QANTITATIVE GEOMORPHOLOGICAL STUDY OF EUROTAS RIVER DRAINAGE NETWORK (GREECE)

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ΠΕΡΙΛΗΨΗ

Η εργασία αυτή αφορά στην ποσοτική γεωμορφολογική μελέτη του υδρογραφικού συστήματος του ποταμού Ευρώτα. Ο Ευρώτας είναι ο κυριότερος ποταμός της Λακωνίας. Πηγάζει από το οροπέδιο της Μαντίνειας (Ασέα). Ρέει προς ΝΑ δια μέσου μιας καλά διαμορφωμένης κοιλάδας που έχει διεύθυνση ΒΔ-ΝΑ και εκβάλλει στο Λακωνικό κόλπο. Η υδρογραφική του λεκάνη περιβάλλεται από υψηλούς ορεινούς όγκους, τον Ταύγετο και τον Πάρνωνα και έχει εμβαδόν 1799,5 km^2.

Το υδρογραφικό δίκτυο είναι έβδομης τάξης, καλά αναπτυγμένο. Η μορφή του υδρογραφικού δικτύου διαφέρει στα διάφορα τμήματα της λεκάνης, γιατί ελέγχεται από τη γεωλογική και τεκτονική δομή του υποβάθρου. Γενικά παρουσιάζει μορφή δενδριτικού τύπου, κυρίως στο βόρειο και βορειοανατολικό τμήμα και υπο-παράλληλο και ορθογώνιο στις άλλες θέσεις.

Η πυκνότητα και συχνότητα του υδρογραφικού δικτύου μεταβάλλεται στις διάφορες θέσεις γιατί επηρεάζεται από ποικίλους παράγοντες, αλλά κυρίως από τη λιθολογία. Μελετήθηκαν και αξιολογήθηκαν επίσης στοιχεία που αφορούν τόσο στην ανάπτυξη των ρευμάτων όσο και στη λεκάνη απορροής και από τα στοιχεία που προέκυψαν εξήχθησαν συμπεράσματα σχετικά με τη δημιουργία και εξέλιξη του υδρογραφικού δικτύου.

ABSTRACT

In this paper the quantitative geomorphical analysis of the drainage network of Eurotas River is presented. Eurotas is the main river of Lakonia. Eurotas springs from the plateau of Mantinea (Asea). It flows to SE through a well developed valley of a NW - SE direction into Lakonikos gulf. Its drainage basin is surrounded by high mountains, Taygetos and Parnon and the total area covers 1799.5 km^2.

The drainage network is of the 7^{th} order and is well developed. Its pattern is dendritic at the northern and northeastern part and rectangular or subparallel at the other parts.

The drainage density and channels frequency is of a high variation as a result of many factors ,the most important of which is lithology. The coefficients of drainage systems and of drainage basins have been studied and results have been reached regarding the creation and the evolution of the drainage network.

INTRODUCTION

Eurotas river springs from the plateau of Mantinia (Asea). It flows to SE through a well developed valley of a NW - SE direction and flows into Lakonikos gulf. Its drainage basin is surrounded by high mountains, Taygetos (2.404 m) and Parnon.(1700 m) The total area of the basin is 1799,5 km^2 and the length of the main branch of the river is 82 km. The age of these rocks ranges generally from Triassic up to Holocene with the exception of Miocene. which is absent from the Peloponnese. The tectonic structure is very complicated and the geomorphologic evolution according to previous studies, has gone through many cycles under variable climatic conditions. The subject under study will be presented in parts

1. Ποσοτική γεωμορφολογική μελέτη του υδρογραφικού συστήματος του Ευρώτα ποταμού.
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ORDERING OF THE DRAINAGE NETWORK

The ordering of the Eurotas River drainage network was made on the topographic sheets (scale 1 :50.000) of the following areas: Megalopolis, Kollinae, Astros, Xyrokampio, Kalamata Sparti, Goritsa, Gythion and Molai according to the system of STRAHLER (1951).For the mapping of the drainage network aerial photographs were also used. The entire ordered drainage network is presented in fig. 1, which also shows the boundaries of the basins of the 4^{th} ,5^{th} and 6^{th} order. The streams are indicated by special symbols.

Eurotas River is classified to the 7th order and has three (3) tributaries of the 6^{th} order, which are Eurotas river, Xagdarias river and Xerias river. In addition it has 11 streams of the 5^{th} order, 136 of the 4^{th}, 222 of the 3^{rd}., 909 of the 2^{nd} and 2.889 of the 1^{st} order. Each stream of the drainage network possesses its own basin of the same order, which includes all the lower order basins. All the measured data of the streams and basins (bigger than 4^{th} order) of the Eurotas River are given on tables I - IV. There are also 13 third order and 25 second order basins joined directly to the main channel. It must be emphasized here that the precision of the ordering. and of all the resultant data. is directly dependent on the scale of the topographic maps used.

After the ordering of the Eurotas River drainage network, its quantitative analysis took place.

Geographical distribution

Geographical distribution of basins (Fig. 1,2,3), shows that the 45 4^{th} order basins are assymetrically distributed on both sides of the main channel of Eurotas River. More precisely, of the 45 basins 12 are located in the western part, 13 in the northern part and 20 in the eastern part. Furthermore the basins of the eastern part join directly the main channel, that is without the interference of any 5^{th} order stream, but the basins of the northern part and some of the eastern one, join in groups and then meet the main channel through 5^{th} or 6^{th} order streams. In other words, many basins of the northern part belong to the next higher order basins, whereas these of the southern part transgress the 5^{th} order.In others words many basins of the northern and western part belong to the next higher order basins (5^{th} or 6^{th}). The same figure (1) show that the 5th order basins have a peripheral setting, whereas the central area is occupied by basins of a lower order.

The drainage pattern of the first basin of the northern part and of the basins' majority of the eastern one is dendritic or rectangular, but that of the western basins is usually subparallel. In the northern and western part the 4^{th} order branches, have an E-W direction and in the northern part they flow to the west, while in the western part they flow to the east. In the eastern part the branches are of NE-SW to NNE-SSW direction.

RESULTS OF THE STATISTICAL ANALYSES

Number of streams per order.

The number of streams per order in all the basins shows a high variation. Thus in the 4^{th} order basins N1 varies between 9 and 253, N2 between 10 and 63, and N3 between 2 and 13. In the 5^{th} order basins N1 varies between 82 and 475, N2 between 26 and 104, N3 between 6 and 22, while in the 6^{th} order basin, N1 varies between 236 and 1121, N2 between 63 and 336, N3 between 16 and 56.

After the ordering of Eurotas drainage network, the theoretically expected number of streams has been calculated according to the 1^{st} law of HORTON (1945), (table I) , for the different orders. After that, the deviations from the expected values for each order has been calculated. Positive deviation values show the presence of less streams than the expected ones, and the negative values show more streams.

The number of streams of every order, shows great divergences among the basins of the same order, as well as among basins of different order, (Table I, III). Generally, less streams than expected are observed. In the 7^{th} order basin of Eurotas, a deficiency of streams ranging from 35% up to 70% is observed in every order, with the exception of the streams of the 4^{th} order that are 35% more in number.

