THE DADIA–LEFKIMI–SOUFLI FOREST NATIONAL PARK, GREECE: BIODIVERSITY, MANAGEMENT AND CONSERVATION

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Hydrology and the torrential environment

Fotios Maris and Apostolos Vasileiou

The Dadia–Lefkimi–Soufli Forest National Park contains six watersheds of temporal streams with a torrential character, which are part of the drainage basin of the River Evros. Woodland cover exceeds 65% in five of the six watersheds. We used parametric models to estimate maximum flow rates of the main streams of the park. We also assessed soil erosion on watershed level according to the Universal Equation of Soil Loss. Data collection and analysis as well as the presentation of the results were facilitated by the use of the Geographical Information System. Average maximum discharge ranged from 131 to 480 m^3 d^{-1}. The four larger catchments exhibited the highest soil erosion figures ranging from 1342 to 2140 tonnes yr^{-1}. Overall, the amount of soil erosion is considered to be relatively low, a fact apparently attributed to high woodland cover. However, appropriate measures and actions to avoid any future soil degradation must be implemented, due to the area's high ecological value.

Keywords: Watersheds, maximum flow rate, terrain loss, soil erosion, Geographical Information System

General description and geomorphology

The Dadia–Lefkimi–Soufli Forest National Park (DNP) is part of the Dadia–Lefkimi–Soufli forest complex and lies between latitude 41° 07′ and 41° 15′ N and between longitude 26° 19′ and 26° 36′ E. The area has a high ecological value due to the presence of various raptorial birds, many of which are rare in Europe. Because of its position, the area is also an important habitat for other bird groups and for many reptiles, insects and plants. It is also a crossroad for migrating birds.

The relief of the area is relatively low, with a maximum altitude of 961 m asl in its immediate vicinity. Most of the highest peaks within the DNP lie south of the village of Dadia: Kapsalo (620 m asl), Gamila, Mikri and Megali Gibraina (448 m), Baltzas (354 m), Intsiali (495 m) and Gypaetoi and constitute the watershed between the southern and the northern sides.

The DNP is characterized by an intricate hydrographical network, formed by middle-sized and large-sized streams. They are classified as typical torrential streams of hilly and low mountainous areas. The entire mountain watershed is part of the Greek drainage basin of the River Evros. To the west and south it borders on the catchment area of the Erithropotamos River and to the east, on the main body of the River Evros. Most of the basin is characterized by hills and low mountains.

The morphometric features of the area were estimated by using a Digital Terrain Model (DTM). To create this model, we scanned maps of scale 1:50,000 (Army Geographical Service 1977), geo-referenced them and corrected them to actual coordinates. Afterwards, the contour lines of the maps were digitized using geographical information system (GIS) software. In this way, the morphometric characteristics of the catchments were quickly and reliably calculated (Spartalis et al. 2004).

The DNP occupies all or parts of the catchments of six torrential streams (Fig. 1, Table 1): the Megalo Rema, Dadia or Diavolorema, Provatonas, Kamilopotamos, Lyra and Kazani.

Climate

To characterize the climate of the DNP we relied on meteorological data from the Soufli Meteorological Station of the National Meteorological Service. Meteoro-

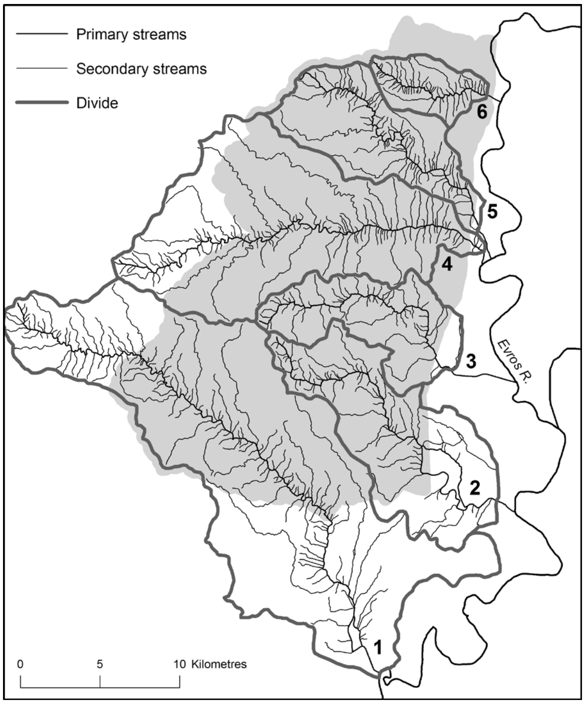

Fig. 1. The torrential streams of the area and their catchments.1 = Megalo Rema, 2 = Provatonas, 3 = Lyra, 4 = Dadia or Diavolorema, 5 = Kamilopotamos, 6 = Kazani.

logical stations are also in operation in Dadia (run by the National Agricultural Research Foundation, NAGREF) and in Lefkimi. However, because the station in Dadia has been in operation for only a few years and the one in Lefkimi is unreliable, data from these two stations were not used in our analysis (Fig. 2).

