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Stream Channel Characterization Vjosa River – a unique natural river

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Geomorphic and geomorphologic studies, according to ROSGEN classification system, were conducted in the Vjosa River, one of the biggest rivers in Albania and considered to be Europe's last wild river. The ROSGEN classification system is commonly used in the USA and this study represents the first attempt to classify the natural rivers in Albania. This classification system provides a key in classifying natural rivers using six morphological measurements, such as the entrenchment, the width/depth ratio, the sinuosity, the number of channels, the longitudinal slope, and the bed material particle size. Based on broad descriptions of longitudinal profiles, valley and channel cross-section and plan view patterns, the different reaches of Vjosa River are classified (Level I of ROSGEN classification system) and related descriptions are given. Further geomorphological (Level II of ROSGEN classification system) studies were conducted in fifteen benchmarked stream channel reference – sites situated in Vjosa River and its main tributaries like Drinos, Kardhiqi, Bënça and Shushica. Morphological descriptions and stream type delineation as well as the sensitivity to disturbance, the recovery potential, the sediment supply and stream bank erosion are described in detail. In general the morphological characteristics and behavior of Vjosa River match with those indicated by ROSGEN system, however some mismatches are found, especially regarding the streambank erosion potential. Limited data and experience make it harder for a conclusive opinion regarding the application of the ROSGEN system in the study of reaches in Albania.

Daja S., Xhemalaj X., Lipo S. & Ago B., 2018: Zur Charakterisierung des Flussbettes der Vjosa – ein einmalig naturnahes Fluss-System.
Die Arbeit berichtet über geomorphologische Studien an der Vjosa unter Bezugnahme auf die ROSGEN-Klassifikation. Diese Klassifikationsschema basiert auf sechs morphologischen Messungen: Flußeintiefung , Breiten/Tiefen-Verhältnis des Flusses, seiner Sinuosität, der Zahl von Flußarmen, dem Geländegefälle, sowie der Korngröße des Substrates.
Nach diesen Messungen wird eine Grobklassifikation (Level I des Klassifikationsschemas) der verschiedenen Flußabschnitte vorgenommen. Detailliertere morphologische Beschreibungen (Level II) beziehen sich auf 15 Referenzstrecken an der Vjosa und ihren wesentlichen Zuflüssen, Drinos, Kardhiqi, Bënça and Shushica. Sie bewerten die Störungsanfälligkeit durch Hochwässer, die Sedimenttransport-Verhältnisse sowie das Ufer-Erosionspotential.

Keywords: ROSGEN, stream classification, Vjosa River, Albania.

Introduction

Systems for classifying channels can be traced as far back as 1900. Since then, a number of more detailed geomorphic classifications were proposed for large alluvial rivers. Leopold & Wolman (1957) describe the streams as straight, meandering and braided. Montgomery & Buffington (1997) defined three stream types as follow: step-pool, plane-bed, and pool-riffle channels. Other studies have used different characteristics to classify the streams (Khan 1971; Schumm 1977; Lotspeich 1980; Lotspeich & Platts 1982; Whiting & Bradley 1993, Rosgen 1994 and 1996).

The ROSGEN stream classification system provides a key to classify natural rivers based on descriptive and measurable morphological features. This classification key represents a

sequential process for river classification and is based on the notion that the most effective classification system is one based on objective, quantifiable criteria that are readily observable and measurable in the field (Rosgen 1994).

ROSGEN stream classification system describes a four-level hierarchy of river inventory and assessment as follows: Geomorphic Characterization (Level I), Morphological Description (Level II); Assessment of stream's condition (Level III) and the Validation (Level IV). Each level use the information derived from the previous level.

In the **Level I**, the Rosgen's system delineates eight primary generalized categories of "stream types" denoted by capital letters A, B, C, D, DA, E, F and G. These categories are based on broad descriptions of longitudinal profiles, valley and channel cross-section and plan view patterns. In the **Level II**, the eight primary categories are further divided into secondary stream types (42 major and 94 total stream types) based on the water surface slope and channel material. The third and the fourth levels involve respectively the stream condition assessment and the validation.