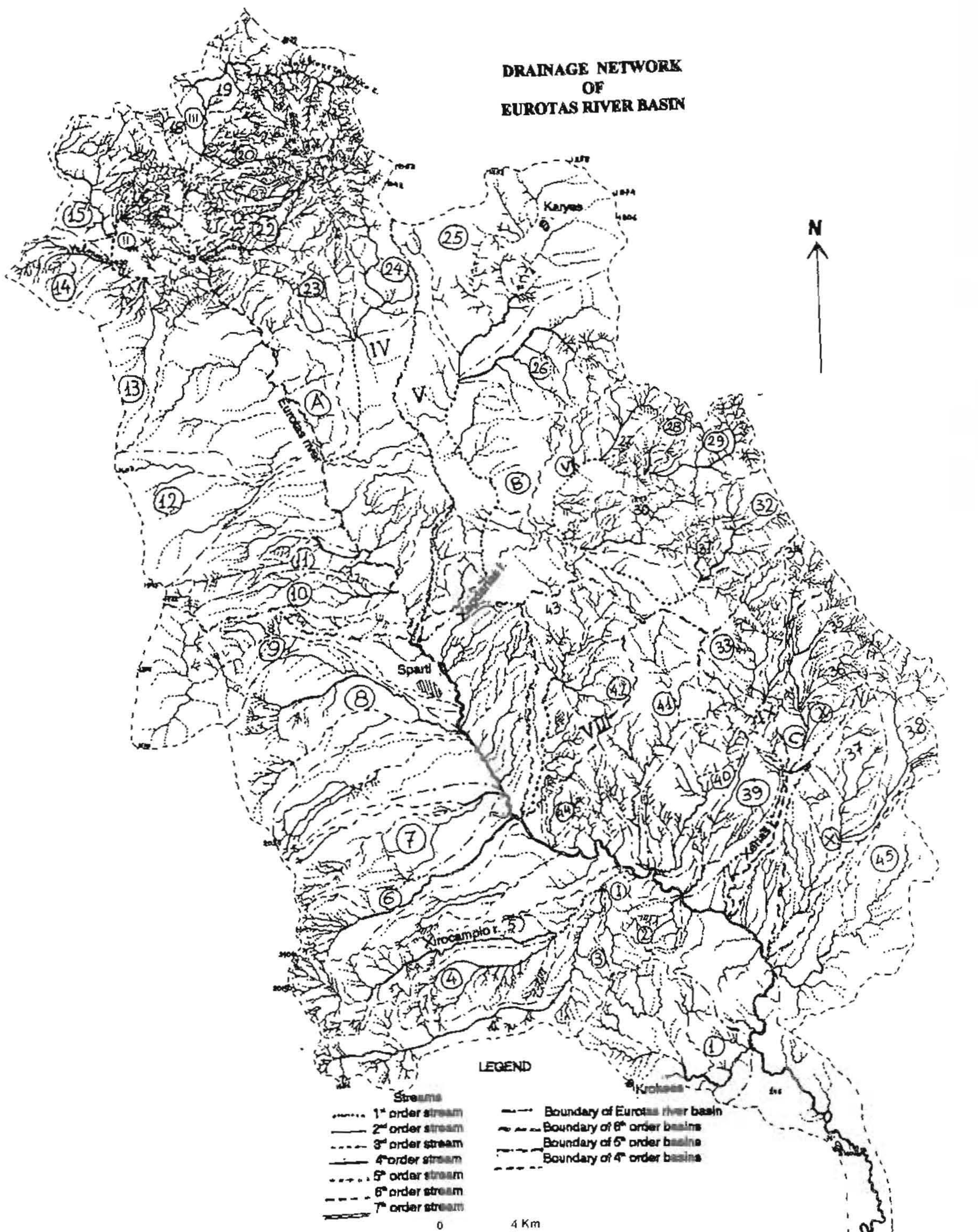

Fig. 1 Map of the drainage system and the drainage basin of Eurotas river.

than theoretically expected. In the 6th order basin, a lower percentage deficiency of streams is observed in every order, with the exception of the basin A΄, where a slight increase of 2nd order streams is observed.

TABLE I. Morphometry of drainage system of Eurotas river. Number of streams per order and the bifurcation ratios.

Basin 6th	Basin 5th	Basin 4th	N1	N2	N3	N4	N5	N6	N7	ΣN	$Rb_{1/2}$	$Rb_{2/3}$	$Rb_{3/4}$	$Rb_{4/5}$	$Rb_{5/6}$	$Rb_{6/7}$	WRb	Deviation % N1	Deviation % N2	Deviation % N3	Deviation % N4	Deviation % N5	Deviation % N6
	I		238	72	15	3	1			329	3.31	4.80	5.00	3,00			4.03	9	-10	7			
		3	78	27	5	1				39	2,89	5,40	5,00				4,43	10	-38	-13			
		4	52	18	4	1				39	2,89	4,50	4,00				3,80	5	-25	-5			
		5	99	26	6	1				39	3,81	4,33	6,00				4,71	5	-17	-27			
	II		214	57	14	7	1			293	3,75	4.07	2,00	7,00			4,21	32	23	21			
		14	31	8	2	1				42	3,88	4,00	2.00				3,29	13	26	39			
		15	62	14	3	1				80	4,43	4,67	3,00				4,03	5	14	26			
		16	36	10	3	1				50	3,60	3,33	3,00				3.31	1	9	9			
		17	25	6	2	1				34	4,17	3,00	2,00				3,06	12	36	35			
	III		475	104	22	4	1			606	4,57	4.73	5,50	4.00			4,70	3	0	0			
		18	23	6	2	1				32	3,83	3,00	2,00				2.94	10	31	32			
		19	253	63	13	1				330	4,02	4,85	13,00				7,29	35	-19	-78			
		20	64	12	3	1				80	5,33	4,00	3,00				4,11	8	29	27			
		21	50	12	2	1				65	4,17	6,00	2,00				4,06	25	27	51			
	IV		122	34	5	2	1			164	3,59	6,80	2,50	2,00			3,72	36	34	64			
		24	90	24	2	1				117	3,75	12,00	2,00				5,92	57	31	66			
		23	21	6	2	1				84	3,50	3,00	2,00				2,83	8	25	29			
		13	20	6	2	1				29	3,33	3,00	2,00				2,78	7	22	28			
		22	55	11	3	1				70	5,00	3,67	3,00				3,89	6	27	23			
A′			**1121**	**336**	**56**	**13**	**3**	**1**		**1530**	**3,34**	**6,00**	**4,31**	**4,33**	**3,00**		**4,20**	**14**	**-8**	**24**	**26**		
	V		174	40	8	2	1			225	4,35	5.00	4.00	2,00			3,84	20	29	46			
		25	82	19	5	1				107	4,32	3,80	5,00				4,37	2	1	-14			
		26	58	11	3	1				73	5,27	3,67	3,00				3,98	8	31	25			
	VI		185	44	9	3	1			242	4,20	4,89	3.00	3.00			3,77	9	18	37			
		27	29	7	2	1				39	4,14	3,50	2,00				3,21	13	32	38			
		28	30	6	2	1				40	5,00	3,00	2,00				3,33	19	46	40			
		29	80	20	4	1				105	4,00	5,00	4,00				4,33	2	-7	8			
	VII		82	22	5	2	1			112	3,73	4,40	2,50	2,00			3,16	17	30	50			
		42	14	4	2	1				21	3,50	2,00	2,00				2,50	10	36	20			
		43	38	11	2	1				53	3,45	5,50	2,00				3,65	22	18	45			
	VIII		120	26	7	3	1			157	4,62	3,71	2,33	3,00			3,42	12	35	40			
		30	46	9	2	1				58	5,11	4,50	2,00				3,87	21	40	48			
		31	15	4	2	1				22	3,75	2,00	2,00				2,58	13	40	23			
		32	42	10	2	1				55	4,20	5,00	2,00				3,73	19	28	46			
B′			**585**	**138**	**30**	**10**	**4**	**1**		**768**	**4,24**	**4,60**	**3,00**	**2,50**	**4,00**		**3,67**	**12**	**24**	**39**	**26**		
	IX		138	37	7	2	1			185	3,73	5,29	3,50	2.00			3,63	20	23	47			
		34	63	15	4	1				88	4,20	3,75	4,00				3,98	0	5	0			
		33	52	17	3	1				73	3,06	5,67	3,00				3,91	13	-11	23			
	X		94	26	9	2	1			132	3,62	2,89	4,50	2,00			3,25	16	24	15			
		35	50	15	5	1				71	3,33	3,00	5,00				3,78	7	-5	-32			
		36	30	7	3	1				41	4,29	2,33	3,00				3,21	9	32	6			
C′			**236**	**63**	**16**	**4**	**2**	**1**		**322**	**3,75**	**3,94**	**4,00**	**2,00**	**2,00**		**3,14**	**22**	**35**	**48**	**59**		
	XI		110	25	6	2	1			144	4,40	4,17	3,00	2,00			3,39	17	36	48			
		37	31	9	2	1				43	3,44	4,50	2,00				3,31	15	18	40			
		38	57	11	3	1				72	5,18	3,67	3,00				3,95	7	29	24			
		1	58	11	3	1				54	5,27	3,67	3,00				3,98	8	31	25			
		2	15	6	2	1				24	2,50	3,00	2,00				2,50	4	4	20			
		6	42	13	4	1				60	3,23	3,25	4,00				3,49	2	-7	-14			
		7	32	10	2	1				45	3,20	5,00	2,00				3,40	19	13	41			
		8	42	15	4	1				62	2,80	3,75	4,00				3,52	3	-21	-14			
		9	54	19	2	1				76	2,84	9,50	2,00				4,78	51	17	58			
		10	10	4	2	1				17	2,50	2,00	2.00				2,17	2	15	8			
		11	37	4	2	1				44	9,25	2,00	2,00				4,42	57	79	55			
		12	9	4	2	1				16	2,25	2,00	2,00				2,08	0	8	4			
		39	25	10	2	1				38	2,50	5,00	2,00				3,17	21	0	37			
		40	44	12	3	1				44	3,67	4.00	3,00				3,56	2	5	16			
		41	56	11	4	1				72	5,09	2,75	4,00				3,95	9	29	-1			
		44	18	6	2	1				27	3,00	3,00	2.00				2,67	5	16	25			
		45	57	12	5	1				71	4,75	2,40	5,00				4,05	14	27	-23			
Tot.			**2889**	**909**	**22**	136	**11**	**3**	1	4171	**3,18**	4,09	**1,63**	**12,36**	**3,67**	**3,00**	**4,66**	72	58	53	-35	49	36

