Acta Agrophysica, 2001, 50, 245-251

THE STRUCTURE OF THE LAND COVERING OF ŽUTICA FOREST, CROATIA

B. Vrbek, I. Pilaš

Forest Research Institute, Jastrebarsko, Cvjetno naselje 41, Jastrebarsko 10450, Croatia

A b s t r a c t. This paper presents pedological research in Žutica forest in northern Croatia. The most common soil types found in this area belong to the hydromorphic class (Pseudogley, pseudogley-gley, eugley, fluvisol) except technogenic soils formed as a result of intensive oil exploitation. Some main chemical and physical characteristics of soils are given. For forest productivity the most productive combination of soils are hypogley and pseudogley-gleysol and minimal productivity is in heavy amphygleic soils. An increase of heavy metals occurs in flooded soils in Žutica from nearby agricultural land. A high concentration of active phosphorus and nitrogen can verify the influence of field fertilisers on the forest. Levels of cadmium found in technogenic soils exceed the permitted concentration. A large amount of $CaCO_3$ in relation to natural forest soils can be found in technogenic soils because of quick lime disposal after oil spills and also pH increase and a nutrition and humus decrease.

K e y w o r d s: Žutica forest, soil productivity, heavy metals, water regime.

INTRODUCTION

The Žutica forest covers an area of 6400 ha surrounded by the Lonja - Strug drain canal to the west and Cesma River and agricultural land in the east. The area can be described as being undulating lowland with a distinct microrelief, which consists of micro-elevations and micro-depressions.

Micro-elevations are out of reach of floods, ponds are micro-depressions deluged for longer periods, and micro-recessions are saturated for a shorter period than ponds. The formation of micro-elevations and micro-depressions has been influenced by relative, not absolute heights of the terrain. The highest point of the Žutica forest is in its central area, 101 m, and the lowest on its southern edge, 94.3 m. The highest point within reach of floodwater is 98.4 m. Precipitation water flows from the north and brings additional moisture which remains for extended periods because of forest roads and ditches which form "cassettes" 400 x 600 m in

size. Water retention in those cassettes causes tree decline because of the anaerobic process in the soil [13].

Parent material consists of the following geological cartographic units [10]: sediments of old riverbeds, flood sediments, swamp land sediments and terrace sediments.

The Žutica area is the biggest oil field in Croatia with more than 250 oil wells built by the INA oil and gas company. There are many slush pits and areas for collecting waste. A customary procedure after oil spills in forests is mixing soil with lime so as to correct it.

MATERIALS

The main aims of the research were the determination of soil types, subtypes, varieties and the production of a pedological map at a scale of 1:10 000, the determination of soil quality and productivity. Soil contamination due to oil drilling and related accidents, as well as inflow of heavy metals from nearby fields were also analysed.

Pedological research of the Žutica forest was based on standards for detailed soil cartography using aerial photos and infrared satellite images. The main source of pedological information and locations of the main and supplementary profiles was the vegetation map (1:25000) of the Žutica forest [1]. Fieldwork consisted of digging 180 cm deep pedological pits in the principal forest phytocenoses. Soil profiles were analysed (soil taxonomy, soil samples from genetic horizons were taken, additional deep auger sampling, and photographing). Samples in order to determine the amount of heavy metals were taken from 13 locations at two depths of soil to assess the influence of oil and other sources of pollution on the forest ecosystem. Soil analyses in a pedological laboratory were done: pH (H_2O, N-KCl), $CaCO_3$ with Scheibler's calcimeter, humus with bichromatic method by Alten and Wandrowsky, total nitrogen by Kjeldahl, physiological active potassium and a phosphorus, mechanical analysis (Na-pyrophosphate) and heavy metals (*aqua regia*).

An estimation of the forest soil quality was undertaken with the use of a pedological quality index for every pedosystematic unit [3]. This index was calculated for the following soil characteristics: mechanical composition, structure, permeability, depth, quantity and quality of humus, nutrition (nitrogen, phosphorus, potassium). The theoretical soil quality index is in the range of 0-100, and a larger number denotes better soil productivity.

Significant amounts of lead, zinc and copper in soils of flooded lowland forest areas in northern Croatia are brought from contaminated water flows [5,7,8]. Very high concentrations occur especially after dry periods with low water levels when strong rainfall washes out contamination from fields and roads [9]. Accumulation

and sedimentation of heavy metals and other toxic substances are most common in forest areas that collect sufficient water from water flows.

RESULTS

According to common classification [6,9,12] main forest types were ascertained, in addition to subtypes, varieties, and forms (Table 1).

