CHARACTERIZING RIVER MORPHOLOGY WITH RS TOOLS IN THE FRAME OF HYDROMORPHOLOGICAL ASSESSMENT: A GREEK CASE STUDY OF PINIOS RIVER, CENTRAL GREECE

CHRONIS IOANNIS, VOUVALIDIS KONSTANTINOS, TOPALOGLOU CHARALAMPOS, DOMAKINIS CHRISTOS, ALBANAKIS KONSTANTINOS

Laboratory of Physical Geography, School of Geology, Aristotle University of Thessaloniki
E-mail: ichronis@auth.gr, vouval@geo.auth.gr

Abstract- This research investigates and assesses the morphological features in the water bodies of the main channel in Pinios river s. Critical mophological information is being analyzed to support hydromorphological assessment of the river basin water bodies in the implementation of River Basin Management Plan in the frame of Water Frame Directive. Sinuosity Index provides important results for the assessment and derives critical conclusions for management of the basin

Index Terms- Hydromorphological Assessment Morphological Features,

I. INTRODUCTION

The management of riverine environment in Europe has reached an important turning-point with the implementation of the Water Framework Directive. The main goals of the WFD require from Member States the assessment of ecological condition of rivers and the achievement or maintaining of good ecological status. In this frame, the hydromorphological assessment of rivers is also required as a pylon for the total classification.

Starting from the beginning of 1980s, several methods and protocols for characterizing and evaluating physical stream conditions that can be defined as 'river habitat survey' or 'physical habitat assessment' were developed, and some attempts have been made to standardize them. As a consequence of the availability of a wide variety of methods, this type of approach has been in most cases identified as the procedure for stream hydromorphological assessment required by the WFD.

Recognition of the importance of geomorphic river conditions is reflected by an increasing effort to develop new methods based on a more sound geomorphological approach and with a stronger consideration of physical processes. The River Styles Framework [1], the MQI [9] are examples of morphological assessment procedures that are based on a geomorphological approach.

Recent advances in Remote Sensing (RS) techniques are transforming the way we look at and analyze river systems and provide a new source of spatially distributed, multi-dimensional information at wider spatial and temporal scales compared to the past. Thanks to RS datasets, hydromorphological indices nowadays can be estimated in a quantitative rather than descriptive way for multiple spatial scales—from reach and sub-reach units up to the entire basin—with continuous information that is more objective and less exposed to operator subjectivity. Monitoring the required data in the frame of the WFD has become a primary obligation over the past years and remote sensing data, with appropriate Geographic Information Analysis can be a powerful tool to provide information for them [11]. A competitive advantage is that satellite remote sensing is being used in monitoring aquatic ecosystems over in-situ field sampling due to the advantages: large-scale, dynamic and low-cost coverage [11].

The central aim of this paper is to investigate morphological indices and other hydromorphological information of the central riverbed of Pinios River and present the morphological situation for the purposes of hydromorphological assessment and consequently the River Basin Management Plan of the area.

II. STUDY AREA

As river Pinios rises in the Pindos mountains in central Greece. Its length is 235 km with a mean slope of 6.92‰ and it drains 11.318 km^2 in the Thessaly basin. Pinios river basin is one of the largest in Greece and drainages a wide area with urban and agricultural activity. In the last 3 years, Greece has lunched the River Basin Management Plans which have fulfilled the delineation of water bodies at national level. In Thessaly Basin District (GR08) [7], the River Basin Management Plan of Pinios contains 15 river water bodies for the central riverbed of Pinios River [5] (Table 1, Figure 1). These 15 water bodies are used for the geomorphological analysis and the calculation of morphological indices. Furthermore, Pinios and Titarissios Rivers are the two main drainage systems of the eastern graben of the Thessaly basin. Titarissios River is a tributary of Pinios River and its channel is located northwards of the Pinios River main channel in the north part of the Larissa plain. Their junction is situated in the NE part