Although it is widely used in the western part of the United States, this system has become subject to various criticisms. Roper et al., 2008 using three different monitoring groups concluded that the estimation of the measured field parameters is operator-dependent. Problems are encountered in the evaluation of entrenchment ratio due to discrepancies in determination of the maximum bankfull depth, leading to potentially large differences in determination of Rosgen's flood-prone width.

The ROSGEN System was applied in the study of the behaviour of the River Vjosa as the only natural river in Albania. The main purpose was the description of its characteristics based on the ROSGEN classification system.

Case study and methodology

The Vjosa watershed is partially located in northwestern Greece and partly in the southern part of Albania, having an elongated shape with a SE-NW direction. The area of the watershed is about 6710 km^2 (Albanian Academy of Sciences 1984) of which 4365 km^2 are included within the territory of Albania. The average elevation of the watershed is about 855 m. The elevation decreases gradually from 1235 m a.s.l. (the upper part) to the Adriatic Sea. The average watershed slope is almost constant from 0.27 % to 0.29 % . Vjosa River is one of the main rivers of Albania. It originates from springs within the Pindos Mountains (Greece) and enters the Albanian territory at Mesareja. The length of Vjosa River in Albania is about 272 km.

Geomorphic Characterization of Vjosa River – (Level I)

Generalized categories of stream types were initially delineated using broad descriptions of longitudinal profiles, valley and channel cross-sections, and plan-view patterns inferred from topographic maps at 1:25000 scale. The parameters used in this level of classification are as follow:

- The plan-view patterns expressed in terms of sinuosity along the river. The sinuosity is calculated as the ratio of stream length in a reach stream to the corresponding valley length.

- The longitudinal profiles expressed in terms of inclination or slope determined as the difference of water surface level per unit stream length.
- Width/depth ratio was estimated on selected sectors (reaches), where the valid data were available in the 1:25000 topographic maps. It should be mentioned that the width/depth ratio defined at this level it is not quite to the Rosgen's width/depth ratio. It is a ratio calculated from topographic map data.

The results of the geomorphic characterization of different stream reaches of Vjosa River are shown in the Table 1 and in the Figure 1.

Tab.1: Stream type of different reaches of Vjosa River and its tributaries. – Tab. 1: Flußtypen der verschiedenen Abschnitte der Vjosa und ihrer Zubringer.

Nr	Steam reach (from-to)	W/D	S	I	TIPI
1	Greek border - Petran	>12	1.1	0.003	F or G
2	Petran - Kelcyre	>12	1.16	0.003	F
3	Kelcyre - Dragot	<12	1.04	0.0026	G
4	Dragot - Memaliaj	>40	1.25	0.0019	D
5	Memaliaj - Dorez	<40	1.17	0.002	DA
6	Dorez - Kalivac	>12	1.04	0.0026	B
7	Kalivac - Pocem	>40	1.5	0.0026	D
8	Pocem - Shushice	>40	1.2	0.0015	D
9	Shushice - Mifol	>12	>1.5	0.0004	C
10	Mifol – Adriatic Sea	>12	1.5	0.00004	C
11	Kardhiqi River	>12	1.2	0.005	F
12	Drino River	>12	1.04	0.003	B or C
13	Benca River	<12	1.02	0.0129	G
14	Shushica River (Gjorm – Drashovice)	<12	>1.2	0.003	G
15	Shushica River (Drashovice – Vjose)	>40	1.14	0.003	D

Geomorphologic characterization of different reach streams of Vjosa River – (Level II)

This characterization has been done in stream reference-sites for each of the selected reaches defined in Level I. These sites were established in Vjosa River and its tributaries such as Shushica, Kardhiqi, Bença and Drinos. A total of fifteen reference-sites were selected from Vllaho – Psillotera to Mifoli Bridge, including four reference-sites in Vjosa tributaries. Their locations are shown in Figure 1.

