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Chapter X

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Water level and quality in ombrophilous forest wetlands in Lasy Rychtalskie Promotional Forest Complex

THE ROLE OF FORESTS AND WETLANDS IN THE PROTECTION OF WATER RESOURCES

One of the most significant problems in contemporary climatology of climate warming. Although not confirmed beyond any doubt, still numerous factors indicate climate change within the recent, relatively short period of time. Opinions presented in literature on the subject vary considerably – from extreme positions, forecasting disastrous effects in many regions worldwide to the claim that "the problem of climate change has been exaggerated against all proportions" (KLEMES 1993).

Primary elements of climate, i.e. air temperature and precipitation, undergo natural changes over time. These are diurnal, season, annual and multi-annual fluctuations, caused mainly by the Earth's revolution, the rotation of the Earth around the Sun as well as changes in solar activity (with estimated intervals of 11, 22, 35, 90 and 180 years) (BORYCZKA 1993; PETIT et al. 1999; WOŚ 1994; MILER, MILER 2005). In the last 200 years temperature and precipitation additionally undergo anthropogenic changes, resulting from an increased content of atmospheric dust (absorption of solar radiation), condensation nuclei of water vapour and greenhouse gases (the greenhouse effect in the atmosphere), or other forms of human activity (drainage, considerable urbanization etc.).

While natural factors of climate change exhibit periodical (cyclic) changes, the anthropogenic factor of climate change is characterized by a constant change trend, i.e. the linear trend. Thus, short-term time trends of climate change depend on cyclicity of natural factors, an increase in atmospheric pollution and an unmeasurable factor connected with randomness.

It is remarkable that if there were no greenhouse effect at all the mean temperature of the Earth's surface would be -18°C (KUNDZEWICZ 2007).

Climate change in some regions of Poland may lead to a reduction of wetlands, further drop of ground water table and intensified extinction of species connected with wetlands. Deep transformations are expected to occur in the composition and health condition of stands. Differences between evolutionarily developed adaptations of Polish tree ecotypes to the climate we have had to date and to new

climatic, hydrological and edaphic conditions will intensify. Among other things, we need to focus here on riparian forests (TOMIAŁOJĆ 1995).

In studies concerning the role of forest cover in the water balance of catchments some authors stressed considerable retention capacity of forested areas. This capacity influences an increased total runoff from catchments with higher forest cover in dry years and its reduction in wet years, as well as increased runoff in summer half-years and its reduction in winter half-years (OSTROWSKI 1965; KOSTURKIEWICZ 1976; TYSZKA 1995).

In studies on catchments with different degrees of forest cover Miler et al. (1999) showed high retention capacity of catchments with a higher forest cover. This is evidenced by very uniform courses of monthly flows and relatively limited monthly changes in retention. Also in long-term studies conducted by the Department of Water Management, the Forestry Research Institute, under conditions found in lowland catchments a stabilizing effect of forest cover may be observed on water runoff from the area of the catchments, mainly a reduction of its uneven distribution (SIENKIEWICZ et al. 1995).

Many foreign authors found a reduction of mean and maximum flows from forest catchments in relation to unforested catchments in the summer period (HARR 1967; SWANSON, HILLMAN 1977; HARR et al. 1979; HELVEY 1980; SWIF, SWANK 1981; KEPPELER 1986, 1998; KEPPELER, ZIEMER 1990; CALDER 1992; FAHEY 1994; JONES, SWANSON 2001; CASSIE et al. 2002; GUSH et al. 2002).

Sustainable water management thanks to its supply in adequate amounts, quality and time should promote permanent, sustainable development of a multipurpose forest economy, biodiversity of species and landscape types, preservation of valuable specimens of flora and fauna as well as habitats (CIEPIELOWSKI 1999a). When trying to care for water resources we need to take into consideration water requirements of the forest site, not only pertaining to the overall amount of water available to plants, but also the adaptation of its supply to the annual and multiannual cycles of vegetation development, as well as maintenance of adequate water fertility, sufficient to meet nutrient requirements (CIEPIELOWSKI 2004).

