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HUMAN IMPACT IN THE CATCHMENT AREA OF THE ŽUKOVSKA RIVER

АНТРОПОГЕНИ УТИЦАЈ У СЛИВУ ЖУКОВСКЕ РЕКЕ

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Abstract: The results of a comparative study of the changes in land use, population, number of households and population density, erosion control works and the intensity of erosion processes in the period from 1955 to 2016 confirm that besides the natural resources of the catchment area, the human factor is the main cause of the change in the intensity of erosion processes.

Keywords: human impact, intensity of erosion, erosion potential model (EPM), erosion control works, The Žukovska River catchment area, eastern Serbia

Апстракт: Резултати компаративне анализе промена начина коришћења земљишта, броја становника, домаћинстава и густине насељености, изведених противерозионих радова и интензитета ерозионих процеса у периоду 1955. - 2016. године потврђују да је антропогени фактор, уз природне предиспозиције слива, основни узрок настанка и промене интензитета ерозионих процеса.

Кључне речи: антропогени утицај, интензитет ерозије, Метод Потенцијала Ерозије, противерозиони радови, слив Жуковске реке, источна Србија

Introduction

The interaction of climate, heterogeneous geological composition, topography, aspect, different quality of forest ecosystems, as well as the adverse effects of human activity have caused the development of intensive erosion processes and frequent torrential floods in the catchment area of the Žukovska River. Inadequate land use has further contributed to the development of erosion processes (Braunović, Ratknić, 2012). Human activity in agriculture and forestry has had harmful effects on the vegetation cover, soil structure and stability and thus intensified the erosion. Because of the strong human impact, the rapid erosion is rightly said to be of anthropogenic origin.

Human migration in the catchment area of the Žukovska River has been caused by historical and economic factors: old people stay in the villages and they are engaged in agriculture, while young people leave their homes in search for existence in the industry and other economic activities. The villages have been sparsely populated, with the average population age around 70 years.

Material and methods

The map of land use and the map of erosion for the period before the erosion control works were performed (in 1955) were created on the basis of the existing technical documentation and the map of erosion from that period (Bilibajkić, 2012). The erosion coefficients were calculated after prof. Gavrilović's methodology for both periods (Gavrilović, 1972). The field maps of

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the processes of excessive and severe erosion, satellite images and thematic (topographic, geological, soil, land use, erosion, etc.) maps, as well as the climate characteristics and the distribution of vegetation were used to determine the erosion coefficient (Z) for each of the determined homogeneous plots.

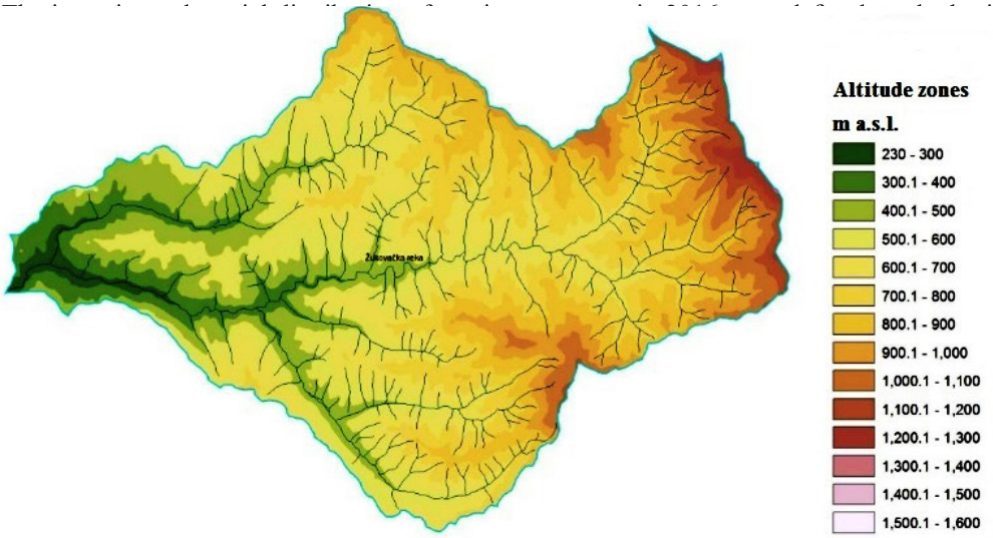

Figure 1. Altitude zones in the catchment area of the Žukovska River
Слика 1. Висинске зоне у сливу Жуковске реке

Table 1. Overview of the area by the altitude zones of the catchment area
Tabela 1. Преглед површина према висинским зонама у сливу

Area	Altitude zones (m a.s.l)				
	Hilly terrain		Low-mountainous terrain		Medium to high mountainous terrain
	below 300	300-500	500-700	700-1000	above 1000
k^m2	1.42	18.73	37.10	39.50	7.71
%	1.4	17.9	35.5	37.8	7.4

The share of soil types and their spatial distribution are shown in Table 2. The most frequently occurring soil type is brown soil: on shallow gabar (53.97%), on phyllite and shale (12.13%) and on mica shist and gneiss (11.39%), *etc*.