of the plain, just before their entrance in the narrow straits of Rodia valley. Through the Rodia valley and the Tembi valley farther downwards, the fluvial system of Pinios River discharges to the Aegean Sea. Thessaly is an extensive intra-mountainous draft Central Greece, which is bounded on the east by starting off nous tumors Pelagonian and west the mountains of Pindos. This Draught, is not a single geomorphological and it separated to two individuals draughts of the West and Eastern Thessaly [13]. To the east, Tyrnavos-Larissa basin splits hydrologically to two parts. The northern part which is drainaged by the Pinios River and it tributary river of Titarisios and southern part which belongs to the catchment basin of Lake Karla. These two rivers entering from the west to the valley and in the northern part of the basin, through the narrow valley of Kalamaki-Damasiou connect the network of the valley and through the north eastern edge of the basin, continues to Rodia and Tempi drive out to the Aegean Sea [13].

Table 1 Water bodies of main channel of Pinios from RBMP

Id	WATER BODY
1	GR0008000400220670N_A
2	GR0008000400220670N_B
3	GR0008000400220670N_C
4	GR0008000400220580N_A
5	GR0008000400220580N_B
6	GR0008000400220320N_A
7	GR0008000400220320N_B
8	GR0008000400220310N
9	GR0008000400220160A
10	GR0008000400220150H
11	GR0008000400220140N
12	GR0008000400220130N
13	GR0008000400220120N
14	GR0008000400220110N
15	GR0008000400220100N

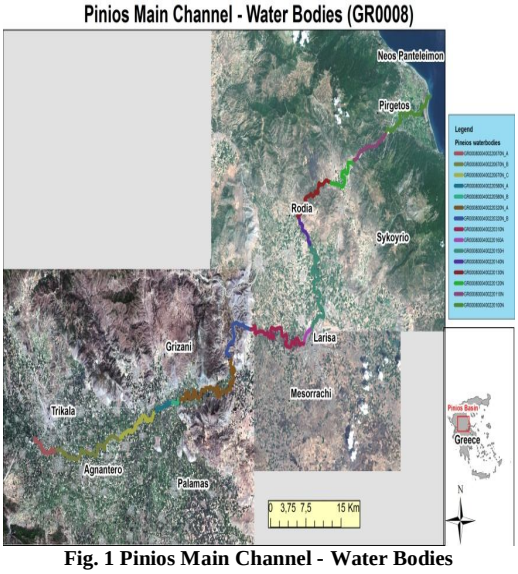


Fig. 1 Pinios Main Channel - Water Bodies

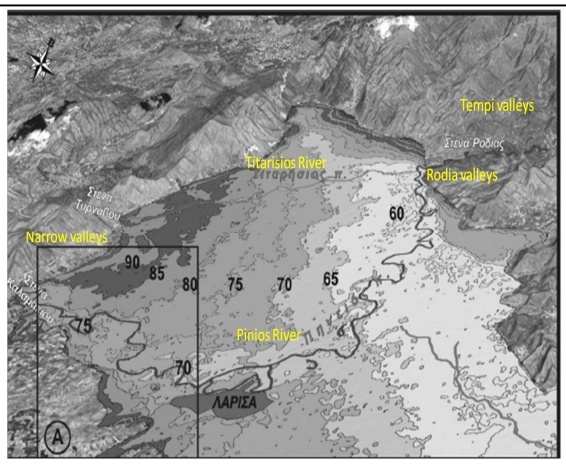


Fig. 2 Geomorpohological Setting of Pinios Basin (Vouvalidis et al, 2006)

III. MATERIALS AND METHODS

Four Sentinel-2 images were selected for the area that covers Pinios River. Pixel depth is 16-bit and images have 10m spatial resolution in visible and in near-infrared channel. The images acquired on 22 July 2016 2 images and 12 August 2016, they are clear from clouds in the study area. In order to represent the low tide of the water in Pinios River, satellite data was chosen to represent the summer period.

