Geomorphic response of streams to neotectonic deformation in low relief areas: case study of Bilogora Mt. (NE Croatia)

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Understanding about tectonic and surface processes which control topography and development of landscape features represents the core for many quantitative morphotectonic investigations using nowadays widely available digital elevation models (DEMs).

This work is aimed to identify areas with neotectonic deformation signature in Bilogora Mt. area by means of DEM based morphometric analysis combined with geological, geophysical and seismotectonic data (Prelogović & Velić, 1988 & Herak et al., 2009).

Bilogora Mt. (average elevation <300 m) represents c. 90 km long and 10 km wide hilly terrain along the southwestern margin of the Drava River basin in northern Croatia. According to recent studies it formed due to transpression along the Drava basin boundary fault system that was inverted from previously normal into predominantly dextral sense of slip during Pliocene and Quaternary times (e.g. Prelogović et al., 1998). Bilogora Mt. is composed of deformed Neogene and Quaternary clastic series highly variable in thickness, covering pre-Neogene basement units (e.g. Prelogović & Velić, 1988). Database on historical seismicity reports rare occurrences of moderate earthquakes with intensity of VI°-VIII° MCS concentrated in the northwestern part of the area, close to towns of Koprivnica and Virovitica (Herak et al., 2009).

In order to analyze a potential geomorphic response of streams to on-going tectonic activity we employed a DEM raster with cell resolution of 10 m modeled according to procedure described in Matoš et al. (2012). Study area was truncated into 130 drainage units *(Figure 1, Table 1)*, each unit was analyzed by computing its morphometric parameters that include:

hypsometric integral-***Hi***, absolute asymmetry factor-***AF(abs)*** and statistical parameters of longitudinal stream profiles *(Figure 2, Table 1)*, i.e. maximal concavity-C_{max}, distance from the source-$\Delta I/L$ and concavity factor-C_f.

