area greater than 5000 m^2.

Kamenichka catchment									
	R km	H m	L m	W m	L/W	P m	Af m^2	Ac km^2	Ac/Af
1.	4.50	610	192	188	1.02	620	20700	16.850	812
2.	7.40	690	146	130	1.12	416	10590	0.450	42
3.	8.15	725	230	190	1.21	707	21600	0.530	25
4.	8.80	760	160	98	1.63	425	7800	0.320	41
5.	9.05	780	208	130	1.60	637	15400	0.600	39
6.	9.30	805	160	160	1.00	514	14870	1.150	77
7.	9.75	850	236	215	1.10	729	25300	4.750	188
8.	tribut.	780	180	70	2.57	437	8350	0.780	93
Radanjska catchment									
	R km	H m	L m	W m	L/W	P m	Af m^2	Ac km^2	Ac/Af
1.	0.80	399	145	140	1.04	453	8780	0.250	28
2.	1.40	410	130	105	1.24	360	6780	0.494	73
3.	2.80	447	240	230	1.04	775	25540	0.689	27
	-	-	420	230	1.83	1233	35090	-	20
4.	4.05	475	130	147	0.88	445	8520	1.488	175
	-	-	550	147	3.74	1660	18290	-	81
5.	4.60	502	118	95	1.24	360	6260	0.141	23
6.	4.70	505	107	70	1.53	302	5070	0.035	7
7.	5.15	525	175	110	1.59	475	9720	0.676	70
8.	5.30	529	138	92	1.50	378	5600	0.180	32
9.	5.40	531	110	105	1.05	345	7040	0.041	6
10.	5.90	549	220	122	1.80	550	13060	2.660	204
	-	-	825	122	6.76	1776	32120	-	83

Explanation: R-distance from the influx in Kalimanci reservoir and from Radanje village; H-altitude a.s.l. of fan base; L-length of fan; W-width of fan; P-perimeter of fan; Af-fan area; Ac-fan catchment area.

Soil erosion intensity

Although with clearly visible processes of severe erosion, field monitoring and measuring of erosion intensity or sediment yield in Kamenichka and Radanjska River is not perform. Thus, principal way of soil erosion estimation in these areas is by empiric models approach. In Macedonia, as well as in other countries in former Yugoslavia, estimation of average soil erosion potential and sediment yield is generally achieved with equation of Gavrilovic (1972), which take into account mean annual temperature (T), precipitations (H) and the most important - erosion index (Z). Traditional approach of this model is implemented in Erosion map of the Republic of Macedonia (Djordjevic et al., 1993). The map show average erosion rate in Kamenichka River of 1258 $m^3/km^2/y$ and sediment yield of 944 $m^3/km^2/y$, while for Radanjska River average erosion rate is 359 $m^3/km^2/y$, and sediment yield is 197 $m^3/km^2/y$.

Because of well proven accuracy, there are several recent GIS adaptations of Gavrilovic model (Milevski, 2001; Petras et al., 2007). Unlike the traditional cartographic tools, in GIS approach most of the equation parameters are derived from digital elevation model and satellite imagery. Thus, from preprocessed 3”SRTM DEM (to 60 m), with evaluated vertical gradient interpolation, climate indices T and H were obtained, as well as slope value J for every cell on the grid. Land cover index Xa is prepared from CORINE Land cover map with values from 0.1 (dense forests) to 1 (bare soils). Index φ is prepared from Landsat ETM+ band 3, according to relation: $\varphi = (b3/255)^{0.5}$. In GIS procedure factor Y (soil and rock erodibility) is taking to be optional, unless sufficient parameters are available. Finally with successive calculations of all grid layers, average erosion rate is obtained.

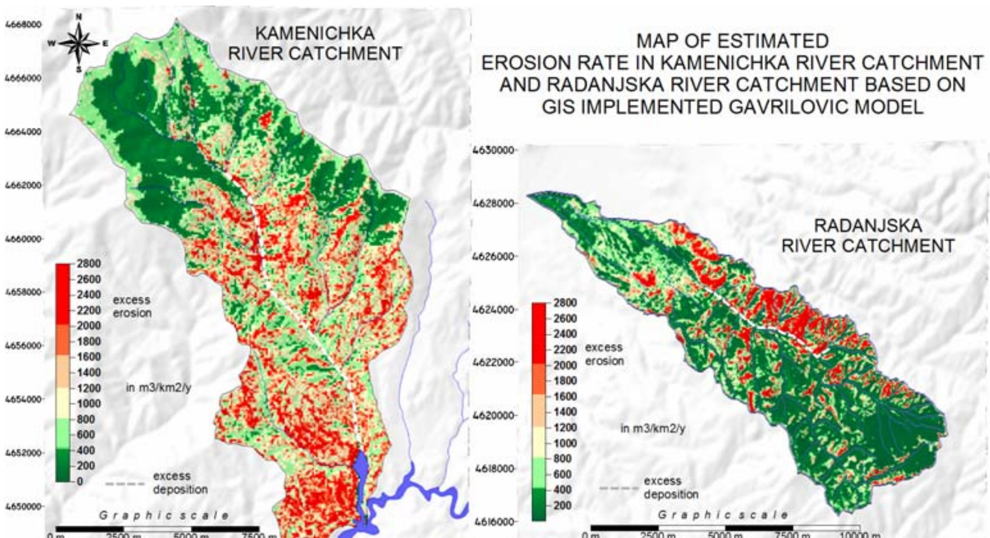

Figure 6. Map of GIS-based estimation of average erosion rate in Kamenichka and Radanjska River catchments.