The available delineated water bodies according to national report were acquired from national database [6] reporting water bodies in GR08. Fifteen water bodies according to national categorization for the main channel of Pinios River were selected.

The methodology used can be divided in 4 steps. The first step is referred to image analysis. Firstly, satellite images were reprojected in Greek Geodetic Reference System (GGRS ’87). Afterwards, an RGB combination was selected using the infrared channel as a red channel, and a radiometric enhancement was applied in order to distinguish differences in water reflection. Moreover, a new color space was produced from the initial bands and served as input data for mapping the study area. The second step was the delineation of Pinios River. A polyline was digitized along the riverbed. Afterwards, braids were distinguished and were digitized in the riverbeds. Moreover, in each water body was digitized the straight line between the sidewalls of levees in order to calculate, morphological indices. The third methodological step refers to geographical analysis. The polyline which represents the river was divided in smaller polylines at the borders of the water bodies and Sinuosity Index was calculated for each part. Then these segments of the river, which belong to a different water body, were characterized according to indices. Then, with visual inspection each part of the stream which was characterized in the two least categories, was divided in two parts in order to observe the percent of sinuous and meandering.

Finally, the riverbed width was calculated with GIS tools.

Initially four morphorological indices were selected and calculated according to methodology of spatial analysis described before. Those indices are WB Length, Straight Length, Mean WB Width and Meandering Percentage of WB which expresses the percentage of length of WB under constant meandering formation.

In addition, three morphological indices from Hydromorphological assessment [9] [11], were selected and calculated. Sinuosity Index, Braiding Index and Anabranching Index. Sinuosity Index (Si) is defined as the ratio between the distance measured along the (main) channel and the distance measured following the direction of the overall planimenitric course (or meander belt axis for single thread rivers). Braiding index (Bi) is defined as the number of active channels at baseflow separated by bars. Anabranching Index (Ai) is defined as the number of active channels at baseflow seperated by vegetated islands. Based on these parameters, the following six Basic River Typologies [9] of partly confined and unconfined channels are defined (Table 2):

- Single-thread channels: straight, sinuous, meandering
- Transitional channels: wandering
- Multi-thread channels: braided, anabranching.
- Further morphologies, described by the Extended River Typology [9], can be identified during the step 4 and/or during the characterization and assessment stages.

Table 2 Types according to morphologic indices

Typology	Sinuosity Index (Si)	Braiding Index (BI)	Anabrancing Index (AI)
Straight (ST)	1≤Si<1.05	1+1.5 (normally approx. 1)	1+1.5 (normally approx. 1)
Sinuous (S)	1.05≤Si<1.5	1+1.5 (normally approx. 1)	1+1.5 (normally approx. 1)
Meandering (M)	≥ 1.5	1+1.5 (normally approx. 1)	1+1.5 (normally approx. 1)
Wandering (W)	n.a.	1<Bi<1.5	1<Ai<1.5
Braided (B)	n.a.	≥ 1.5	< 1.5
Anabranching (A)	n.a.	1+1.5	≥ 1.5

IV. RESULTS AND DISCUSSION

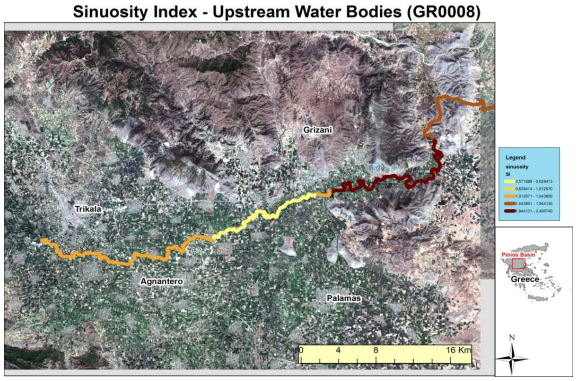
According to spatial analysis morphological indices were calculated and presented in Table 3 and Table 4 according to methodology. Sinuosity index for the fifteen water bodies of the central part of Pinios River is also presented in two maps for upstream & downstream water bodies showing in classification the result.