Table 1. List of pedosystematic units

Type	Subtype	Varietes	Form
Tehnogenic soil - (Deposol)	-	-	-
Pseudogley	on level terrain	Medium deep	Eutric
Fluvisol	Calcareous gleic	Medium deep Deep	Loamy Clayey
Humofluvisol	Medium deep gleic	Calcareous	Loamy Clayey
Semigley	Aluviall	Calcareous	
Pseudogley-gley	-	-	-
Eugley	Hipogley Epigley Amphigley	Mineral Humic	Calcareous Noncalcareous
Subaqval soils (Dy and Sapropel) -	-	-	-
Anthropogenic soil	-	-	-

One can see that 95% of soils are of the hydromorphic class except areas around oil wells and slush which belong to the automorphic class, that is, technogenic soils. Subaqual soils are present in areas with active ponds and old waterways where water remains for a long period of time or for a whole year. The main characteristics of soil types are given in Table 2.

Average results of heavy metals (Cu, Pb, Zn, Cd) collected at two depths from 13 different locations in Žutica are shown in Table 3.

In terms of soil geography, the relationship between the micro- and meso-reliefs of the researched area and infrastructure built in Žutica is good. Above a height of 98.4 m, where there is an absence of floods (or flooding is very rare) typical lowland pseudogley soils, pseudogley-gleysoils and some epigleic soils can be found. This is because of stagnation of precipitation water in micro depressions. In the

Table 2. Average chemical and physical characteristics of some forest soils in Žutica

Soil type	Layer	Depth	pH	pH	P_2O_5	K_2O	Humus	Total	C/N	Clay
		(cm)	H_2O	KCl	mg/100 gr		(%)	N (%)	(%)	
Deposol	I	5-10	7.7	7.5	92.9	6.0	3.44	0.15	13.33	14.2
	II	11-30	8.2	7.6	2.9	8.8	1.19	0.05	13.80	20.9
	III	31-75	7.8	7.4	3.1	7.8	2.34	0.10	13.60	25.6
Pseudogley	A	6-11	5.45	4.2	13.7	33.5	9.83	0.51	11.01	22.22
	E	6-45	4.90	3.73	4.9	5.6	2.04	0.11	10.29	20.65
	B	32-85	5.53	3.73	3.4	5.9	-	-	-	24.8
Pseudogley-gley	A	1-10	5.85	4.1	14.1	17.9	6.08	0.34	12.35	24.2
	E	11-32	5.30	3.8	15.5	5.9	2.48	0.13	11.09	26.4
	B	33-60	5.95	4.0	2.8	5.5	-	-	-	29.5
Eugley, hipogley	A	0-20	7.5	6.6	6.8	12.9	7.32	0.37	11.51	33.9
	Gso	21-45	6.9	5.1	0.7	6.6	-	-	-	38.4
	Gr	46-78	7.0	5.4	2.4	5.4	-	-	-	31.4
Eugley, amphygley	A	0-25	5.9	4.7	13.2	24.1	14.67	0.66	10.92	50.5
	Gr	26-50	6.9	5.0	6.8	9.8	4.61	0.27	9.98	59.9
	Gr, so	51-80	7.6	6.0	5.2	6.6	-	-	-	46.4

Table 3. Heavy metals contents at two depths

	Pb	Cu	Zn	Cd
		μg/1 g (Aqua regia)		
		Depth 0-5 cm		
Average	32.4	11.1	69.0	1.7
min	26.0	7.0	56.0	1.0
max	37.0	23.0	107.0	3.1
		Depth 6-15 cm		
Average	28.8	9.3	65.7	1.7
min	24.0	6.0	53.0	1.1
max	42.0	22.0	108.0	2.8

northern part, epigleic soils with a heavier mechanical composition and some amphygleic soils are predominant. In the western part, the Lonja river overflows excess water in Žutica and with it conveys carbonate sand and unclean sediments onto the soil's surface. These profiles are very often carbonate in their entire depth or up to 40 cm. Besides fluvisols, there are some epigleic soils in micro-depressions. In this area, floods do not persist for long and water moves south to the lowest terrain. In the southern area heavier soils can be found, the most common being amphygleic soils with more than 50% of clay in their texture. Ecological

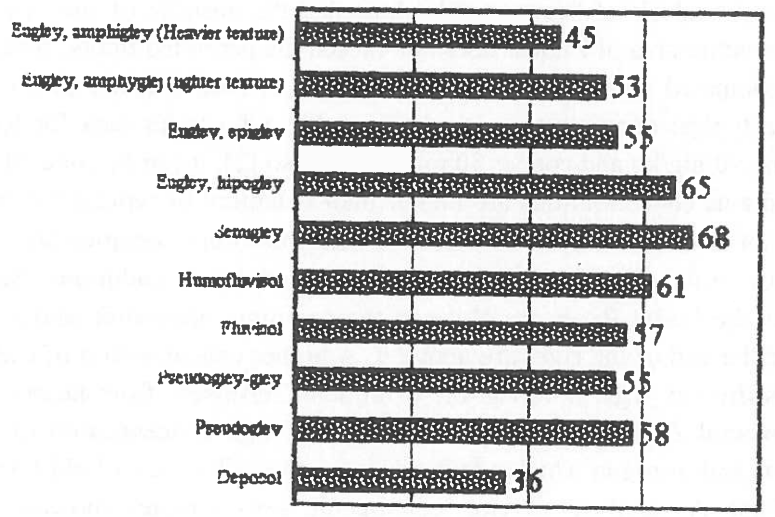

Fig. 1. Soil quality index.

conditions for survival of forest vegetation in these types of soil are minimal and therefore only meadow vegetation with sporadic willows or ash are present. Terrain in the eastern part of Žutica is once again elevated and pseudogley - gleysol and some minor inclusions of humofluvisol with amphygleic soil in depressions are common. The most productive combination of soils are hypogley and pseudogley-gleysol with an excellent air-water relationship and nutrition quantity. Adjacent to oil wells, slush pits, pipelines and roads, technogenic soils are commonplace.