The results from GIS model are something different than traditional one. Thus, average erosion rate for Kamenichka River catchment is 1050 $m^3/km^2/y$ (1.05 mm/y), and average sediment yield of 787 $m^3/km^2/y$. These values are little smaller than of traditional map. However, in both maps there are large areas with severe and excess erosion rate of above 1500 $m^3/km^2/y$, which occupied 27.5 km^2 or 23% of the catchment.

Average erosion rate estimated for Radanjska River catchment is 697 $m^3/km^2/y$ (0.7 mm/y), while sediment yield is 383 $m^3/km^2/y$. These values are almost double than in traditional map where are clearly underestimated with regard to the real field situation. It is interesting that GIS-map show high contrast in erosion rate. From one side there is badlands-like area with severe and excess erosion (over 1500 $m^3/km^2/y$), occupying 8.9 km^2 or 14.2% of the catchment, and from other side was areas with gentle slope, partly forested and with low erosion rate.

Conclusion

Field analysis and soil erosion modelling show that in Kamenichka and Radanjska catchments, accelerated erosion dominates in the landscape. In both catchments there are numerous forms of excess erosion and deposition: gullies, landslides, badlands, alluvial fans and alluvial plains. Most of these landforms are on south-west and west (sunny), steep-slope valley side, in vicinity of the settlements, which point to high anthropogenic influence in their formation. Good indicators of erosion intensity are numerous alluvial fans and large alluvial plains with fresh, coarse deposits. Thus, in Kamenichka catchment there are 8 larger fans (one of them in Mostichka tributary) with total area of about 125,000 m^2, and deposed material of 1.5 million m^3. Alluvial plain of Kamenichka River is impressive with its length of 13 km and estimated deposits of 3.5 millions m^3. A bit smaller is alluvial plain of its left tributary-Mostichka River (16.8 km^2), which is 3.5 km long and 40-60 m wide. Because of huge quantity of deposits, Kamenichka River fulfils its valley bottom and even built small delta at the influx in Kalimaci reservoir. Moreover, this river carried-out large quantity of deposits in Kalimanci reservoir, quickly shrinking its useful storage. Similar situation is in Radanjska catchment, where torrential tributaries formed 10 larger and many smaller alluvial fans with total area of 181,000 m^3, and about 1-2 millions m^3 of deposits. Large blocks in the fans and in alluvial plain show incredible torrential energy.

Because of such excess erosion and deposition, some protection measures were undertaken in 1960-ties and 1970-ties. But devastating effect of excess erosion in Kamenichka and Radanjska catchments is still present. Actually the real origin of the problem is not well treated, while in last decades no any serious activity. Meantime because of lack of arable land and fresh water, most of the population in rural areas emigrate in near or further cities.

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ИВИЦА МИЛЕВСКИ

Р е з и м е

ЕКСЦЕСИВНА ЕРОЗИЈА И АКУМУЛАЦИЈА У СЛИВОВИМА КАМЕНИЧКЕ И РАДАЊСКЕ РЕКЕ У РЕПУБЛИЦИ МАКЕДОНИЈИ

Теренска анализа и моделовање ерозије земљишта показале су да у сливовима Каменичке и Радањске реке доминира интензивна ерозија. У оба слива присутни су бројни облици ерозије и акомулације: вододерине, клизишта, бадландс, речне долине и алувијалне равни. Већина ових облика рељефа су на југозападу и западу, на стрмим странама падина, у близини насеља, што указује на висок антропогени утицај на њихово формирање. Добар показатељ интензитета ерозије су алувијалне равни са свежим акумулацијама. Тако, у сливу Каменичке реке постоји 8 (један од њих Мостичке притока), са укупном површином од око 125.000 m^2 и акумулираним материјалом од 1,5 m^3. Алувијална раван Каменичке реке је импресивна са својом дужином од 13 km и процењеним наслагама од 3,5 m^3. Мало мања је алувијална раван њене леве притоке Мостичке реке (16,8 m^2), која је 3,5 km дуга и 40-60 m широка. Због велике количине наслага, Каменичка река у потпуности испуњава своје дно, а чак и гради малу делту на ушћу у Калимаци језеро. Ова река доноси језеру велику количину материјала. Слична ситуација је и са сливом Радањске реке у којем бујичне притоке формирају плавину површине 181,000 m^2 са материјалом од 1-2 m^3. Велики блокови стена у плавинама и алувијалним равнима указују на изузетну енергију бујичних токова.

Услед високог интензитета ерозије и акумулације, током 1960-их и 1970-их година предузете су мере заштите. Ипак ексцесивна ерозија је и даље присутна у сливовима Каменичке и Радањске реке. Стварни узрок проблема још увек није уклоњен и последњих декада у том правцу нису предузимане активности. У међувремену, услед недостатка обрадивог земљишта и свеже воде становништво руралних области мигрирало је у урбане.