Mean bifurcation , Rb, range from 2,17 to 4,78, with the exception of basins 19 and 24 which have Rb 7,29 and 5,92 correspondingly. According to HORTON (1945), ideal value of Rb is 2. Values 2-5 show well developed drainage networks. Values obviously higher than 5 show a higher creation of streams due to lithologic or tectonic factors.

TABLE II. Morphometry of the drainage system of Eurotas river. Streams length per order.

Bas in 7th	Bas in 6th	Bas in 5th	Bas in 4th	L1	L2	L3	L4	L5	L6	L7	ΣL	L1-	L2-	L3-	L4-	L5-	L6-	SL-	RL 2/1	RL 3/2	RL 4/3	RL 5/4	RL 6/5	RL 7/6	WRL
		I		112,0	63,00	18,10	41,00	6,0			240,1	0,47	0,88	1,21	13,67	6,00		4,44	2,9	1,9	6,4	1.37			3,12
			3	40,00	20,00	4,00	20.00				84,00	0,51	0,74	0,80	4,00			6,05	2,9	1,6	2,9				[illegible]
			4	23,00	12,50	5,10	8,00				48,60	0,44	0,69	1,28	8.00			10,41	4,3	2.1	4,3				3,80
			5	39,00	25,00	9,00	13,00				86,00	0.39	0,96	1,50	13,00			15,86	5,6	2,1	5,6				4,40
		II		124,5	62,40	30,90	28,45	8,60			254,8	0,58	1,09	2,21	4,06	8,60		16,55	2,1	1,6	2.1	2,08			[illegible]
			14	16.00	8.10	4,00	2,00				30,10	0.52	1,01	2,00	2,00			5,53	1,6	2,3	1,6				1,81
			15	38.50	19,00	5.00	6,00				68,50	0,62	1,36	1,67	6,00			9,64	2,6	1,8	2,6				2,38
			16	16.00	4,00	1,50	2,05				23,55	0,44	0,40	0,50	2.05			3,39	2,5	1,6	2,5				2,21
			17	6,50	2,70	1,90	0,90				12,00	0,26	0,45	0,95	0.90			2,56	1,5	2,3	1,5				1,81
		III		257,0	241,7	34,70	47,20	7,80			588,1	0,54	2,32	1,58	11,80	7,80		24,04	1,5	1,6	3,7	1,48			2,04
			18	12,00	3,00	3,00	18,50				36,50	0,52	0,50	1,50	18,50			21,02	2,0	2,5	8,3				4,25
			19	148,0	111,0	16,00	4,00				279,0	0.58	1,76	1,23	4,00			7,58	2.1	1.5	2,1				1,92
			20	36,00	7,00	5,00	1,00				49,00	0,56	0,58	1,67	1,00			3.81	1,4	2,5	1.4				1,72
			21	17,00	7,50	4,50	23,50				52,50	0,34	0,63	2,25	23,50			26,72	8,3	3,3	8,3				[illegible]
		IV		89,50	42,60	18,10	16.00	8,10			174.3	0,73	1,25	3,62	8.00	8,1		21,71	1,6	2,8	2,4	1.6			[illegible]
			24	51,00	19,50	8,00	8,00				86,50	0,57	0,81	4,00	8,00			13,38	2,5	3.9	2.5				2,96
			23	27,50	13,10	8,10	8,00				56.70	1,31	2,18	4,05	8,00			15,54	2,1	2,2	2,1				2,09
			13	17,50	17,50	17,50	17,50				70,00	0,88	2,92	8,75	17,50			30,04	2,4	3,3	2,4				[illegible]
			22	36.00	11,00	4,00	6,50				57,50	0,65	1,00	1,33	6,50			9,49	3,2	1,8	3,2				[illegible]
	A΄			594,0	402,7	103,7	91,65	24,50	28,5		1423,	0,53	1,20	1,85	7,05	8,2	28,5	47,30	2,5	2,1	3,0	1,77	2.5		2.37
		V		124.0	60,80	26.00	14,00	12.00			236,8	0.71	1,52	3,25	7,00			12.48	2.3	2.5	2.3				[illegible]
			25	48,00	30,00	22,00	6,00				106.0	0.59	1,58	4,40	6,00			12,56	1.9	3,0	1,9				2,29
			26	40,00	18,00	4,00	8,00				70,00	0,69	1,64	1,33	8,00			11.66	3,2	1.6	3,2				[illegible]
		VI		111,5	53,80	9.90	9,50	6,50			191,2	0,60	1,22	1.10	3.17	6,5		12,59	2,1	1,6	2,1	2.07			[illegible]
			27	12.00	7,00	2,00	2,00				23,00	0,41	1,00	1,00	2.00			4,41	1.8	1,7	1.8				[illegible]
			28	11,50	2,20	4,00	1,00				18,70	0.38	0,37	2,00	1,00			3,75	1,4	3,7	1,4				[illegible]
			29	44.00	33.00	3.00	6,50				86,50	0,55	1,65	0,75	6,50			9,45	3,2	1,3	3,2				[illegible]
		VII		36,10	32,00	5,30	2,20	7.00			82.60	0,44	1,45	1,06	1,10	7		11,05	2,7	1,6	1,4	2,73			2,10
			42	10,10	5.00	0,30	1.10				16.50	0,72	1,25	0,15	1.10			3,22	1,5	1,1	1,5				[illegible]
			43	22,00	17,00	5.00	1,10				45,10	0,58	1,55	2,50	1,10			5,72	1,2	2,2	1,2				[illegible]
		VII		82,00	31,60	12,10	8,00	9,10	3		145,8	0.68	1,22	1,73	2,67	9,1		15,39	2,4	1,9	1,7	2,45			[illegible]
			30	33,00	9.00	6,00	4,00				52,00	0.72	1,00	3,00	4,00			8,72	1,8	2,7	1,8				[illegible]
			31	3,50	2.50	1,10	1,00				8,10	0,23	0,63	0,55	1,00			2,41	1,7	1,6	1,7				[illegible]
			32	25,00	11,00	4,00	3,00				43,00	0,60	1,10	2,00	3,00			6,70	1,8	2,2	1,8				[illegible]
	B΄			356,6	184,2	55,70	28,00	25,50	10,6		660,6	0,61	1,33	1,86	2,80	6,38	10,6	23,58	1,8	2,0	1,7	1,97	1,8		1,86
		IX		79.00	27.00	9,00	11,00	4,5			130,5	0,57	0,73	1,29	5,50	4,5		2,52	0,3	2,0	3,1				1,81
			34	35,00	15,00	5,00	4,00				59,00	0,56	1,00	1,25	4,00			6,81	2,4	1,8	2,4				[illegible]
			33	32,00	9,00	3,00	7,00				51,00	0,62	0,53	1,00	7,00			9,14	4,3	1,9	4,3				3,47
		X		52,14	22,00	12,00	8,50	3,5			98,14	0,55	0,85	1,33	4,25	3,5		2,10	0,3	2,0	2,6	1,5	13		[illegible]
			35	39,00	12,00	7,00	6,50				64,50	0.78	0,80	1,40	6,50			9,48	3,2	1,9	3,2				[illegible]
			36	13,10	5,00	4,00	2,00				24,10	0,44	0,71	1,33	2,00			4,48	1,8	2,2	1,8				[illegible]
	C΄			137,0	49,00	21,00	19,50	8,05	8,9		243,4	0,58	0,78	1,31	4,88	4,03	8,90	20,5	1,8	2,0	2,8	1,5	1,77		1,97
		XI		70,00	26,60	14,00	4,00	8,0			122,6	0,64	1,06	2,33	2,00	8,00		14,03	2,7	2,4	1,5	2,33			[illegible]
			37	16,00	9,00	6,50	2,00				33,50	0.52	1,00	3,25	2,00			6,77	1,4	3,1	1,4				[illegible]
			38	43,00	9,50	6,00	2,00				60,50	0,75	0,86	2,00	2,00			5,62	1,6	2,2	1,6				[illegible]
			1	43,50	24,00	13,00	6,00				86,50	0,75	2,18	4,33	6,00			13,27	1,8	2,5	1,8				2,04
			2	9,00	5,00	2,50	1,00				17,50	0,60	0,83	1,25	1.00			3.68	1,4	1,9	1,4				1,54
			6	21,00	10,00	7,50	12,50				51,00	0,50	0,77	1,88	12,50			15,64	5,0	2,5	5,0				[illegible]
			7	18.00	14,00	11,50	10,00				53,50	0,56	1,40	5,75	10.00			17,71	2,3	3,9	2,3				2,84
			8	44,00	20,00	12,50	11,00				87,50	1,05	1,33	3,13	11,00			16,51	3,0	2,3	3,0				[illegible]
			9	40,00	17,00	2,00	16,50				75,50	0,74	0,89	1,00	16.50			19,14	7,3	1,6	7,3				[illegible]
			10	68,20	54,00	10,60	16,50				149,3	6,82	13,50	5,30	16,50			42,12	1.6	1,3	1,6				[illegible]
			11	25,00	5,00	14,00	3,00				47,00	0,68	1,25	7,00	3,00			11,93	1,3	4,6	1,3				2,44
			12	27,50	10,00	5,00	3.10				45,60	3,06	2,50	2,50	3,10			11,16	1,4	1,5	1,4				[illegible]
			39	10,50	12,00	9,00	2,00				33,50	0,42	1,20	4,50	2,00			8,12	1,3	3,8	1,3				2,14
			40	53,00	37,00	14,00	7,20				111,2	1,20	3,08	4,67	7,20			16,15	1,8	2,1	1,8				1,90
			41	45,00	15,00	6,50	11,00				77,50	0,80	1,36	1,63	11,00			14,79	3,9	1,7	3,9				[illegible]
			44	6,00	2,90	5,00	1,00				14,90	0,33	0,48	2,50	1,00			4,32	1,3	4,1	1,3				[illegible]
			45	32,00	15,00	8,00	8,00				63,00	0,56	1,25	1,60	8,00			11,41	3,3	1,9	3,3				2,86
				2155,	1207,	454,7	292,9	72,05	48,0	56,	3603,	0,75	1,33	2,05	0,10	6,55	16,0	85,63	8,02	1,99	1,0	2,59	2,50	1,90	3.00

The 2[nd] law of HORTON (1945) has been applied for the mean length of streams ($\bar{L}$), and the divergences of the theoretically expected values have been calculated. Positive divergence values indicate a length smaller than the ideal one, whereas negative divergence values show a bigger than the expected length. For the calculation of the mean stream length, the cumulative mean stream length has been considered .As for the mean stream length, the following are observed. In the 7[th] order basin, the divergences of the mean length of streams of all the orders are positive and range from 33%-89% over the theoretically expected. The same is observed as well in the basins of 6[th] and 5[th] order, but with fewer variations. The greater positive divergences, that reach up to 54%, is observed in the basin C′ at $\bar{L}5$. Negative divergences are observed as an exception in the following cases: basin III, $\bar{L}2$ and $\bar{L}4$ with values -110 and -156 correspondingly, and basin B′, $\bar{L}2$ with value -18. Also the 45% of the 4th order basins show mean stream length, $\bar{L}2$ and $\bar{L}3$ longer than the expected, and in the basin 45. $\bar{L}3$ reaches up to 133% longer.