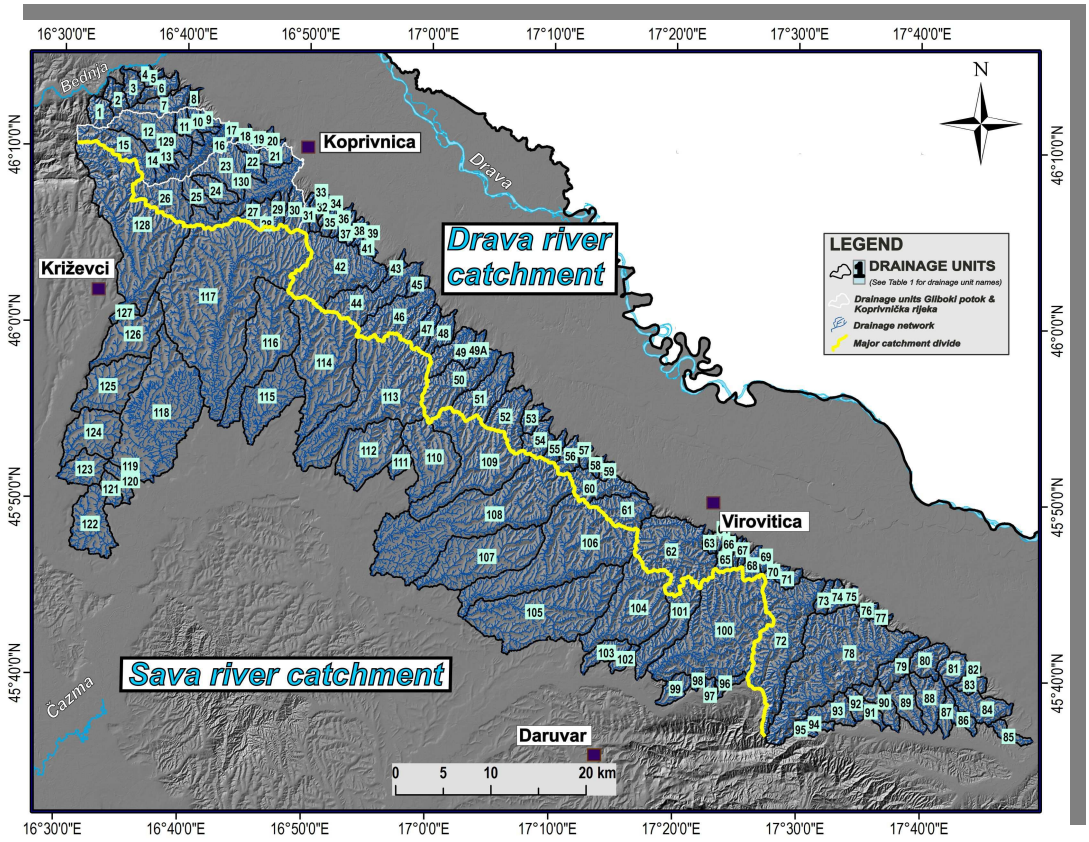

Figure 1: DEM hillshade of Bilogora Mt. area with analyzed drainage units.

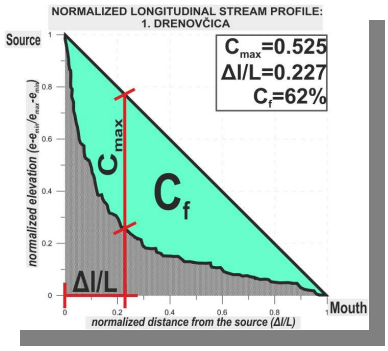

Figure 2: Normalized longitudinal stream profile with statistical parameters.

Calculated ***Hi*** values range between 0.12-0.55 *(Table 1)* and shows that most catchments in a young stage of landscape evolution with highest values of $H_i \geq 0.50$ are recorded in NW and central part of Bilogora Mt. *(catchments No. 5, 8, 16-17, 19, 27-32, 34-39, 41, 43, 45-47)*, while in SW and SE part only three catchments *(No. 97, 98 and 119) obtained the same value.* Extrapolation of ***AF(abs)*** was addressed to recognition of

possible active tectonic block tilting. Very high values of Af(abs)≥0.25 pointed out to several catchments in NW part *(No. 11-12, 23, 37, 122 and 128),* central part *(No. 54, 106 and 109)* and SE part (No. *81,* 87 and 99) of Bilogora Mt. Finally, parameters C_{max}, $\Delta l/L$ and C_f have been used to identify on-going tectonic warping of main streams. Obtained values of $C_f \leq 32.16\%$ and $C_{max} \leq 0.265$ positioned ($\Delta l/L$) in upper reach of streams suggests that those streams *(No. 4, 8, 14, 19, 27-30, 32, 36-40, 43-44, 46-47, 49A, 56, 97-98)* are less graded and in non-equilibrium state, probably as a result of on-going tectonic deformation. Based on obtained values of geomorphic indices (including slope and elevation data), combined and correlated with results of previous studies we conclude that catchments in NW part *(No. 4-5, 7-8, 17-19, 29-32, 36-39 and 41)*, in central part *(No. 44-49, 52 and 56)*, and in SE part of Bilogora Mt. *(No. 89, 95, 97-99)* correspond to areas of possibly on-going tectonic deformation that is reflected in a present-day landscape geomorphology.

