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SPATIAL VARIABILITY OF ACTUAL SOIL MOISTURE, pH AND BULK SOIL ELECTRICAL CONDUCTIVITY WITHIN THE AREA OF THE FORMER OLESZEK MILL POND BASIN**

Abstract. The aim of this study was to evaluate the spatial variability of actual soil moisture (SM_a), pH and bulk soil electrical conductivity (EC_a) of soil surface horizons in the former Oleszek Mill Pond basin. Water mills are one of the first hydro-technological constructions in Poland. They appeared at the turn of the XI and XII centuries and became common in the XIII century. Construction and operation of water mills had influenced the transformation of the natural environment around them. Especially subject to transformations were the relief and water conditions. This research includes measurements of SM_a, pH and EC_a in soil surface horizons (0–30 cm). Actual soil moisture and bulk soil electrical conductivity were measured in situ using TDR Field Operated Meter – Easy Test FOM/mts and pH using CP-105 ELMETRON field pH-meter in 49 points located within the former mill pond basin. Differentiation of moisture, pH, and bulk soil electrical conductivity shows variability of the surface layer of the sediments accumulated in the former mill pond basin. On the other hand, the surface layer of the sediments does not show differences with regard to the division of the basin on the proximal, middle or distal part. The observed variability of spot-occurring extreme values is associated with the microrelief formed after the period of mill pond functioning (levees) or caused by local factors strongly modifying the surface of the biogenic plain within the basin, such as the seepages of water at the edge of the former water body.

Water mills are one of the first hydro-technological constructions in Poland. They appeared at the turn of the XI and XII century and became common in the XIII century [6]. The energy of the water was not used for grinding grain only, but also in fulleries, granaries, mills, tanneries and sawmills [1, 25]. Construc-

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tion and operation of water mills had influenced the transformation of the natural environment around them. Especially subject to change were the relief and water conditions [25].

Research on the former water mills is mainly concerned with the analysis and assessment of the impact of location factors, both natural and anthropogenic [3, 4, 13]. Many papers focus also on changes in the river valleys systems. These changes have occurred as a result of setting and subsequent removal of water mills [21, 14]. Attention is also drawn to activities involving the restoration of ponds and their use for the, so called, small retention [21, 18].

Mill pond sediments are studied mainly by geomorphologists and sedimentologists. They use these sediments as an indicator of anthropogenic environmental changes [15–17, 25–27, 30]. Sediments of small and large reservoirs are also studied due to their agricultural use [8, 22, 28, 29]. Pedological research is concerned mainly with sediments and soil developed in fish ponds [9, 10, 19, 20].

The aim of this study was to evaluate the spatial variability of actual soil moisture (SM_a), pH and bulk soil electrical conductivity (EC_a) of soil surface horizons in the former Oleszek mill pond basin.

MATERIAL AND METHODS

The study area included the former Oleszek Mill Pond basin. It was located on the eastern branch of the Struga Rychnowska river. The river uses a subglacial channel in the western part of the Chełmińskie Lake District, approximately 20 km northeast of Toruń (Fig. 1 – I and II). This part of the channel is bordering a morainic plateau of the east and outwash plain of the west.

The history of the bottom sediments of the basin begins with a natural body of water that existed since approximately 10 700 years BP until the XVI century. The river mill operated from the middle of the XVIII century until the 1920s. After this period, it was used as a storage reservoir for about 30 years and later drained. In 1924, the pond covered the area of 2.60 ha and was 615 meters long [25].

The research was carried out in November of 2013. It included measurements of actual soil moisture (SM_a), pH and bulk soil electrical conductivity (EC_a) in soil surface horizons (0–30 cm). SM_a and EC_a were measured in situ using the TDR Field Operated Meter – Easy Test FOM/mts and pH using CP-105 ELMETRON field pH-meter in 49 points located within the former mill pond basin (Fig.1 – C). The time-domain reflectometry method is recognized as a proper non-destructive approach to in situ measurements of the water content and electrical conductivity. It seems especially attractive for spatial variability studies involving soils [5]. However, there are still several problems associated with using this method, especially when working with wet, saline soils [24]. The position of every point was determined with an accuracy of 3 meters using the GARMIN GPSmap 60 CSx receiver.