Streams that show negative divergence at smaller orders and positive at bigger ones, are in stage of transition to a higher order. This results to the smoothing of the network with fewer divergences. These branches are in a more advanced stage than these which have positive values in every order. Negative divergences are due to lithology, because the branches are developed on impermeable formations. Positive divergences are due to the high inclination of the relief that are caused by recent uplifting movements.

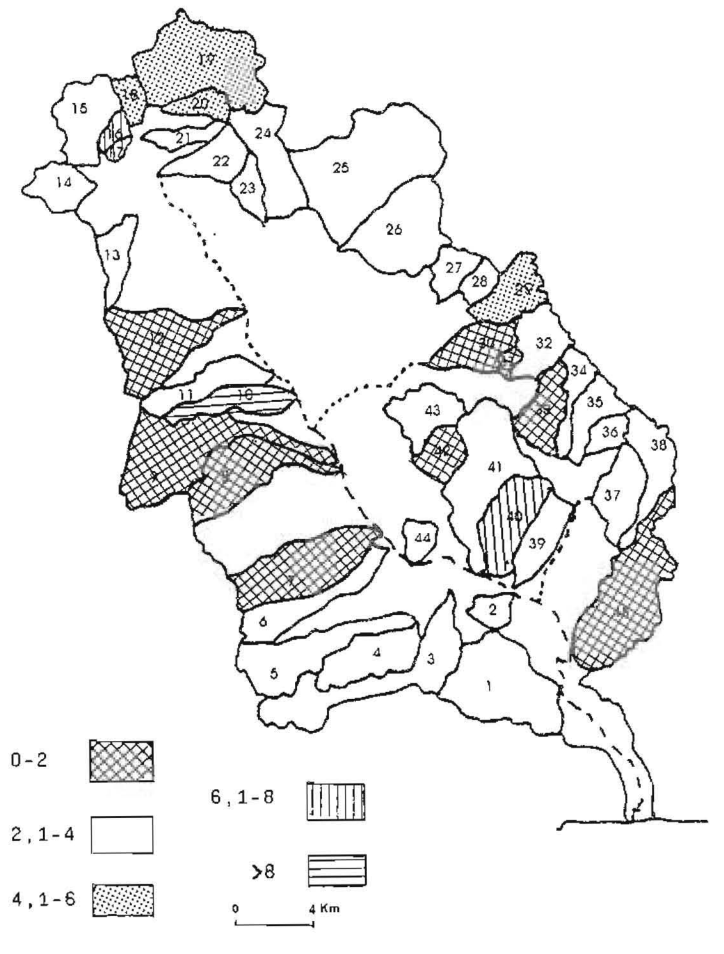

Fig.2. Sketch showing the distribution of the 4th order basins, as well as their classification according to the drainage density (D),in km^2.

Smaller number of streams shows that the drainage network has not been completed yet and it is at a stage of evolution caused by recent uplifting movements (KRAFT, 1972). The higher deviation at the number of streams is observed in the 4th order basins Nr 9 and 11, while deviations of the length of the streams are observed in many basins.

Basin area

The smallest area of 5th order basins is 75.25 km^2 (basin C) and the largest one is 460,15 km^2 (basin A). As for the 4th order basins the smallest is 3 km^2 (basin17) and the largest is 66,63 km^2 (basin 25). 12 basins (26.5%) have an area smaller than 10 km^2, 14 basins (31%) have an area 10-20 km^2, and

only 7 basins (15,5%) are bigger than 40 km^2. The smaller basins are located in the northern and eastern part of the basin of Eurotas river.
The basin Nr 19 covers more than the double area than the adjoining basins. These, as well as the very big number of streams (330), the flow direction of the streams from East to West, and the morphological observations, lead to the thought that it is about streams piracy of an other river after the headward extension of the above branches due to the uplifting movements that acted during Pleistocene.

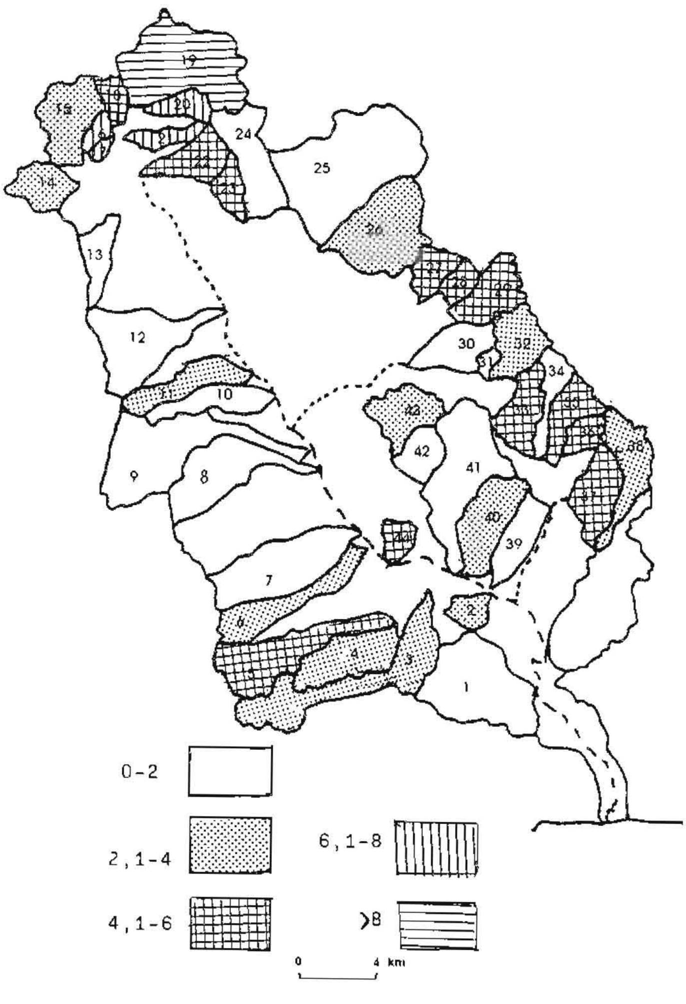

Fig. 3. Sketch showing the 4th order basins classified according to their channel frequency (F), in Nu/km^2.

Drainage density and channels frequency
The drainage density (D) of the 7th order basin of Eurotas is 2.00 km/km^2. The values of D in the 6th order basins varies from 2,94 km/km^2 to 3,24 km/km^2, while in the lower order basins varies from 1,05 km/km^2 (basin 41) to 8,72 km/km^2 (basin 10). The fig. 2 shows the 4th order basins classified according to their drainage density.
In general the drainage density is depended directly on the lithology of the underlying rocks. However, it can be clearly recognized only where the other factors and particularly climate, altitude, tectonic structure, area and inclination of the slopes, are uniform. The higher values are observed in the basins of the smaller area. The other factors differ so much in the drainage system of Eurotas, that no obvious relation exists between drainage density and lithology.

The values of channel frequency (F) show a similar image to the drainage density. Its values vary for the 6^{th} order basins from 3,33 N/km^2 to 4.28 N/km^2 ,for the 5^{th} order from 1,42 N/km^2 to 6,5 N/km^2.The channel frequency values of the 4^{th} order basins vary from 0,99 N/km^2 (basin 10) to 13,3 N/km^2 (basin 16) (Fig. 3). The high correlation between D and F is expected because they are defined by the area, the total number of the streams and the total length of the them, while they are also highly correlated. Thus, the factors which control the values of the channel frequency are more or less the same as those of drainage density. The values of the channel frequency are almost every time higher than those of the drainage density. An exception is observed in 13 basins, which have values of channel frequency 12% to 89% lower than the correspondent values of drainage density.