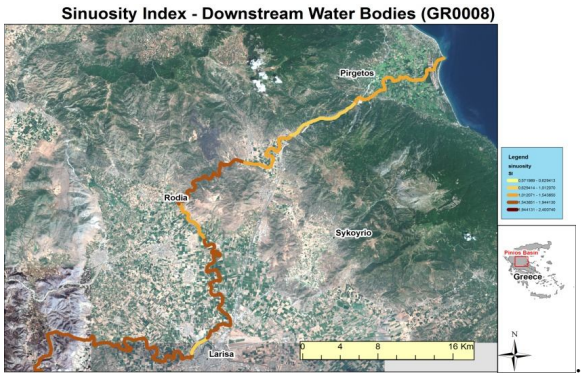
Table 3 Morphological Indices of Pinios WBs

	WB Length	WB Straight Length	Mean WB Width	Meandering % of WB
1	7005,1	4948,8	31,11	**100**
2	18766,4	12708,0	37,88	**93,52**
3	12751,9	12123,2	20,62	-
4	4319,1	4226,0	28,36	-
5	2180,8	1669,2	44,06	**100**
6	24889,4	10367,4	48,99	**100**
7	10121,8	6179,9	47,43	**67,34**
8	20861,3	11207,4	51,47	**25,94**
9	2517,2	2487,1	66,98	-
10	20884,0	10742,1	59,03	**87,07**
11	5242,2	3871,1	58,55	**43,56**
12	12293,4	6958,6	54,56	**81,19**
13	9579,3	6204,8	55,13	**62,90**
14	8153,8	8098,1	66,41	-
15	14058,0	9850,8	66,83	**69,56**

Table 4 Morphological Indices of Hydromorphological Assesmment of Pinios WBs

	Sinuosity Index	Braiding Index	Ana-brancing Index	Typology
1	1,42	1	1	Sinuous
2	1,48	1	1	Sinuous
3	1,05	1	1	Straight
4	1,02	1	1	Straight
5	1,31	1	1	Sinuous
6	2,40	1,04	1	Meandering
7	1,64	1,07	1	Meandering
8	1,86	1,09	1	Meandering
9	1,01	1	1	Straight
10	1,94	1,04	1	Meandering
11	1,35	1	1	Sinuous
12	1,77	1,2	1	Meandering
13	1,54	1,17	1	Meandering
14	1,01	1	1	Straight
15	1,43	1	1	Sinuous





CONCLUSIONS

Critical morphological features of the main channel of Pinios River are calculated and analyzed respectively. According to sinuosity index, the main channel of Pinios River appears to be sinuous to meandering. These channel types correspond to low energy conditions although Pinios River drains a quite large plain with great contribution of other tributaries. The channel morphology of Pinios River, just before the city of Larissa, shows that long channel segments are incised and the tracked changes are not due to its graded profile. The lateral sedimentation of Titarissios River alluvial fan deposits is responsible for the channel displacement of the Pinios River to the lower areas of the valley, creating a meandering channel and low energy flow conditions. The study of the geomorphological evolution of the Pinios and Titarissios drainage systems showed that the straits of the Rodia valley play an important role on the drainage control of the Larissa plain (Eastern Thessaly). The channel incision on an initial meandering drainage network pattern and the simultaneous tectonic uplift of the fault-bounded Rodia block are responsible for the formation of a control point along the main channel of Pinios River. According to SL index and channel slope values, the fluvial system controlling the channel erosion in Rodia valley, and is also in equilibrium with the upstream fluvial processes, is the Titarissios River (Vouvalidis et al, 2006).

This conclusion drives to the point that hydromorphological assessment of the all water bodies in the Pinios River Basin must also combine the hydromorphological assessment of Titarisios River which finally changes the morphological behavior of Pinios River. This step is critical in the implementation of River Basin Management Plans (Chronis et al, 2016) in the area and the final restoration measures that the State will implement to improve both water and habitat quality.

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