DISCUSSION AND CONCLUSIONS

According to the calculated estimations, it can be concluded that soil capability for forest productivity varies significantly. Predominant productivity is in pedosystematic unit with Pseudogley - gleysol and eugley, hypogley, mineral, carbonate. Minimal productivity is in units with heavy amphygleic soils with a large percentage of clay and with very low permeability which are sites for willows, reed and, in some areas, ash. Other cartographic units are in between. Forest management in areas with heavy soils can be very difficult, in particular in the establishment of new tree populations, as well as in the case of incorrect sylvicultural practice in older tree populations. Improvement of site conditions is very difficult and needs enormous financial support.

Chemical analysis of heavy metals show that the quantity of zinc, cadmium and lead in entire area of Žutica does not exceed the permitted limits. If these results are compared with the natural concentration of lead of about 10-20 mg/kg [11] and a typical concentration according to [4], who states data for lead, 35 mg/kg, zinc 90 mg/kg and copper 30 mg/kg and also [2], it can be concluded that copper and zinc concentrations are higher than is natural or typical but in most cases do not exceed the level of tolerable concentrations. Samples taken from technogenic soils exceed the allowed concentration for cadmium. Samples taken near the Lonja River are close to the cadmium allowance and samples taken near the end of the river are above it. A higher concentration of cadmium can be justified as regards to run-off of mineral fertilisers from nearby fields which surround Žutica. All samples had a very high concentration of active phosphorus and nitrogen which can account for the influence of field fertilisers on the forest. An analysis of two technogenic soils samples showed a large amount of $CaCO_3$ in relation to natural forest soils because of quick lime disposal after oil spills. The mechanical composition of these soils has also changed from light clay or clayey loam to sandy loam because of sand deposition after rectification, pH increase and nutrition and humus decrease. According to these analyses, it can be concluded that an increase of heavy metals occurs in flooded soils in Žutica. The impermeability of heavy soils causes retardation and accumulation of heavy metals in the upper, microbiologically active layer of soil, and poor nutrition of trees. On the other hand, the lighter mechanical composition of alluvial, humic fluvisols and gleysols absorbs fewer heavy metals but are then accumulated in micro-depressions after floods.

REFERENCES

1. **Baričević D.:** Ecological - vegetation characteristics of Žutica forest. MSc. Thesis, Faculty of Forestry, Zagreb, 1998.
2. **Brune H., Elinghaus R.:** Schwermetalllgehalte in hessischen Boden. Landw. Forschung Trier, 38, 338-349, 1981
3. **Ćirić M., Miloš B., Palac J.:** The concept of soil quality index determination, Zemljište i biljka, 22, 1-2, 87-98, 1982.
4. **Friedman B.:** Environmental Ecology, Toxic Elements. Acad. Pres., London, 53-63, 1989.
5. **Komlenović N., Mayer B., Rastovski P.:** Import of heavy metals by contaminated waterflows in soils of lowland forests of Eastern Slavonia. Šumarski. list br., 11-12, 131-149, 1991.
6. **Martinović J.:** Soil science and enviromental protection. Priručnik za inženjere, Zagreb, 1997.
7. **Mayer B.:** Preliminary results of heavy metals research in soils of lowland forest of the Pokupsko Basin. Šumarski. list br., Zagreb, 1-2, 19-27, 1987.
8. **Mayer B., Pezdirc N.:** Heavy metals (Pb, Zn, Cu) in soils of lowland forests in the north-west part of Croatia, Šumarski, list br., 6-8, 251-260, Zagreb, 1990.

9. **Mayer B.:** The importance of waste water recycling in order to avoid ecotoxical pollution of soils in northern Croatia. Rad. šum. inst., Zagreb, 1, 95-104, 1991.
10. **Pikija M.:** Geological map 1:100 000. Saveznog geološkog zavoda, Beograd., 1987.
11. **Smith H.W.:** Air Pollution and Forests, Springer Verlag, New York, 1981.
12. **Škorić A., Filipovski G., Ćirić M.:** Soil classification. Academy of Science of Bosnia and Herzegovina, Special Edition, Sarajevo, 1985.
13. **Vajda Z.:** The influence of hydromelioration on health condition of forests in Posavina, Jugosl. akad. znan. i umjet., centar za znan. rad Vinkovci, Savjetovanje o posavini, 363-369, Zagreb, 1971.