The need for water retention may be assessed by:

- Observations of stands,
- Observation of trends in changes of ground water tables (a rapid lowering of the water table in the vegetation season and maintenance of such ground water table over a longer time period, inadequate for the forest site type, constitutes an indicator of transformation capacity of ecosystems),
- Observation of trends in changes of water resources in water reservoirs and wetlands,
- Analysis of changes of retention in the water balance of a hydrographic unit (CIEPIELOWSKI 1999b).

When talking of small water retention in forests, both in the quantitative and qualitative aspects (autopurification of waters), it needs to be remembered that its primary role is not to accumulate usable water reserves (adequate for direct economic use), but to change site water content, to raise ground water table and change the microclimate. For this purpose a more important role is played by the total area of even very shallow water bodies, than a bigger volume of water,

contained e.g. in one reservoir (CIEPIELOWSKI et al. 1995). This means that from the nature point of view for an increase in the internal water cycle it is more advantageous to have a bigger number of small water bodies than one big reservoir (KĘDZIORA 1995).

Until recent times forest hydro-amelioration was conducted only in excessively wet sites. At present we may observe the problem of lowering ground water tables, resulting in a deterioration of water relations, as well as the disappearance of wetlands. The primary goal of water retention is to stop the degradation of water relations threatening the stability of forests. Water retention in forests should contribute to an increased moisture content of sites in accordance with the forest site type, enhanced biodiversity, limitation of erosion processes and alleviation of consequences of climate change. The goal of retention is also to satisfy water requirements of animals and birds, to provide water for forest control, to supply water for forest nurseries, farms, fish farming and to enhance recreation value of forests (CIEPIELOWSKI 1999b). At least a partial restoration of previous water conditions in forests would initiate mechanisms of slow self-regulation of species composition of phytocenoses and diversification of the forest environment. At each stage of forest economy we may undertake various activities aiming at an improvement of water relations. Their goal should be first of all to restore in the forest ecosystems an adequate role of moist and swampy sites (CIEPIELOWSKI et al. 2000).

The indispensable role of wetlands in the natural environment may not be underestimated. Thus it is crucial to maintain their natural or semi-natural condition. For this purpose it is necessary nationwide to:

- Counteract excessive or unjustified outflow of water from such areas,
- No longer regulate rivers or smaller watercourses,
- Rationally use water resources,
- Reduce the application of mineral fertilizers and crop protection products in the immediate vicinity of wetlands,
- Maintain or restore extensive use of semi-natural ecosystems,
- Cease afforestation of valuable non-forest wetlands,
- Reduce the exploitation of gyttja and peat (digging peat only for therapeutic purposes),
- Counteract fragmentation of wetlands at the stage of spatial management planning,
- Incorporate protection of wetlands into spatial planning processes and cover “live” wetland ecosystems with legal protection (RYCHARSKI www.gis-mokradla.info).

FOREST WETLANDS IN LASY RYCHTALSKIE PROMOTIONAL FOREST COMPLEX

The term “forest wetlands” is used to define areas of strongly damp forest ecosystems, in which we may roughly include the areas which according to stand description are classified as boggy coniferous forest (Bb), boggy mixed coniferous

forest (BMb), boggy mixed forest (LMb), alder swamp forest (Ol), ash-alder swamp forest (OlJ) and riparian forest (Lł). The classification of a given area to wetlands is finally determined by the position of ground water table not deeper than 1 m from the ground surface (apart from watershed areas).

Promotional Forest Complexes (Leśne Kompleksy Promocyjne – LKP) are formed in order to promote sustainable forest economy and nature resources in forests. These complexes include also "Lasy Rychtalskie" (with an area of approx. 48 thousand ha, established in 1996) comprising forests of two forest divisions of the Regional Directorate of State Forests in Poznań: Antonin and Syców, as well as forests of the Forest Experimental Station in Siemianice (Fig. 1).