Table 2. *Distribution of the soil types in the catchment area of the Žukovska River*
Табела 2. Заступљеност типова земљишта у сливу Жуковске реке

Soil type	Share (%)
Brown soil on shallow gabar	53.97
Brown acid soil on phyllite and shale	12.13
Brown acid soil on mica shist and gneiss	11.39
Brownised rendzina on hard skeletal limestone	11.05
Brown acid soil on the Miocene sands and clays	3.13
Rocky limestone	2.86
Ranker on gneiss	2.36
Brown acid soil on sandstone	1.24
Brown soil on gabar and flysch; Brown acid soil on granite; Brown forest soil; Alluvial sandy non-calcareous sediment	<1.00

The bedrock of the catchment area is composed of limestone, sandstone, green rocks and green schist, gabar and granite. The spatial distribution of the bedrock and the shares of different geological formations are shown in Table 3.

Table 3. *Geology of the catchment area of the Žukovska River*
Табела 3. Геолошки састав слива Жуковске реке

Bedrock	Share (%)
Pyroxene medium-grained gabar (a); pyroxene gabar (b)	46.21
Microgabar	11.78
Layered and thick-bedded limestone and dolomite (Valanginian and Hauterivian)	11.08
Limestone, argillaceous limestone, shale (Lower Urgonian facies)	7.64
Conglomerates, sandstones, sands; limestone (a)	4.29
Sandstones, shale, limestone (Upper Urgonian facies)	4.27
Biotite-amphibole and amphibole-biotite gneisses	3.31
Granodiorite-porphyrite of Aldinac	1.22
The lower river terrace	1.18
Green rocks and green schists	1.08
Amphibolites and amphibole schist; gabro-porphyrites; sandstones, marls, chert, shale; migmatites *etc*.	< 1.0

The vegetation cover is mainly composed of oak forests, beech and hornbeam forests, introduced Austrian pine and locust forests, meadows, pastures and agricultural fields.

Table 4. *Land use in the catchment area in 1955 and 2016*
Табела 4. Начин коришћења земљишта у сливу 1955. и 2016. године

Land use	in 1955		in 2016	
	Area			
	(km^2)	Share in %	(km^2)	Share in %
Bare land	34.74	33.26	1.82	1.74
Forests	30.55	29.25	51.41	49.22
Scrubs	6.58	6.30	0.41	0.40
Arable fields	19.12	18.30	0.79	0.75
Meadows and pastures	12.64	12.10	47.34	45.32
Vineyards	0.31	0.30	0.31	0.30
Orchards	0.52	0.50	0.13	0.12
Human settlements	-	-	2.24	2.15
	104.46	100.00	104.46	100.00

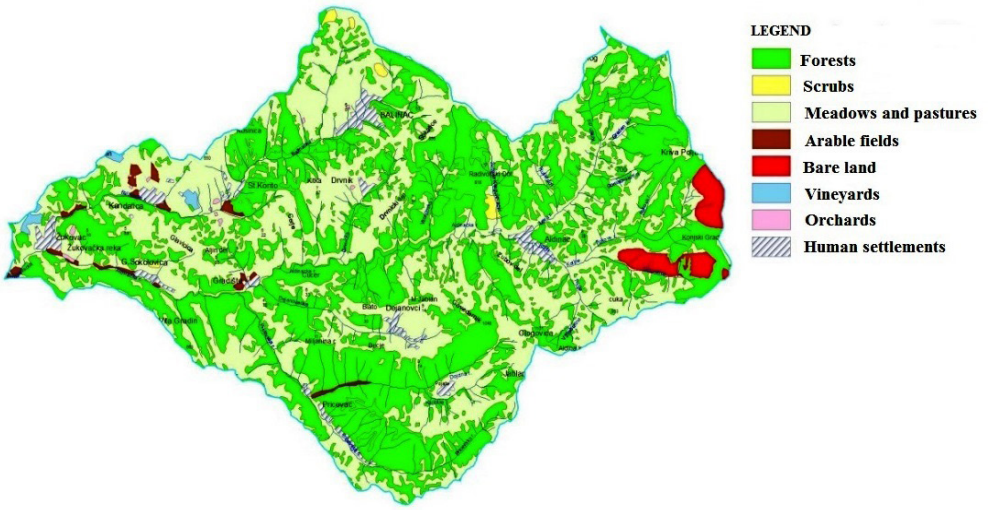

Figure 2. *Map of land use in the catchment area in 2016*
Слика 2. Карта начина коришћења земљишта у сливу 2016. године