Higher values of drainage density and channel frequency are observed in the 4^{th} order basins which are included in basins II and III, that are in the northern part. Values D1 and F1 are compared to values D to define, if these high values are due to an increase of number or of length of 1^{st} order branches. The comparison showed that F1 values are much higher in general than the corresponding D1 values of the same basins. This is due to uplifting movements, that occurred in the area and show that the drainage network is at a young stage of evolution because of a continuous tectonic activity.

The constant of channel maintenance has in general low values. They vary from 0,11 to 0,77. The higher values are observed in the basins of the western part.

The correlation of D, F, D1, F1 and C shows that the basins are in an advanced young stage of evolution because a continuous tectonic activity.

The relief roughness (Rn) shows a variety of values. Three groups according to its values can be distinguished. In the first group are included basins with Rn lower than 0,5 in the second group those with Rn between 0,5-1 and the third group those with Rn values higher than 1. In the first group almost all the 4^{th} order basins of the eastern part which are directly joined to the main channel of Eurotas are included. In the second group are included the 4^{th} and 5^{th} order basins of the northern and northeastern part. Finally high values show the basins of the eastern part. Rn is a factor that influenced by H of the basins as well as by D. Higher values of Rn are observed in areas where both H and D are high. The higher Rn values show bigger inclination and length of the slopes. The domain factor in the under study basins is the very high altitude.

The relief ratio (Rh) shows the total degree of inclination of the basin and it is an indicator of the intention of the erosion processes that occurred and are still in progress at the slopes of the drainage basin (STREHLER, 1964). The Rh values range from 0,03 to 0,42. The 6^{th} order basins has lower Rh than that of the lower order basins which are included in them .High Rh values show an advanced stage of evolution, while lower values show a younger one. Low Rh values show an intensive relief due to uplifting movements caused by tectonic activity. According to SCHUMM (1964) there is a strong correlation between the Rh and the amount of the sediments yield at the mouth of the drainage basin. Higher Rh values show larger quantities of sediments.

So from the circularity ratio (Cu), as from the elongation ratio (Er), is obvious that the shape of the basins is very elongated, because they are at a young stage of evolution, or they are rejuvenated due to uplifting movements that acted in the area.

TABLE III. Divergences of the number of the streams and of the mean length of the streams of Eurotas river.

Basin 7th	Basin 6th	Basin 5th	Basin 4th	Deviation% N1	Deviation% N2	Deviation %N3	Deviation N4	Deviation N5	Deviation N6	Deviation %L2	Deviation %L3-	Deviation% L4-	Deviation% L5-	Deviation% L6-	Deviation% L7-	D km/km²	F Nu/km²	D1 L1/km²	F1 N1/km²
		I		9	-10	7				40	74	4	87			2,55	3,49	1.19	2.53
			3	10	-38	-13				42	75	51				2,02	2,67	0.96	1.88
			4	5	-25	-5				56	78	61				2,37	3,66	1.12	2.54
			5	5	-17	-27				45	80	61				2,76	4,23	1.25	3.17
		II		32	23	21				4	1	6	-1			3.36	3.87	1.64	2.83
			14	13	26	39				-8	53	28				2,46	3,43	1.31	2.53
			15	5	14	26				8	77	57				3,11	3.64	1.75	2.82
			16	1	9	9				59	-12	41				6,26	13,30	4.26	9.57
			17	12	36	35				4	30	-156	17			4,00	11,33	2,17	8.33
		III		3	0	0				-110	84	54				6.31	6.50	2.76	5.09
			18	10	31	32				77	43	3				5,96	5,23	1.96	3.76
			19	35	-19	-78				-57	0	65				5,69	6,73	3.02	5.16
			20	8	29	27				40	85	76				5,76	9,41	4.24	7.53
			21	25	27	51				72	-11	-16	44			6,77	8,39	2.19	6.45
		IV		36	34	64				19	19	45				1.85	1.74	0,95	1.30
			23	57	31	66				52	29	33				3,00	4,05	1.77	3.12
			24	8	25	29				20	-37	-2				1,56	0,82	0.76	0.58
			13	7	22	28				-23	72	51				4,44	1.84	1.11	1.27
			22	6	27	23				44	38	0	51	28		4,69	5,71	2,94	4.49
A'				14	-8	24	26			4	16	23				2.71	3.33	1.29	2.44
		V		20	29	46				9	-44	14				1.50	1.42	0.78	1.10
			25	2	1	-14				-18	72	38				1,59	1,61	0.72	1.23
			26	8	31	25				10	52	30	26			2,10	2,19	1.20	1.74
		VI		9	18	37				-4	24	15				3.16	3.99	1.84	3.05
			27	13	32	38				-35	-15	73				2,56	4,33	1.33	3.22
			28	19	46	40				55	80	31				2,27	4,73	1.39	3.64
			29	2	-7	8				-16	45	73	18			4,74	5,75	2,41	4.38
		VII		17	30	50				-58	89	41				1.20	1.63	0.53	1.20
			42	10	36	20				-26	-80	49				1,07	1.37	0.66	0.91
			43	22	18	45				-72	44	60	36			2,61	3,01	1,28	2.20
		VII		12	35	40				17	9	44				2.65	7.10	1.4.84	38.71
			30	21	40	48				35	10	30				1,13	1,26	0,72	1.00
			31	13	40	23				-59	17	11				0,51	1,40	0.22	0.95
			32	19	28	46				4	12	28				2,61	3,33	1,52	2.55
B'				12	24	39	26			-18	31	-63	12	22		1,98	2,31	1,07	1.76
		IX		20	23	47				29	54	34				3.90	5.53	2.36	4.13
			34	0	5	0				19	86	73				5,69	8,00	3.37	6.07
			33	13	-11	23				75	3	-95	-2			2,97	4,25	1,86	3.03
		X		16	24	15				3	76	60				3.10	4.17	1.65	2.97
			35	7	-5	-32				63	17	36				4,69	5.16	2,84	3.64
			36	9	32	6				15	42	-9				3,32	5,66	1.81	4.14
C'				22	35	48	59			32	25	71	54	49		3.24	4.28	1.82	3.14
		XI		17	36	48				25	-58	51				2.15	2.52	1.23	1.93
			37	15	18	40				3	16	53				3,72	4,78	1,78	3.44
			38	7	29	24				36	-38	6				2,69	3,20	1,91	2.53
			1	8	31	25				-42	12	54				2.22	1.87	1.12	1.49
			2	4	4	20				10	78	65				2,69	3,69	1.38	2.31
			6	2	-7	-14				63	-27	22				2,27	2,67	0.93	1.87
			7	19	13	41				12	61	51				1,65	1,38	0.55	0.98
			8	3	-21	-14				54	95	86				1,98	1,40	1,00	0.95
			9	51	17	58				78	66	31				1,51	1,52	0.80	1.08
			10	2	15	8				-31	-75	69				8,72	0.99	3.98	0.58
			11	57	79	55				24	59	64				2,94	2,75	1.56	2.31
			12	0	8	4				42	65	39				1,29	0,45	0.78	0.26
			39	21	0	37				-33	-52	73				1,33	1,50	0.42	0.99
			40	2	5	16				-35	80	58				6,90	3,72	3.29	2.73
			43	9	29	-1				47	-7	13				1,90	1,76	1.10	1.37
			44	5	16	25				35	-133	52				2,38	4.32	0.96	2.88
			45	14	27	-23				22	61	78	82	83	66	1,24	1,47	0.63	1.12
Eurotas			Total	72	58	53	-35	49	36	41	69	100	89	91	84	3.7	3.0	4.7	1.61

TABLE IV. Morphometry of the drainage basins of Eurotas river.