The stream channel reference-sites were selected according to the followings criteria:

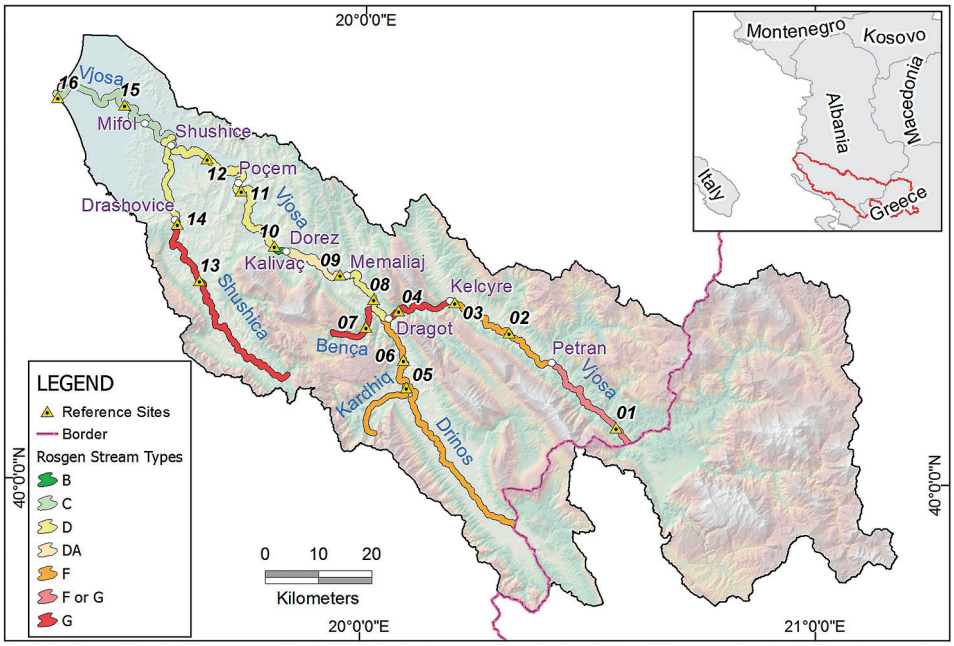

Fig. 1: Geomorphic characterization and reference sites location for Vjosa River and its tributaries. – Abb. 1: Geomorphologische Charakterisierung der Vjosa und ihrer Nebenflüsse. Die Lage der Referenzstrecken ist eingezeichnet.

- Lithological criteria – The reference sites are located in such positions as to represent all kinds of rocks along the Albanian part of Vjosa valley,
- The morphological characteristics of the stream channel – the reference-site positions – are determined in order to cover all types of the stream channels defined in the First Level of classification, located in the upstream, midstream and the downstream of the river. Similar observation reference-sites have been located in the main confluents of Vjosa, such as Shushica, Kardhiqi, Bença and Drinos.
- Measurement facilities; a location near the hanging bridges has been used to facilitate the passage on both sides of the river.

In each permanent reference-site, two survey monuments and one benchmark were established in suitable measurement locations. The determination of the coordinates and elevation for survey monuments and benchmarks was performed with GPS measurements, based on the geodetic reference points of state network. Control measurements with total station are carried out in order to find the best fit between the reference points of the state network and the GPS measurements.

Multiple cross-sections surveys, longitudinal profile of the channel and measure of the bed material, were performed. The bars, pools, riffles, cut bank and other features of the terrain like the position of the terraces in both sides of the channel and bankfull points are mapped for each reference site. An example of a Site Map, referring to V-11 is given in the Figure 2.