No.	Drainage unit	Hi	Af (abs)	Cmax	Δl/L	Cf (%)	No.	Drainage unit	Hi	Af (abs)	Cmax	Δl/L	Cf (%)
1	Drenovčica	0,38	10,82	0,525	0,227	62,00	66	Katinac	0,35	6,19	0,421	0,168	48,57
2	Slanje	0,43	5,62	0,457	0,191	55,60	67	Travni potok	0,35	4,50	0,500	0,095	51,72
3	Tinavčice	0,39	8,50	0,354	0,322	43,40	68	Dabrovica	0,38	6,29	0,558	0,141	64,15
4	Vinogradi	0,44	10,00	0,247	0,449	28,20	69	Borova	0,41	11,01	0,393	0,246	42,59
5	Vinogradi Ludbreški	0,50	17,25	0,326	0,155	40,40	70	Bukova	0,40	7,29	0,466	0,159	53,75
6	Črnoglavec	0,42	0,43	0,333	0,244	43,40	71	Bukovi jarak	0,43	6,85	0,463	0,160	56,31
7	Šegovina	0,47	13,56	0,269	0,428	34,44	72	Brežnica	0,13	19,07	0,611	0,261	71,90
8	Bolfan	0,55	4,84	0,208	0,277	25,01	73	Žubrica	0,35	3,24	0,522	0,195	60,13
9	Rasinja	0,36	1,60	0,403	0,165	44,73	74	Budanica	0,37	1,79	0,433	0,253	52,59
10	Cesarova jama	0,35	12,60	0,395	0,235	43,70	75	Cabuna	0,46	2,38	0,472	0,183	51,39
11	Crna Rijeka	0,44	30,03	0,386	0,319	43,76	76	Bistrica	0,43	7,09	0,408	0,207	47,44
12	Medenjak	0,39	30,54	0,362	0,165	45,59	77	Markovac	0,40	15,10	0,354	0,260	41,66
13	Ciganski potok	0,48	16,79	0,262	0,352	33,85	78	Čađavica	0,12	12,76	0,605	0,203	75,89
14	Veliki poganac	0,48	7,24	0,170	0,291	18,56	79	Lukavčić	0,34	3,40	0,496	0,146	57,28
15	Gliboki potok	0,33	5,51	0,417	0,277	52,08	80	Jova rijeka	0,37	11,15	0,585	0,204	65,62
16	Martinčec	0,50	9,38	0,452	0,102	45,27	81	Grabovac	0,34	30,31	0,514	0,149	60,13
17	Kostanjevac	0,51	7,61	0,307	0,084	36,37	82	Kozički potok	0,40	10,58	0,364	0,226	40,88
18	Subotica Podravska	0,46	3,13	0,289	0,348	32,40	83	Vodenička	0,36	17,94	0,475	0,231	59,24
19	Drakšin	0,51	3,63	0,264	0,473	30,59	84	Branica	0,33	15,63	0,410	0,131	49,85
20	Zvirišće	0,41	4,21	0,396	0,314	42,91	85	Mikleuš	0,42	0,00	0,430	0,304	52,50
21	Prespa	0,35	18,44	0,437	0,266	51,06	86	Radusnovac	0,45	13,62	0,330	0,231	44,20
22	Mučnjak	0,37	11,34	0,303	0,557	40,12	87	Ljeskovački potok	0,38	26,10	0,271	0,183	37,30
23	Velika Mučna	0,47	38,07	0,291	0,317	37,52	88	Konik	0,42	3,67	0,451	0,083	55,92
24	Kraljevac	0,38	23,41	0,329	0,275	39,88	89	Duboki potok	0,45	22,01	0,368	0,185	44,84
25	Dubrava	0,39	2,68	0,369	0,259	43,42	90	Martin potok	0,43	0,81	0,437	0,155	49,04
26	Koprivnička rijeka	0,37	18,11	0,499	0,126	59,56	91	Macute	0,49	1,08	0,305	0,201	30,59
27	Rojanov jarak	0,53	3,85	0,179	0,277	22,32	92	Šermečanci	0,43	7,44	0,471	0,148	54,89
28	Srnski potok	0,52	4,09	0,229	0,342	27,53	93	Lisičina	0,32	11,77	0,514	0,151	61,00
29	Kamenica	0,54	6,34	0,237	0,348	31,51	94	Pasjak	0,32	6,39	0,449	0,319	50,21
30	Jagniedovac	0,53	9,76	0,252	0,273	29,37	95	Rakovac	0,48	0,00	0,262	0,275	32,36
31	Draganovac	0,50	16,24	0,241	0,331	32,31	96	Lipovac	0,41	4,55	0,280	0,306	32,78
32	Petrov Dol	0,52	6,54	0,238	0,277	30,55	97	Dujakovac	0,54	20,97	0,122	0,750	11,55
33	Ivanačka	0,45	2,82	0,307	0,311	35,17	98	Selnički potok	0,55	2,43	0,147	0,377	16,51
34	Bakovčica	0,53	0,00	0,271	0,280	33,61	99	Krivaja	0,46	27,64	0,277	0,484	32,16
35	Ridina Barica	0,50	1,62	0,333	0,155	40,37	100	Ilova	0,34	7,38	0,553	0,096	63,47
36	Jaružnica	0,50	20,35	0,187	0,404	24,35	101	Rastovac	0,41	15,91	0,439	0,207	51,66
37	Borovljanski potok	0,53	25,57	0,180	0,097	23,17	102	Ivanovo	0,46	3,65	0,444	0,172	53,06
38	Brzava	0,52	8,63	0,131	0,469	15,75	103	Rašenički potok	0,46	19,20	0,411	0,222	53,34
39	Vlaislav	0,53	8,42	0,165	0,452	21,61	104	Peratovica	0,40	18,19	0,461	0,134	55,32
40	Plavšinac	0,48	7,63	0,265	0,199	31,12	105	Barna	0,32	10,45	0,490	0,128	58,78
41	Prkos	0,52	13,29	0,290	0,122	31,38	106	Grdevica	0,35	32,33	0,471	0,104	58,44