Basin 7th	Basin 6th	Basin 5th	Basin 4th	Area km²	L km	W km	P km	H m	D km/km²	F Nu/km²	Dl L_t/km²	Fl Nl/km²	C	S	Er	Cu	Basin mouth hm	Total altimeter m	Rh= H/L	Rn= H*D	F/D
		I		*94,25*	*19,50*	*8,00*	*47,60*	*2404*	*2,55*	*3,49*	*1,19*	*2,53*	*0,39*	*2,44*	*0,50*	*0,51*	*120*	*2284*	*0,12*	*0,94*	*1,37*
			3	41,50	9,00	8,20	42,00	1651	2,02	2,67	0,96	1,88	0,49	1,10	0,36	0,44	140	1511	0,18	0.82	1.32
			4	20,50	9,10	3,40	31,00	1026	2,37	3,66	1,12	2,54	0,42	2,68	0,39	0,78	160	866	0,11	0,43	1.54
			5	31,20	19,05	4,50	35,00	2404	2,76	4,23	1,25	3,17	*0,36*	4,23	0,40	0,69	120	2284	0,13	0,87	1,53
		II		*75,75*	*9,90*	*17,20*	*42,90*	*1526*	*3,36*	*3,87*	*1,64*	*2,83*	*0,30*	*0,58*	*0,07*	*0,40*	*360*	*1166*	*0,15*	*0,45*	*1,15*
			14	12,24	5,00	4.60	14,00	960	2,46	3,43	1,31	2,53	0.41	1,09	0,35	0,76	420	540	0,19	0.39	1.40
			15	22,00	6,70	5,35	20,00	991	3,11	3,64	1,75	2,82	0,32	1,25	0,41	0,66	400	591	0,15	0,32	1,17
			16	3,76	14,90	2,00	10,80	991	6,26	13,30	4,26	9,57	0.16	7,45	0.35	0,63	500	491	0,07	0.16	2.12
			17	3,00	2,80	1,30	7,00	722	4,00	11,33	2,17	8,33	0,25	2,15	0,40	0,58	500	222	0,26	0,18	2,83
		III		*93,25*	*13,15*	*10,00*	*42,10*	*1097*	*6,31*	*6,50*	*2,76*	*5,09*	*0,16*	*1,32*	*0,29*	*0,56*	*360*	*737*	*0,08*	*0,17*	*1,03*
			18	6,12	4.00	1,90	11,00	991	5,96	5,23	1,96	3,76	0,17	2,11	0,24	0,49	500	491	0,25	0.17	0,88
			19	49,00	10,00	6,20	32,50	1097	5,69	6,73	3.02	5,16	0,18	1,61	0,33	0,53	500	597	0,11	0,19	1,18
			20	8,50	5,60	2,95	13,80	1042	5,76	9,41	4,24	7,53	0,17	1,90	0.30	0,22	500	542	0,19	0,18	1,63
			21	7,75	6,60	1,80	14,00	1082	6,77	8,39	2,19	6,45	*0,15*	3,67	0,55	0,76	490	592	0,16	0,16	1,24
		IV		*94,00*	*16,50*	*6,70*	*47,20*	*1082*	*1,85*	*1,74*	*0,95*	*1,30*	*0,54*	*2,46*	*0,25*	*0,49*	*520*	*562*	*0,07*	*0,58*	*0,94*
			23	28,88	10,00	4,70	40,00	1082	3,00	4,05	1,77	3,12	0,33	2,13	0,50	0,56	600	482	0,11	0,36	1,35
			24	36,38	6,20	2,75	13,95	983	1,56	0,82	0,76	0,58	0,64	2,25	0,32	0,55	600	383	0,16	0,63	0,53
			13	15,76	6.30	2,32	21,00	1526	4,44	1,84	1,11	1,27	0,23	2,72	0.35	0,72	380	1146	0,24	0,34	0,41
			22	12,25	7,85	4,00	17,60	1082	4,69	5,71	2,94	4,49	0,21	1,96	0,34	0,20	360	722	0,14	0.23	1,22
	A΄			**460,1**	**24,00**	**16,50**	**100,0**	**1526**	**2,71**	**3,33**	**1,29**	**2,44**	**0,37**	**1,45**	**0,44**	**0,50**	**190**	**1336**	**0,06**	**0,56**	**1,23**
		V		*158,1*	*22,20*	*12,15*	*60,00*	*1383*	*1,50*	*1,42*	*0,78*	*1,10*	*0,67*	*1,83*	*0,33*	*0,75*	*320*	*1063*	*0,06*	*0,92*	*0,95*
			25	66.63	13,00	8,20	3,40	1364	1,59	1,61	0,72	1,23	0,63	1,59	0,39	0,16	720	644	0,10	0,86	1,01
			26	33,38	9,60	5,80	2,60	1383	2,10	2,19	1,20	1,74	*0,48*	1,66	0,37	0,74	720	663	0,14	0.66	1.04
		VI		*60,60*	*10,00*	*7,40*	*38,70*	*1708*	*3.16*	*3.99*	*1,84*	*3,05*	*0,32*	*1,35*	*0,15*	*0,26*	*500*	*1208*	*0,17*	*0,54*	*1,27*
			27	9,00	5,10	3,00	11,50	1559	2,56	4,33	1.33	3,22	0,39	1,70	0,56	0,88	800	759	0,31	0,61	1.70
			28	8,25	4,20	2,70	8,00	1559	2,27	4,73	1,39	3,64	0,44	1,56	0,56	0,63	860	699	0,37	0,69	2,09
			29	18,25	6,50	4,30	17,50	1708	4,74	5.75	2,41	4,38	0,21	1,51	0,56	0,40	860	848	0,26	0.36	1,21
		VII		*68,56*	*12,35*	*7,40*	*46,20*	*1708*	*1,20*	*1.63*	*0,53*	*1,20*	*0,83*	*1,67*	*0,56*	*0,60*	*500*	*1208*	*0,14*	*1,42*	*1,36*
			30	15,38	7,10	4,20	18,00	1364	1,07	1,37	0.66	0,91	0,93	1,69	0,56	0,73	640	724	0.19	1,27	1,27