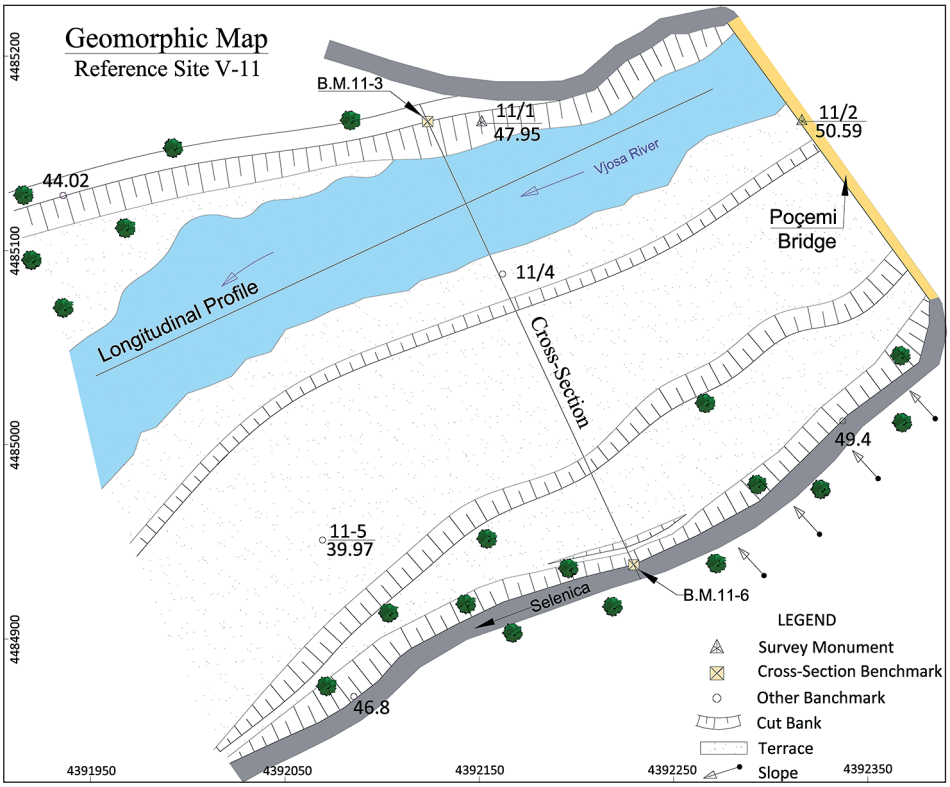

Fig. 2: Site Map of the V-11 reference site (Poçem). – Abb. 2: Das Gebiet der V-11 Referenzstrecke bei Poçem.

The bankfull stage (Fig. 3) is defined as the water discharged when stream water just begins to overflow into the active floodplain (Harrelson et al. 1994). In areas where the floodplain is absent one or more of the bankfull stage indicators are used as proposed by C.C. Harrelson et al, 1994 as follows: the height of depositional features (especially the top of the pointbar, which defines the lowest possible level for bankfull stage); changes in vegetation (especially the lower limit of perennial species); slope or topographic breaks along the bank; changes in the particle size of bank material, such as the boundary between coarse cobble or gravel with fine-grained sand or silt; undercuts in the bank, which usually reach an interior elevation slightly below bankfull stage; and stain lines or the lower extent of lichens on boulders.

In order to classify the selected sites the following parameters are determined for each of them.

- **Entrenchment ratio (E)** – is the ratio of the width of the flood-prone area to the bankfull surface width of the channel. The flood-prone area is defined as the width measured at an elevation which is determined at twice the maximum bankfull depth. The bankfull depth corresponds to the average depth measured at the bankfull discharge (Fig. 3).