42	Komarnica	0,37	6,53	0,459	0,216	52,71	107	Kovačica	0,33	19,39	0,471	0,238	60,01
43	Novigrad Podravski	0,53	7,56	0,172	0,306	20,87	108	Račačka	0,25	4,29	0,543	0,060	66,13
44	Zdelja	0,48	6,49	0,233	0,096	25,45	109	Bedenička	0,31	36,58	0,545	0,097	67,21
45	Podgorice	0,52	9,66	0,328	0,349	33,19	110	Severinska	0,30	4,46	0,523	0,145	65,23
46	Hotova	0,50	16,42	0,147	0,186	16,22	111	Gaj	0,29	3,92	0,281	0,428	39,27
47	Sv. Anski jarak	0,50	8,91	0,264	0,119	30,39	112	Tomaška	0,30	2,27	0,437	0,227	56,55
48	Tumarski potok	0,49	14,84	0,289	0,068	33,58	113	Bjelovačka	0,36	1,24	0,486	0,197	58,20
49	Barna potok	0,48	11,51	0,277	0,066	23,54	114	Plavnica	0,31	2,34	0,565	0,126	67,41
49A	Budrovac	0,45	3,04	0,186	0,165	19,90	115	Bokana	0,34	5,04	0,422	0,312	52,61
50	Sirova Katalena	0,48	3,99	0,332	0,211	40,50	116	Konjska rijeka	0,30	2,72	0,547	0,145	64,41
51	Suha Katalena	0,45	13,65	0,410	0,120	45,04	117	Velika rijeka	0,26	18,78	0,570	0,157	68,24
52	Kozarevac	0,41	22,08	0,391	0,090	46,60	118	Dunjara	0,25	3,19	0,477	0,210	60,47
53	Lepo Vrelo	0,34	20,43	0,353	0,324	42,91	119	Smrdenec	0,55	5,12	0,288	0,244	33,25
54	Rijeka	0,36	25,46	0,531	0,156	61,42	120	Kučara	0,49	4,30	0,333	0,228	38,98
55	Velika Črešnjevica	0,38	0,44	0,396	0,249	46,37	121	Podlužan	0,48	0,42	0,316	0,241	40,07
56	Josina rijeka	0,39	6,18	0,239	0,185	24,10	122	Dragićevci	0,41	26,06	0,416	0,180	51,23
57	Konački jarak	0,40	9,53	0,300	0,281	35,05	123	Ladina	0,39	13,79	0,412	0,319	51,83
58	Vukosavljevica	0,49	17,05	0,265	0,232	34,05	124	Koritna	0,39	22,32	0,365	0,227	43,74
59	Drobnašica	0,43	5,65	0,353	0,237	39,64	125	Lubenica	0,40	17,48	0,417	0,224	50,20
60	Lužnjak	0,39	0,85	0,438	0,079	52,56	126	Prašnica	0,34	14,67	0,430	0,202	53,38
61	Lendava	0,35	14,19	0,435	0,229	50,43	127	Rečica	0,44	11,80	0,329	0,344	42,62
62	Odenica	0,38	14,51	0,609	0,129	67,79	128	Glogovnica	0,21	25,42	0,580	0,130	72,09
63	Bošnjakuša	0,42	3,64	0,305	0,113	36,10	129	Gliboki (area)	0,26	22,56	0,463	0,201	57,53
64	Čavina jama	0,45	2,90	0,338	0,228	39,11	130	Koprivnička (area)	0,44	19,10	0,355	0,132	38,17
65	Novi Rezanovac	0,38	4,90	0,512	0,186	58,81		mean value	0,41	10,96	0,37	0,23	44,50

Table 1: Drainage units with calculated and highlighted anomalous values of morphometric parameters referring to possible on-going tectonic active areas.

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