The average annual precipitation received by the watersheds of the area is 652.9 mm, while its annual distribution follows a Gaussian normal curve. The average

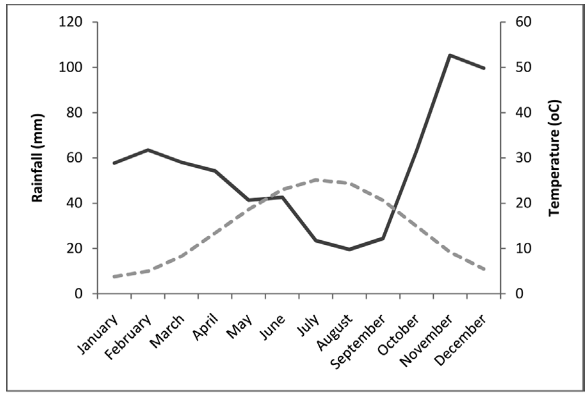

Fig. 2. Ombrothermic diagram according to Gaussen (1954) based on 1973 – 1997 data from the Meteorological Station of Soufli (15 m asl) of the Hellenic National Meteorological Service. Dashed line represents temperature.

minimum precipitation falls in August (19.6 mm), and the absolute maximum is reached in November (105.3 mm). The October–March period has more rain than the April–September period (Petalas et al. 2004).

Mean annual temperature is 14.3 °C with the lowest values in January and the highest in July –August. Additionally, the index of aridity (Gaussen 1954) shows a relatively limited biological dry period of almost three months (July–September); it is even shorter in the mountain areas.

The climate of the area is similar to that predominating over most of Macedonia and Thrace and, according to Köppen, is characterized as a Mediterranean Csa type, or temperate with dry, warm summers. In Thornthwaite's classification, the climate belongs to the $C_{1s}B'_{2}b'_{3t}$ type (Thornthwaite and Mather 1957, Karras 1973, Flokas 1997).

Table 1. Morphometric and hydrographical features of the watersheds of the DNP. All the streams are tributaries to the River Evros.

Name of stream	Area of watershed (km^2)	Altitudes (m asl)					Average slope of watershed	Main riverbed		Perimeter of watershed
		H_{max}	H_{min}	ΔH	H_m	$H_{max\text{-}torrent}$	%	Length (km)	Gradient (%)	U (km)
Megalo Rema	279.15	961	32	929	276.1	914	10.18	42.98	2.082	111.44
Dadias	163.92	500	26	474	173.1	469	5.22	23.98	1.838	59.33
Provatonas	93.65	560	21	539	207	519	10.41	22.71	2.261	43.34
Kamilopotamos	63.27	820	22	798	296	780	10.34	32.16	2.613	71.91
Lyra	54.84	460	26	438	184.9	433	6.07	23.40	1.324	44.30
Kazani	21.30	280	20	260	158.3	248	7.82	11.03	2.638	23.07

Table 2. Land-use cover (%) in the watersheds of the streams of the area.

Name of stream	Woodland	Partly wooded land	Scrubland	Grazing land	Cropland	Human settlements
Megalo Rema	65.8	5.6			28.1	0.4
Diavolorema / Dadias	84.5	2.2		2.4	10.7	0.2
Provatonas	82.0	8.0	0.4		9.3	0.3
Kamilopotamos	78.1		5.2		16.7	
Lyra	38.9	3.8	12.9	14.4	26.9	3.1
Kazani	70.9	13.9	9.6	1.2	4.2	0.2

Land use and geological substrates

Land use analysis was performed on a panchromatic LandSat picture with a resolution of 15 m taken in 2000. In the uplands, the watersheds of the DNP are mainly covered with woodland (Table 2). Woodland cover exceeds 65% in all of the watersheds except the Kamilopotamos stream, where it covers only 38.9%; this watershed includes extensive farmland and human settlements. However, partly wooded areas, scrubland, pasture and farmland, occupy a notable proportion of the land area in all catchments.

From a phytosociological and floristic aspect, and according to the forest vegetation typology of Greece developed by Dafis (1973), two vegetation zones are represented in the Park: (1) the Para-Mediterranean vegetation zone (*Quercetalia pubescentis*) with the sub-zones *Ostryo carpinion* and *Quercion confertae*; and (2) the zone of beech and fir forests and mountain Para-Mediterranean conifers (*Fagetalia*) with the sub-zone *Fagion moesiacae*.