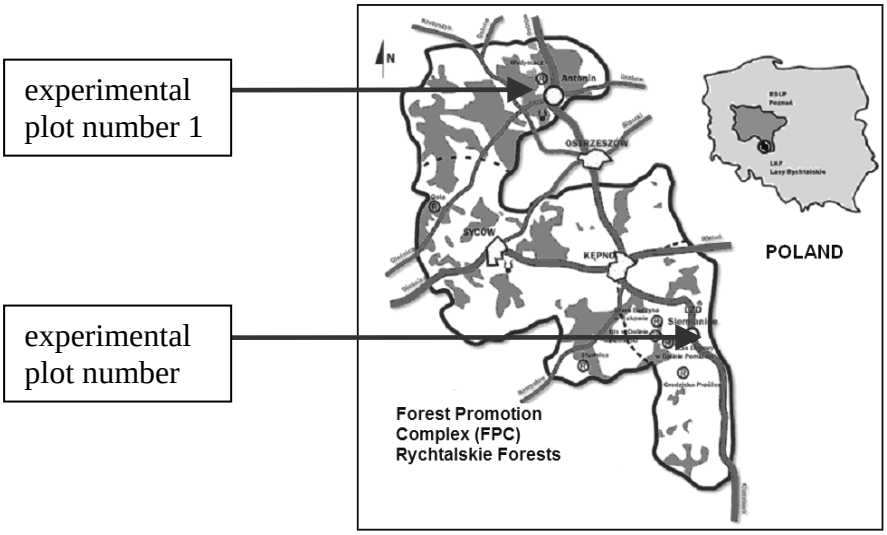

Fig. 1. "Lasy Rychtalskie" Promotional Forest Complex and experimental plot location (http://www.lasy.ipolska.info/index.htm)

Fig. 2a. Soils' types on the experimental plot number 1

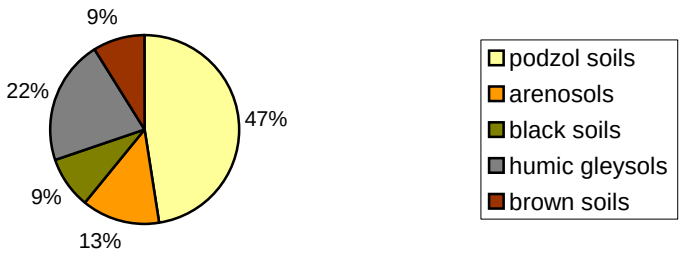

Fig. 2b. Soils' types on the experimental plot number 2

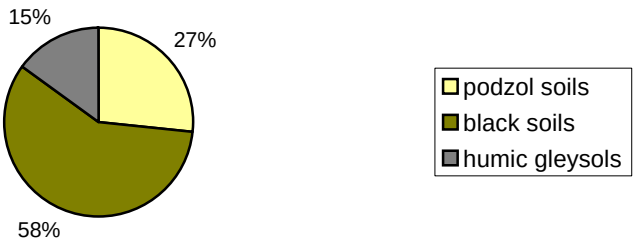

Fig. 2c. Soils' types on the experimental plot number 3

Fig. 3. A ditch collecting and discharging water from catchment number 1
(photo by A. Krysztofiak-Kaniewska)

Fig. 4. Water gauging stations on ditch – the profile closing catchment number 2 (photo by A. Krysztofiak-Kaniewska)

Fig. 5. A ditch collecting and discharging water from catchment number 3 (photo by A. Krysztofiak-Kaniewska)

According to the natural-forest classification the Lasy Rychtalskie Promotional Forest Complex is located in the 3rd Wielkopolska-Pomerania Region, the 9th Natural Forest Province – the Żmigród-Grabów Basin, and in the 5th Silesian Region, the 2nd Wrocław Province. The proportions of dominant forest sites are as follows: Antonin – fresh coniferous forest (Bśw) 48%, Syców – fresh mixed forest (LMśw) 33% and fresh mixed coniferous forest (BMśw) 31%, as well as Siemianice

– fresh mixed forest LMśw 39% and fresh mixed coniferous forest BMśw 22%. Moist sites (Bb, BMb, LMb, Ol, OlJ, Lł), found under the immediate influence of ground water there are the following areas: Antonin 1.2%, i.e. 239 ha, Syców 1.0%, i.e. 221 ha, and Siemianice 6.3%, i.e. 375 ha forest area.