According to data from 1955, barren land occupied 33.26%, forests 29.25%, arable fields 18.30% and meadows and pastures 12.10% of the catchment area. In 2016, forests covered 49.22%, meadows and pastures 45.32%, arable fields 0.75%, vineyards 0.30%, orchards 0.12%, bare land 1.74% and human settlements 2.15% of the total area (Table 4; Figure 2).

Compared to the land use in 1955, the share of forests increased from 29.25% to 49.22%, and the share of barrens decreased from 33.26% to 1.74% of the total catchment area.

According to CORINE methodology (Table 5), the share of forested area increased to 70.54% (by 41.29% compared to 1955).

Table 5. *Land use in the catchment area of the Žukovska River – CORINE*
Табела 5. Начин коришћења земљишта у сливу Жуковске реке

CORINE category	Area (km^2)	Share in %
2.4.2. The complex of cultivated plots	2.82	2.70
2.4.3. Predominantly agricultural land with larger areas of natural vegetation	14.79	14.16
3.1.1. Deciduous forests	50.55	48.39
3.1.2. Coniferous forests	13.10	12.54
3.1.3. Mixed forests	1.18	9.61
3.2.1. Grassland	11.99	1.13
3.2.4. Transitional area between forests and underbrush	10.04	11.47
Total	104.46	100.00

The catchment area of the Žukovska River stretches in 10 cadastral municipalities (Figures 3), at the altitude of 302 (CM Žukovac) to 694 m (CM Balinac and CM Drvnik). The population of the catchment area decreased almost 17 times in the period from 1948 to 2011 (see Table 6, Figure 4).

Figure 3. *Cadastral municipalities in the catchment area*
Слика 3. Катастарске општине у сливу

Table 6. *Population by census years*
Табела 6. Број становника према пописним годинама

Cadastral municipality	Altitude m a.s.l.	Population by census years								Reduction 1953-2011 (%)
		1948	1953	1961	1971	1981	1991	2002	2011	
Štrbac	246	741	719	622	582	453	379	246	153	78.7
Žukovac	302	427	419	349	280	216	169	114	63	85.0
Kandalica	394	256	251	223	174	129	88	52	25	90.0
Gradište	501	189	184	162	128	73	37	31	22	88.0
Vidovac	502	228	230	207	150	116	73	45	23	90.0
Staro Korito	587	287	280	250	173	128	78	51	23	91.8
Pričevac	605	418	426	374	282	163	96	54	25	94.1
Aldinac	693	847	744	611	391	151	75	26	16	97.8
Dejanovac	693	492	466	392	262	106	51	27	15	96.8
Balinac	694	556	493	400	287	126	61	39	19	96.1
Drvnik	694	259	199	180	149	76	37	15	7	96.5
Total		4700	4411	3770	2858	1737	1144	700	391	91.1

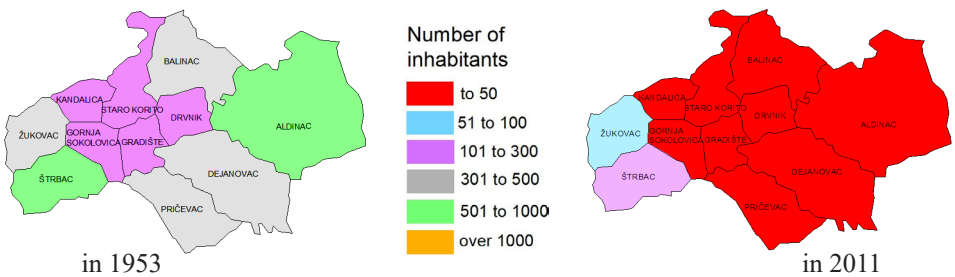

Figure 4. *The change in the population of the catchment according to census years*
Слика 4. Промена броја становника у сливу према пописним годинама

The largest population reduction in the study period was in the cadastral municipalities above 500 m a.s.l. All the cadastral municipalities in the catchment area had a marked reduction in the number of households and the average number of household members (2014). Population density decreased from 44.9 inhabitants/km^2 in 1948 to 3.74 inhabitants/km^2 in 2011.