The petrographic formations of the area are of Tertiary and Quaternary age and belong to the Rhodope massif zone (Demiris 1993, Yordanova 2004). The rocks are mostly basic igneous peridotites, tertiary depositions and pumice tuffs, with limited areas of crystalline schists, metamorphic rocks (gneisses) and acid igneous granites (Katerinopoulos et al. 2004). Using the 1:500,000 scale map of the Institute of Geology and Mineral Exploration (1983) together with field confirmation, made it possible to estimate the extent of the various geological substrates in each of the studied watersheds (Table 3). Igneous formations predominate in the uplands, with schists also being important. Substrates appear vulnerable to surface and gully erosion, as well as to rock weathering, whilst intense fracturing and foliation of the rock material are also widespread.

The torrential environment so formed, produces sediments of both coarse and fine particles, which are transported by water to the low-lying plains. The protective role of the forest cover is, of course, very important on more gentle slopes. This protection is lessened in the higher uplands where slopes are steeper, which results in the transport of more material to the plains (Iliadis et al. 2004a, b).

Stream discharge and estimation of surface erosion

A stream's discharge at a particular point depends on the size of the catchment area above that point, the amount

Table 3. Contribution of various rock types in the watersheds of the DNP streams (%).

Name of stream	Crystalline igneous	Schists	Neogene deposits	Alluvial
Megalo Rema	74.2		25.2	0.6
Dadias	61.0	17.4	21.6	
Provatonas	87.3		8.5	4.2
Kamilopotamos	74.4			25.6
Lyra	88.2		8.9	2.9
Kazani	53.8	28.3	15.9	1.3

Table 4. Discharge of the DNP streams according to the most commonly used calculation methods (Kotoulas 1973, 2001, Viessman et al. 1989).

Name of stream	Area (km^2)	Friedrich(Q_{max})	Countagne (Q_{max})	Valentini (Q_{max})	Average
Megalo Rema	279.15	440.99	501.23	499.67	480.63
Dadias	163.92	335.06	384.09	383.57	367.57
Provatonas	93.65	251.00	290.31	290.31	277.21
Kamilopotamos	63.27	205.01	238.62	238.52	227.38
Lyra	54.84	190.43	222.16	222.10	211.56
Kazani	21.30	116.90	138.45	138.45	131.27

of precipitation falling there, ground water movement, stream modifications such as dams and irrigation diversions, and on the amount of evapotranspiration. Discharge estimates according to various calculation methods are presented in Table 4.

The Universal Soil Loss Equation (USLE, Wischmeier and Smith 1978) is usually applied to estimate loss to surface erosion in the absence of measurement data. Soil loss is considered as the difference between the amounts of soil lost to erosion, minus the amounts deposited, in the same area. Using the USLE we calculated the annual erosion values for the watersheds of the DNP (Table 5).

Conclusions

The catchment basins of the area are characterized by the dominance of crystalline-igneous formations, their extensive forest cover and the intense action of climatic factors upon them. Specifically, the substantial precipitation and the marked temperature fluctuations, especially in upstream areas, are the factors determining the magnitude of the torrential phenomena by fragmenting and foliating the substrate material. The result is that sediments are transported to the plains and finally to the River Evros. The catchments showing the strongest erosion are those of Megalo Rema, Diavolorema, Provatonas and Kamilopotamos.

Forest cover is the only factor that controls sediment production (Kotoulas 1986). Consequently, protection and enhancement of the qualitative features of the DNP forests are deemed necessary. This can be achieved through the application of suitable management measures including silvicultural practices that promote an irregular network of shelter woods and an avoidance of harvest practices that compact or degrade the soil. In situations where management measures do not produce the desirable results, reforestation techniques and small-scale technical works, such as dams and supporting walls, etc., as proposed in Dafis (1976), are suggested for the mountainous parts of the catchments. Very good examples are the small dams constructed in the higher reaches of several small streams in the Dadia forest in 2005 and 2006 by WWF Greece within the framework of a LIFE-Nature project (http://www.wwf.gr/index.php?option=content&task=view&id=355) . Furthermore, two relatively larger dams were constructed on the Lyra and Provatonas streams after 2004 to serve groundwater recharge, irrigation and outdoor recreation needs. Neither catchment faces any important problems concerning surface soil erosion, a fact attributed to the presence of forest cover (Maris et al. 2005, Vasileiou et al. 2006). They also meet the water requirements of the area's extremely important fauna.

Table 5. Estimated annual soil erosion in the watersheds of the DNP

Name of stream	Watershed area (km^2)	General erosion (tonnes yr^{-1})
Megalo Rema	279.15	2140.86
Diavolorema / R. Dadias	163.92	1310.27
Provatonas	93.65	1234.36
Kamilopotamos	63.27	1342.56
Lyra	54.84	796.58
Kazani	21.30	144.81

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