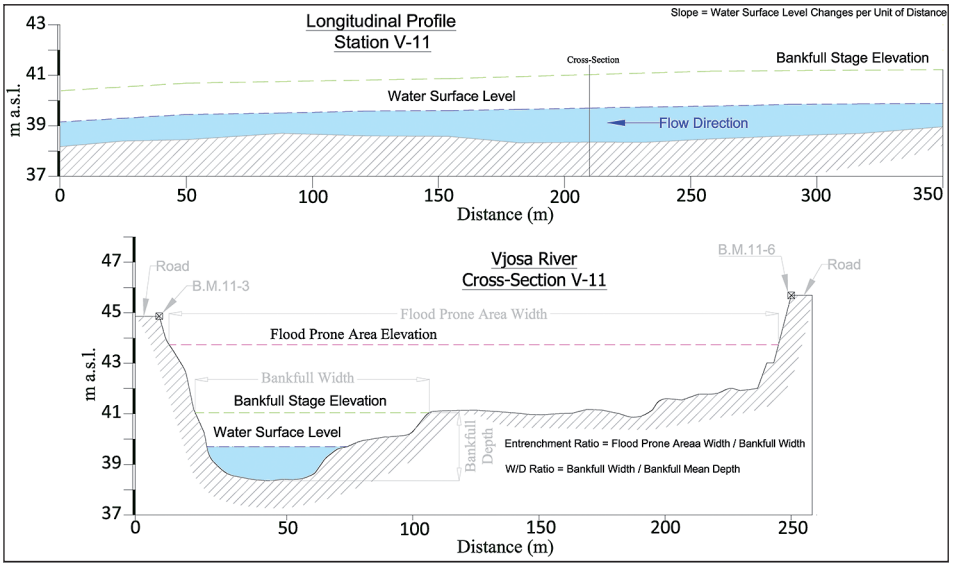

Fig. 3: Longitudinal profile and Cross-Section of V-11 reference site. – Abb. 3: Längs- und Querprofile der V-11 Referenzstrecke.

- **Width/depth ratio (W/D)** – Is the ratio of bankfull channel width to the bankfull mean depth (Fig. 3).
- **Sinuosity (S)** is the ratio of stream length to valley length or the ratio of valley slope to channel slope.
- **Water surface slope (I)** is determined by measuring the difference in water surface elevation per unit stream length (Fig. 3).
- **Channel materials (M)** – The dominant particle size (D_{50}) corresponding to the size of 50% of the population in a cumulative percentage curve is defined. Field determination of channel materials were conducted utilizing the "pebble count" procedure developed by Wolman (1954), with a few modifications to account for bank material and for sand and smaller sizes. Related to the median particle size of the bed material, numbers are given to the stream types as follow: 1 for bedrock, 2 for boulders, 3 for cobbles, 4 for gravel, 5 for sand and 6 for clay and silts (Rosgen 1994).

The results of geomorphologic classification of the selected sites (Level II od ROSGEN System) are summarized in the Table 2.

Stream conditions assessment

The Vjosa River enters the Albanian territory as a formed river, with relatively low gradients, a high width/depth ratio and low sinuosity. These characteristics extend from the border between Greece and Albania to the Këlcyra Gorge. In this sector the stream is classified as F – stream type (Fig. 1), characterized low sinuosity (meandering) shallow but entrenched gentle gradient channel, with limited or absence of the floodplain. Riffle-pool sequences occur.

Tab. 2: Stream type of the references sites for Vjosa River and its tributaries. – Tab. 2: Flußtypen der Referenzstrecken der Vjosa und ihrer Zubringer.

Geographic location	Ref. Site	E	W/D	S	I	M	Rosgen Stream Type
Vllaho-Psillot.	V- 01	1.43	15.7	1.1	0.0014	C	F3
Bual	V- 02	1.19	27	1.15	0.0019	C	F3
Kelcyre	V- 03	1.19	28.9	1.1	0.0019	G	F4
Dragot	V- 04	1.6	38.6	1.1	0.0038	G	B4c
Palokaster	V- 05	1.1	41.2	1.04	0.007	G	F4
Ura e Subashit	V- 06	1.01	33.6	1.04	0.0027	G	F4
Bence	V- 07	1.35	32.6	1.02	0.006	G	F4
Tepelene	V- 08	1.43	80.3	1.2	0.0026	G	D4
Vasjar	V- 09	1.75	95.4	1.17	0.0021	G	D4
Kalivac	V- 10	1.53	49.4	1.5	0.0013	G	B4c
Pocem	V- 11	2.6	34.5	1.5	0.0002	G	C4c
Romes	V- 12	-	103.1	1.2	0.0004	G	D4
Ura e Gjormit (Shushica River)	V- 13	4.05	14	>1.2	0.0038	G	C4
Drashovice (Shushica River)	V- 14	2.4	91.8	1.14	0.004	G	D4
Ura e Mifolit	V- 15	>2.2	38.4	1.5	0.00001	S	C5c

Through Këlcyra Gorge the reach is classified as G – stream type according to ROSGEN classification, characterized by low sinuosity well entrenched and low width/depth ratio steep/pool ("gullies") channel.