After a detailed analysis of materials collected from forest divisions, site inspections, analysis of large-scale maps (1:10 000) etc. three experimental plots were selected for detailed studies, i.e. microcatchments, which are situated so that they are almost completely located on forest wetlands (comprising 8.58, 30.61 and 32.00 ha). This was the crucial point of the experiment, since the aim, among other things, was to estimate runoff from such areas. When we discuss ombrogenic wetlands we mean wetlands which origin (water supply) is connected with atmospheric precipitation, differently than in case of flow valley wetlands. The proportions of individual types of soils in catchment areas are presented in Figures 2a, b, c. These soils are formed from sands (catchment no. 1) or sands and silts (catchments nos. 2 and 3), (Forest Management Plans for the Antonin Forest Division and the Siemianice Experimental Forest Division).

In the microcatchments an observation bore-holes were made. Work on each of them was completed at the drilling to the ground water table. In the bore holes, PCV pipes with a diameter of 50 mm were placed. From the top wells were sealed with a PCV cork to prevent possible contamination from getting into the pipe. These wells represented three location variants: in watershed areas, in slopes and in valleys of the catchments. In 2004 systematic field studies were initiated, including e.g. measurements of ground water levels (51 wells) and measurements of water stages in watercourses (3 Thomson triangular weirs) as well as periodical analyses of water quality. Ground water levels were measured once a week and the recorded result was read accurate to ±0.5 cm. The area of each microcatchment was drained by a ditch collecting and discharging water from the analysed plots. Water gauging stations were established on all ditches in the profiles closing the catchments. Water depth in the ditches was measured once a week and the readings were accurate to ±0.5 cm. In the summers of 2005 and 2006, due to a considerable lowering of ground water tables, deeper foundation of wells was necessary.

Weather conditions were evaluated in the period of the study on the basis of data from the Siemianice Station, situated in the central part of Lasy Rychtalskie Promotional Forest Complex, where measurements have been taken since 1975. The analysis included the hydrological year of 2004/2005, which in terms of total precipitation (514.5 mm) and mean annual temperature (8.6^{o}C) may be considered as average, since deviations of the above values do not exceed 10% respective means. Individual components of resource balance were as follows: precipitation based on standard measurements Hellmann's rain gauge (on above named station), evapotranspiration was calculated according to Konstantinow, runoff based on water stages at weirs, change in retention was estimated based on changes in ground water stages in wells (MILER et al. 2004-2007, 2005).

During field trips, the total of 47 samples of ground and surface waters were collected from monitoring points selected on the experimental areas. All surface and ground water analyses were conducted in The Department of Water and Soil Analysis the Adam Mickiewicz University in Poznań. The way in which water

samples were taken, containers for samples, storage and transport were carry out according to proper standards (PN-76/C-04620/03, PN-87/C-04632/01, PN-87/C-04632/02, PN-88/C-04632/03, PN-88/C-04632/04, PN-EN ISO 5667/3), (DOJLIDO 1995).

The obtained research results were compared with the Quality criteria and ways of estimate of ground water described in the Directive of the Minister of Environment of July, 23rd 2008 (Dz. U. Nr 143, poz. 896) and the Quality criteria uniform parts of surface water described in the Directive of the Minister of Environment of August 20th 2008 (Dz. U. Nr 162, poz. 1008).

SURFACE AND GROUND WATER IN FOREST WETLANDS

Annual runoff from the analyzed wetlands is relatively small, approx. 4% total annual precipitation (2004/2005). Periodically watercourses disappear – for example in two years runoff was only recorded during 202 days (15.11.2004-5.6.2005) and 192 days (1.12.2005-10.6.2006), respectively. Even relatively considerable summer precipitation of 41.2 mm (22 - 26.8.2005) or 66.4 mm (3-9.8.2006) did not result in such an elevation of water stages in watercourses to observe runoff at weirs. In the period of analysis no typical floods were observed, i.e. those based on surface flow, which in the analyzed catchments at torrential precipitation should last at least several hours. Observed floods – elevated flood runoff or rain runoff are fed by subsurface and underground runoff. The above indicates a relatively very high retention capacity of analyzed wetlands (the stand, litter, depressions, soils).

Average ground water levels (51 wells) lie rather shallow at a depth of 97.5 cm below the ground, at a standard deviation of 55.5 cm. The depth of the ground water table changes in the analyzed wetlands relatively regularly, with no marked phase shifts. Moreover, short periods of water stagnation on the ground surface were observed.