			32	17,25	6,85	4,80	17,20	1708	2,61	3,01	1,28	2,20	0,38	1,43	0,56	0,27	900	808	0,25	0.65	1,15
			31	3,10	3,00	1,60	12,00	1254	2,65	7,10	1,4,8	38,7	0,38	1,88	0,56	0,53	900	354	0,42	0,47	2,68
		VII		*45,88*	*25,70*	*6,00*	*47,00*	*853*	*1,13*	*1,26*	*0,72*	*1,00*	0,88	*4,28*	*0,56*	*0,61*	*160*	*693*	0,03	0,75	*1,12*
			42	15,75	4,00	4.30	13,00	819	0,51	1,40	0,22	0,95	1,94	0,93	0,56	0,32	490	329	0,20	1.59	2,72
			43	16,50	5,50	6,30	18,00	853	2.61	3,33	1,52	2,55	0,38	0,87	0,56	0,60	490	363	0,16	0,33	*1,28*
	B΄			**333,2**	**22,50**	**14,00**	**73,00**	**1708**	**1,98**	**2,31**	**1,07**	**1,76**	**0,50**	**1,61**	**0,29**	**0,18**	**190**	**1518**	**0,08**	**1,76**	**1,16**
		IX		*33,43*	*12,60*	*4,65*	*26,10*	*1777*	*3,90*	*5,53*	*2,36*	*4,13*	*0,26*	*2,71*	*0,28*	*0,19*	*340*	*1437*	0,14	*0,46*	*1,42*
			34	10,38	9,35	2,20	20,00	1777	5,69	8,00	3.37	6,07	0,18	4,25	0,30	0,63	580	1197	0,19	0,31	1,41
			33	17,19	8,00	3,80	19,00	1777	2,97	4,25	1,86	3,03	0,34	2,11	0,26	0,56	580	1197	0,22	0,60	1,43
		X		*31,68*	*10,90*	*4,30*	*46,10*	*1777*	*3,10*	*4,17*	*1,65*	*2,97*	*0,32*	*2,53*	*0.24*	*0,38*	*340*	*1437*	0,16	*0,57*	*1,35*
			35	13,75	7,50	4,45	30,00	1777	4,69	5,16	2,84	3,64	0,21	1,69	0,08	0,33	540	1237	0,24	0,38	1,10
			36	7,25	5,10	2,60	12,00	1777	3,32	5,66	1,81	4,14	0,30	1,96	0,24	0,34	540	1237	0,35	0,53	1,70
	C΄			**75,25**	**19,00**	**5,00**	**41,00**	**1777**	**3,24**	**4,28**	**1,82**	**3,14**	**0,31**	**3,80**	**0,28**	**0,52**	**70**	**1707**	**0,09**	**0,55**	**1,32**
		XI		*57,13*	*17,90*	*4,70*	*43,20*	*1685*	*2,15*	*2,52*	*1,23*	*1,93*	*0,47*	*3,81*	*0,40*	*0,29*	*58*	*1627*	*0,09*	*0,79*	*1,17*
			37	9,00	20,20	9,80	18,50	1259	3,72	4,78	1,78	3,44	0,27	2,06	0,28	0,27	290	969	0,06	0,34	1,28
			38	22,50	11,20	4,60	29,00	1685	2,69	3,20	1,91	2,53	0,37	2,43	0,17	0,32	290	1395	0,15	0,63	1,19
			1	39,00	9.20	6,05	22,00	392	2,22	1,87	1,12	1,49	0,45	1,52	0,22	0,54	120	272	0,04	0,18	0,84
			2	6,50	3,40	3,10	9,20	485	2,69	3,69	1,38	2,31	0,37	1,10	0,31	0,53	90	395	0,14	0,18	1,37
			6	22,50	14,00	3,50	26,50	2404	2,27	2,67	0,93	1,87	0,44	4,00	0,27	0,37	155	2249	0,17	1.06	1.18
			7	32,50	11,90	4,50	28,80	2024	1,65	1,38	0,55	0,98	0,61	2,64	0,38	0,78	160	1864	0,17	1.23	0.84
			8	44,20	13,00	6.00	34,00	2031	1,98	1,40	1,00	0,95	0,51	2,17	0,38	0,76	160	1871	0,16	1.03	0.71
			9	50,10	17,00	7,80	45,00	1784	1,51	1,52	0,80	1,08	0,66	2,18	0,12	0,43	170	1614	0,10	1.18	1.01
			10	17,13	10,70	2,80	20,00	1784	8,72	0,99	3,98	0,58	0,11	3,82	0,33	0,72	260	1524	0,17	0.20	0.11
			11	16,00	10,00	2,00	21,00	2031	2,94	2,75	1,56	2,31	0,34	5,00	0,19	0,40	260	1771	0,20	0,69	0,94
			12	35,25	10,80	8,60	29,00	1612	1,29	0,45	0,78	0,26	0,77	1,26	0,27	0,49	320	1292	0,15	1.25	0,35
			39	25,25	8,60	3,60	21,00	757	1,33	1,50	0,42	0,99	0,75	2,39	0,27	0,50	100	657	0,09	0,57	1.13
			40	16,13	8,50	2,20	20,00	724	6,90	3,72	3,29	2,73	0,15	3,86	0,42	0,76	90	634	0,09	0.10	0,54
			41	40,88	13,60	5,30	37,00	1171	1,90	1,76	1,10	1,37	0,53	2,57	0,23	0,47	105	1066	0,09	0,62	0,93
			44	6,25	3,70	2,50	10,00	338	2,38	4,32	0,96	2,88	0,42	1,48	0,23	0,31	140	198	0,09	0,14	1.81
			45	51,00	33,00	6,70	38,60	1136	1,24	1,47	0,63	1,12	0,81	4,93	0,29	0,48	47	1089	0,03	0.92	1,19
Eurotas				**1799,**	**72,90**	**36,20**	**226,5**	**2404**	**2,00**	**2,32**	**1,20**	**1,61**	**0,50**	**2,01**	**0,33**	**0,44**	**0**	**2404**	**0,03**	**1,20**	**1,16**