The analyzed demographic and socio-economic changes in the researched area have affected indirectly to the regeneration of natural ecosystems (Braunović, Ratknić, 2011).

Excessive erosion processes were the most dominant in the catchment area in 1955 (77.28% of the total area). The processes of severe erosion accounted for 18.34%, moderate for 3.98% and very weak for 0.4% of the catchment area (Table 7, Figure 5). The erosion coefficient was Z = 1.14 (Bilibajkić, 2012).

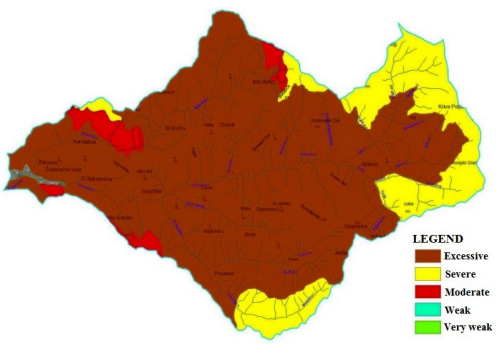

Figure 5. *Map of the erosion in 1955*
Слика 5. Карта ерозије 1955. године

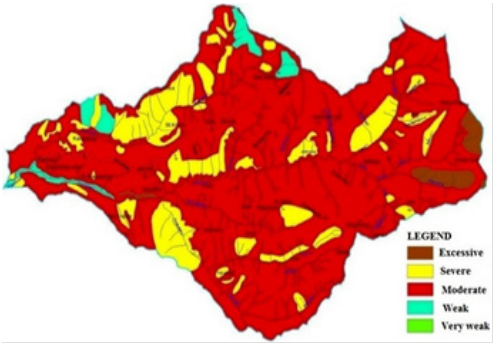

Figure 6*. Map of the erosion in 2016*
Слика 6. Карта ерозије 2016. године

Source: Bilibajkić, 2012

The intensity of erosion was reduced by 2016. Moderate erosion affected the big part of the catchment area (79.67%), followed by excessive erosion processes which affected 1.97%, while severe erosion accounted for 15.74% and weak for 2.62% of the catchment area.

The areas affected by excessive erosion decreased by 35.31%, and the areas under moderate erosion increased by 75.69%. The coefficient of erosion was Z = 0.61, which means that the catchment area was dominated by the erosion processes of destructiveness category III, *i.e.* the erosion processes of moderate intensity (Table 7, Figure 6).

Table 7. *Mean erosion coefficients (Z_{mean}) in 1955 and 2016*
Табела 7. Средња вредност коефицијента ерозије ($Z_{ср}$) 1955. и 2016. године

Erosion category	in 1955			in 2016		
	Z_{mean}	Area (km^2)	Share in %	Z_{mean}	Area (km^2)	Share in %
Excessive	1.25	80.73	77.28	1.25	2.06	1.97
Severe	0.85	19.15	18.34	0.85	16.44	15.74
Moderate	0.55	4.16	3.98	0.55	83.23	79.67
Weak	0.30	0.42	0.40	0.30	2.74	2.62
Very weak	0.10	-	-	0.10	-	-
Total	1.14	104.46	100.00	0.61	104.46	100.00

The works conducted in the period from 1956 to 1980 mostly included biotechnical and biological structures as well as the construction of several dams in the riverbed. The catchment area had 457,747.0 m' of retention structures built (bench terraces, terraces, wattling, horizontal walls, *etc*.).

Table 8. *The planned and performed works of afforestation of the Žukovska River catchment*
Табела 8. Изведени и предвиђени радови на пошумљавању слива Жуковске реке

Watercourse	Performed	Planned	Species	Afforestation technique
	(ha)			
Aldinačka reka	150,00	150,00	Austrian pine	Bench terraces
Balinačka reka	1.610,00	1.610,00	Austrian pine	Terraces
Pričevska reka	600,00	819,00	Scots pine, locust	Terraces; Pit planting
Dejanovačka reka	300,00	400,00	Aus. pine, locust	Dry stone dams; wattlework in gullies
Drvnička reka	1.000,00	1.000,00	Aus. pine, locust	Bench terraces; dry stone walls and wattlework
Vitonjska reka	2.000,00	2.000,00	Austrian pine	Terraces (on steeper slopes with wattlework)
Kragujevački potok	1.650,00	1.650,00	Austrian pine;	Ditches, Terraces, dry stone walls, wattlework
Leva reka	500,00	1.000,00	Aus. pine, locust	Bench terraces
Kosmatica	47,91	147,91	Austrian pine	Terraces
Šipkova reka	105,00	1.105,00	Austrian pine	Terraces