Based on data from Siemianice (1975-2006) time trends were calculated – annual changes for total annual precipitation and mean annual temperatures for individual months and the whole year, respectively (Table 1). These trends are on the usually acceptable materiality level limit $\alpha = 0.05$ or they are statistically irrelevant on this level. In connection with this all analyses mentioned below are hypotheses.

The positive annual trend for mean annual air temperatures (+0.041^{o}C/year) will obviously stimulate an increase in evapotranspiration, but as it commonly known it depends on many factors, one of which is e.g. availability of water. Thus in the forecast of changes in water relations of analyzed areas it was assumed that evapotranspiration will not undergo significant changes. Runoff from the analyzed wetlands is so slight that its changes may be omitted in these forecasts.

Finally, the forecast of changes in water relations on the analyzed wetlands of the Lasy Rychtalskie Promotional Forest Complex, manifested in changes of ground water levels, was based on the negative annual trend of total annual precipitation (-1.573 mm/year).

Table 1

Yearly changes for months and for year in period 1975-2006 of total precipitation and mean air temperature

Months	Yearly changes	
	Precipitation [mm]	Air temperature [^{o}C]
XI	-0.06	+0.01
XII	+0.05	-0.01
I	-0.66	+0.02
II	+0.82	+0.09
III	+0.07	-0.01
IV	-0.04	+0.08
V	+0.40	+0.05
VI	-0.57	+0.07
VII	+0.08	+0.07
VIII	-0.30	+0.10
IX	-0.75	+0.02
X	-0.60	+0.01
Year	**-1.573**	**+0.041**

Authors assumed, that significant changes in wetland ecosystems will occur if the mean ground water level falls by approx. 50 cm (50% present mean ground water level), as a result of decreasing total annual precipitation it may be estimated that it will happen after approx. 100 years. At the adoption of the above mentioned assumptions and soil porosity in the aquifer of 34%, after 100 years decreasing precipitation will cause a lowering of ground water levels on average by 46.3 cm. Such an estimate may be found objectionable, since it is based on only a 30-year long series of observations of precipitation at Siemianice and not taking into consideration the cyclicity of changes in precipitation.

Obviously the 100 years calculated above is only an estimate. However, it reflects the range of magnitude of a period, after which such changes in water relations in these wetlands are possible that these marshes may change in character and cease to be excessively moist sites.

WATER QUALITY IN FOREST WETLANDS

Results of analyses of quality of surface and ground waters are listed in Tables 2, 3 and 4. It may be observed from the presented results that surface waters were of a slightly better quality. This dependence was confirmed, irrespective of the season in which water was analyzed. In surface waters the parameter with the poorest value in all seasons was chemical oxygen demand. The highest level was recorded in the spring season of 2006. Poor quality of ground waters was determined by inorganic elements such as ammonia and soluble phosphates. Depending on the seasons they reached values characteristic of quality classes III, IV and V (being the worst in spring of 2006).

Table 2

Mean range of chemical properties of surface and ground water samples analysed at autumn season 2005

Properties and units		Surface water	Ground water
Conductance	μS/cm	520 [I]	656
Reaction (pH)	-	6.35	6.77 [I]
Chemical oxygen demand with $K_2Cr_2O_7$	mg O_2/l	54.4*	62.5
Ammonium	mg NH_4/l	1.43 [II]	3.05 [V]
Nitrite nitrogen	mg NO_2/l	0	0.043 [II]
Nitrate nitrogen	mg NO_3/l	0 [I]	1.01 [I]
Sulphates	mg SO_4/l	55 [I]	96 [II]
Chlorides	Mg Cl/l	45 [I]	27 [I]
Dissolved phosphates	mg PO_4/l	0	1.84 [IV]
Total phosphorus	mg P/l	0.08 [I]	0.81
Total alkaline	mg $CaCO_3$/l	-	-
Potassium	mg K/l	2.1	8.0 [I]
Sodium	mg Na/l	9.9	26.6 [I]
Calcium	mg Ca/l	69.5 [II]	82.2 [II]
Magnesium	mg Mg/l	19.7 [I]	13.5 [I]
Total hardness	mg $CaCO_3$/l	297	259
Carbonate hardness	mval/l	2.9	4.13

notation: I – quality class I, II – quality class II, III – quality class III, IV – quality class IV, V – quality class V; * – values' limits not established