The reference-sites included in this reach (segment) are classified as F3 – stream type (V-01 and V-02) and are characterized by moderate sensitivity to disturbance, poor recovery potential and very high sediment supply and streambank erosion potential. The same characteristics are attributed to the stream type F4 (V – 03) with difference in the sensitivity to disturbance which is extreme in this case as well as reference sites V-05 and V-06 situated in the tributaries of Kardhiqi and Drinos.

The segment from Dragot to the confluence of the Shushica River is represented by complex stream patterns and multiple channels, braided (D) and anastomosed (DA), with the exception of the sector from Dorëz to Kalivaç where, due to the passage into a narrow gorge through carbonate deposits, the river sinuosity decreases. The stream reference sites encountered in this reach of the river are V-04, V-08, V-09, V-10, V-11 and V-12. The sites V-08, V-09 and V-12 are classified as D4-stream type and are characterized by very high sensitivity to disturbance, with poor recovery potential, with very high sediment supply and streambank erosion potential, having a moderate vegetation controlling influence. The same characteristics are attributed to the lower part of Shushica river (reference site V-14, Drashovice).

The sites V-04 and V-10 (Dragot & Kalivaç) are classified as B4c – stream type characterized by moderate gradient and entrenchment ratio as well as by moderate sensitivity to

disturbance, with excellent recovery potential, low streambank erosion potential and moderate vegetation control.

The site of Poçem (V-11), is classified as C4c stream type –meandering, slightly entrenched, with well developed floodplain. This site is characterized by very high sensitivity to disturbance, high sediment supply and very high stream bank erosion potential.

From the Shushica River confluence to the river mouth the sinuosity increases, the slope decreases and a high width/depth ratio is maintained classifying the reach stream as C-type. The reference site of "Ura e Mifolit" (V-15) is classified as C5c – stream type is characterized by very high sensitivity to disturbance, very high sediment supply and very high stream bank erosion potential.

Bënça River and the upper part of Shushica River are classified as G stream type: well entrenched steep/pool channel, characterized by low sinuosity and low width/depth ratio. The corresponding reference sites are V-07 and V-13 and are respectively classified as F4 and C4 stream type. The differences in the stream types are attributed to the local conditions of reference-sites.

Conclusions

The upper part from the Greek border to Kalivaç as well as the main branches of Vjosa Bença, Drinos, Kardhiqi and the upper part of Shushica are in dynamic equilibrium status. In general the Vjosa River and its tributaries are characterized by moderate (in the upper parts) to high and very high sensitivity to disturbance in the rest. The recovery potential is **poor** for the F stream types and D stream types located in the upper parts of the stream reaches and in the sector of Vjosa River from Dragot to the confluence of Shushica River and the lower part of Shushica River. Locally good to excellent recovery potential is encountered in the reference sites V-04, V-10, V-11 and V-13.

The characteristics indicated by Rosegn showed some mismatches with those found in Vjosa River and its tributaries, especially regarding the streambank erosion potential. For the stream types F3 and F4 Rosgen describes a very high streambank erosion potential while in these reaches in Vjosa River and its tributaries, erosion of streambank is not observed because in the upper part of Vjosa River the riverbanks are composed of well-cemented conglomerates showing a high resistance to erosion while the Bënça River passes through carbonate deposits forming narrow and deep gorges.

This study is a first attempt to use the ROSGEN system in the study of the river morphology and river behavior in Albania. Limited data and experience make it harder for a conclusive opinion regarding the application of the ROSGEN system in the study of reaches in Albania.

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