Source: (2009a, 2009b)

Biological works were carried out on the slopes of the basin in order to check erosion or to reduce its intensity, to achieve a certain volume of plant production and finally to preserve and improve the environment. In other words, technical works carried out in the hydrographic network of watercourses can solve acute problems, while biological works permanently solve the problem of erosion on the slopes of a basin. The establishment of a vegetation cover creates unfavourable conditions for the development of erosion processes (Kostadinov *et al*., 2018).

Conclusions

The study of the anthropogenic effects in the observed period can explain both the favorable and the unfavorable human activity in the catchment area. The high density of population and livestock, inadequate land use on the slopes, conversion of forest into agricultural land, disruption of the protective function of vegetation and soil structure in the fifties of the twentieth century maximized the development of erosion processes. The works conducted in the period from 1956 to 1980 mostly included biotechnical and biological structures as well as the construction of several dams in the riverbed. Around 75% of the bare land was afforested which halted further development of erosion.

The basic demographic processes in the rural area of the Žukovska River catchment are characterized by a steady population reduction and a decline in the number of households and household members. All the villages have been affected by the population aging. Consequently, the farmland at higher altitudes has been abandoned, the livestock reduced and large areas of the catchment have had the vegetation spontaneously regenerated. Together with previously performed erosion control works, these processes have reduced the erosion and lessened its impact.

However, a considerable part of the catchment plantations was threatened by ice-breaks in 2014. Inadequate rehabilitation of these areas (removal of damaged trees without new afforestation) will create conditions suitable for the occurrence of erosion processes, which often characterized this area in the past.

Figure 7: *Austrian pine plantations damaged by ice-breaks in 2014*

Слика 7: Културе црног бора оштећене ледоломима 2014. године

Photo: Braunović S. (2016)

Figure 8: *Erosion processes in Austrian pine plantations in 2016*

Слика 8: Процеси ерозије у културама црног бора 2016. године

Photo: Ratknić M. (2016)

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АНТРОПОГЕНИ УТИЦАЈИ У СЛИВУ ЖУКОВСКЕ РЕКЕ

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Резиме: Природне карактеристике анализираног слива повољне су за развој ерозионих процеса. Терен је претежно ниско планински, са падинама просечног нагиба 30% и распоном надморске висине од 246 до 1000 m. Геолошку подлогу изграђују условно еродибилне и веома еродибилне стене, а највећу површину слива покрива смеђе земљиште плитко (53,97 %). Према подацима из 1955. године голети су заузимале 33.25%, шуме 29,25%, а пољопривредне површине 21,90 %. У сливу је 2016. године проценат површина под шумом повећан за 19,97% (у односу на 1955 годину), а учешће голети је смањено са 33,25 % на 1,74 % површине слива. Услед демографског пражњења делова подручја присутно је напуштање обраде ораничних површина, њихово закоровљавање или претварање у пашњаке. Број становника се од 1948. до 2011. године смањио приближно 17 пута. Највеће смањење броја становника је у катастарским општинама изнад 500 метара надморске висине. Густина насељености је у анализираном периоду опала са 44,9 становника/km^2 на 3,74 становника/km^2. У сливу су 1955. године доминирали процеси ексцесивне ерозије (77,28 % површине слива), а средњи коефицијент ерозије износио је Zcp=1,14. Према резултатима из 2016. године доминирају процеси осредње ерозије (78,50%). Површине под ексцесивном ерозијом драстично су смањене (за 97,14%), а средња вредност коефицијента ерозије износила је Zcp = 0,61. У периоду од 1956. до 1980. године пошумљено је око 75 % површина голети у сливу. Управо подизањем култура човек је санирао изразито јаку ерозију и успорио даљи развој ерозионих процеса. Последице штета изазваних ледоломима 2014. године у културама за заштиту од ерозије и њихово неадекватно санирање омогућавају развој жаришта ерозије и враћање на стање карактеристично за прошлост овог подручја. Анализа антропогеног утицаја у сливу Жуковске реке објашњава директну зависност промена интензитета ерозионих процеса и активности човека, значај и неопходност спровођења адекватних противерозионих радова и њиховог одржавања.

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