Table 3

Mean range of chemical properties of surface and ground water samples analysed at spring season 2006

Properties and units		Surface water	Ground water
Conductance	μS/cm	402 [I]	429
Reaction pH	-	6,45	5,96 [IV]
Chemical oxygen demand with $K_2Cr_2O_7$	mg O_2/l	100,7*	54,0
Ammonium	mg NH_4/l	1,20 [II]	2,57 [IV]
Nitrite nitrogen	mg NO_2/l	0,02	0,42 [III]
Nitrate nitrogen	mg NO_3/l	1,77 [I]	4,9 [I]
Sulphates	mg SO_4/l	61 [I]	68 [II]
Chlorides	mg Cl/l	19 [I]	25 [I]
Dissolved phosphates	mg PO_4/l	0,2	1,23 [IV]
Total phosphorus	mg P/l	0,12 [I]	0,49
Total alkaline	mg	2,5	2,07
Potassium	mg K/l	1,7	2,79 [I]
Sodium	mg Na/l	10,8	11,9 [I]
Calcium	mg Ca/l	45,4 [I]	46,3 [I]
Magnesium	mg Mg/l	17,9 [I]	14,9 [I]
Total hardness	mg	186	165
Carbonate hardness	mval/l	-	429

notation: I-V – quality classes as described in table 2; * – values' limits not established

Table 4

Mean range of chemical properties of surface and ground water samples analysed at summer season 2007

Properties and units		Surface water	Ground water
Conductance	μS/cm	1123 [II]	887
Reaction pH	-	5,78	5,76 [IV]
Chemical oxygen demand with $K_2Cr_2O_7$	mg O_2/l	47,9 [w.g.n.u.]	51,0
Ammonium	mg NH_4/l	1,38 [II]	2,60 [IV]
Nitrite nitrogen	mg NO_2/l	0	0,0025 [I]
Nitrate nitrogen	mg NO_3/l	1,6 [I]	0,6 [I]
Sulphates	mg SO_4/l	-	-
Chlorides	mg Cl/l	-	-
Dissolved phosphates	mg PO_4/l	0	0,94 [III]
Total phosphorus	mg P/l	0,91 [w.g.n.u.]	3,06
Total alkaline	mg $CaCO_3$/l	-	-
Potassium	mg K/l	1,7	7,1 [I]
Sodium	mg Na/l	-	-
Calcium	mg Ca/l	-	-
Magnesium	mg Mg/l	15,0 [I]	33,7 [II]
Total hardness	mg $CaCO_3$/l	-	887
Carbonate hardness	mval/l	-	5,76

notation: I-V – quality classes as described in table 2, w.g.n.u. – values' limits not established

As a result of conducted analyses no significant processes of anthropogenic pollutants were found in surface and ground waters of ombrogenic forest wetlands in the Lasy Rychtalskie Promotional Forest Complex.

Also other analyses conducted within the framework of this study and which results are not described in this paper (e.g. dioxin monitoring, magnetometry) confirmed the absence of considerable amounts of pollutants, particularly heavy metals and biogens in those areas (MILER et al. 2004-2007). However, in the longer perspective we need to consider elevated concentrations of pollutants in waters in connection with the forecasted water deficit, resulting from the downward trend for total annual precipitation. However, this is a rather long-time perspective.

CONCLUSIONS

Wetland ecosystems in the Lasy Rychtalskie Promotional Forest Complex, being of particular value for biodiversity, are threatened in a relatively near future with water deficit. It may be estimated that after approx. 100 years these forest sites, currently classified as marshy, will become overdried. Pragmatically speaking it should be attempted to completely stop the runoff of water from these areas. This will somewhat slow down the overdrying process, but retention of slight runoff from

these areas (approx. 4% total annual precipitation) in a longer period of time will not be able to stop the degradation of wetlands.

Ground waters in the analyzed ombrogenic wetlands are throughout the year of a slightly poorer quality than surface waters. In the latter high chemical oxygen demand values indicate high pollution, particularly in the spring season. In turn, in ground waters the primary pollutants are ammonia and soluble phosphates. The present relatively good purity state of surface and ground waters in these areas may deteriorate as a result of a deepening deficit of precipitation.

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