CONCLUSIONS

In this paper the quantitative geomorphical analysis of the drainage network of Eurotas River is presented. Eurotas springs from the plateau of Mantinea (Asea). It flows to SE through a well developed valley of a NW - SE direction into Lakonikos gulf. Its drainage basin is surrounded by high mountains, Taygetos and Parnon and the total area covers 1799,5 km^2. The drainage network is of the 7^{th} order and is well developed. Its pattern is dendritic at the northern and northeastern part and rectangular or subparallel at the other parts.

The number of streams of the different orders is generally less than the theoretically expected, showing low divergences. More streams are observed in the 6^{th} order basins B and C.

Mean bifurcation ratio, Rb shows well developed drainage network.

The mean length of streams of all the orders is shorter than the theoretically expected in the most basins, showing positive divergences. Longer mean stream length (negative divergence) is observed, as an exception in some basins, that reaches up to 133% longer. Shorter streams, at smaller orders and longer at bigger ones, are in stage of transition to a higher order. This results to the smoothing of the network with fewer divergences. These branches are in a more advanced stage than these which are shorter in every order. Negative divergences are due to lithology, because the branches are developed on impermeable formations. Positive divergences are due to the high inclination of the relief, that are caused by recent uplifting movements.

In the basin Nr 19 the big area, as well as the very big number of streams (330), the flow direction of the streams from East to West, and the morphological observations, lead to the thought that it is about streams piracy of an other river after the headward extension of the above branches due to the uplifting movements that acted during Pleistocene.

The drainage density and the channel frequency show a high variation. They depend directly on the lithology of the underlying rocks, but this can be clearly recognized only where the other factors and particularly climate, altitude, tectonic structure, area and inclination of the slopes, are uniform.

The correlation of D, F, D1, F1 and C shows that the basins are in an advanced young stage of evolution because of a continuous tectonic activity.

The study of the different relief ratios (Rn, Rh, Cu, and Er) show the shape and the total degree of inclination of the basin. They are also indicators of the intention of the erosion processes that occurred and are still in progress at the slopes of the drainage basin.

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