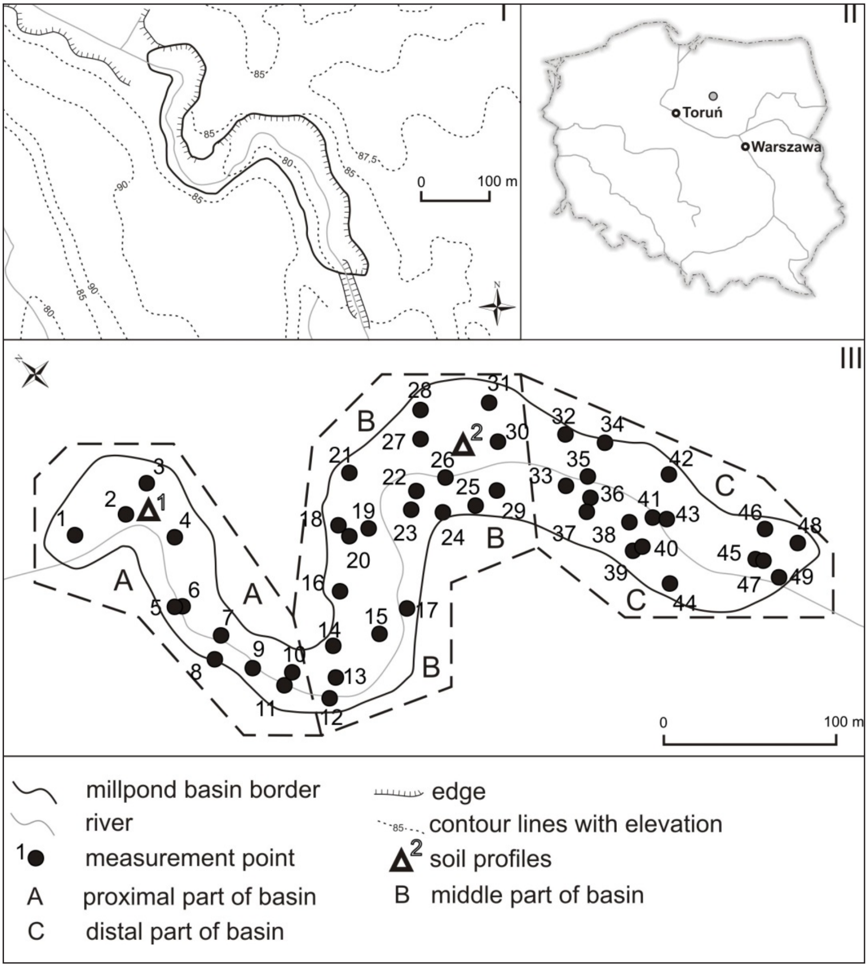

Fig. 1. Topography (I) and location (II) of the study site, location of measurement points (III).

The basin was divided into three parts: proximal part (A), middle part (B) and distal part (C), starting from the inflow of the Struga Rychnowska river (Fig. 1-III) based on its morphological features. Standard deviations and means were calculated for SM_a, pH EC_a, for every part of analyzed basin.

The soil cover of the analyzed basin is dominated by Histosols developed from muds in the middle and distal parts, while Fluvisols or others with fluvic material developed from mineral and mineral-organic sediments accumulated in proximal part. Basic properties of two examples of soils from the proximal part (Profile 1) and the middle part (Profile 2) of the basin are shown in Table 1. The soils were classified according to WRB 2014 [12]. The symbols of soil horizons are given according to the Guidelines for Soil Description [7]. The samples were taken from selected soil horizons. Standard soil analyses were performed using the following methods [2]:

– organic carbon content – using sample oxidation in the mixture of $K_2Cr_2O_7$ and H_2SO_4;

– $CaCO_3$ content — Scheibler volumetric method;

– grain size distribution —hydrometric and sieve method;

TABLE 1. PROPERTIES OF SOILS

Genetic horizon	Depth [cm]	Textural class	Corg [%]	pH		$CaCO_3$ [%]
				H_2O	KCl	
Profile 1 – Greyzemic Fluvic Gleyic Phaeozem (Abruptic. Nechic)						
A(p)	0–27	sandy loam	3.1	7.8	7.3	1.8
A	27–42	loam	2.38	8.3	7.5	3.7
A/Cg	42–65	loamy sand	0.695	8.5	8.0	1.8
Cl1	65–78	loam	2.48	8.0	7.5	5.4
Cl2	78–88	sand	1.01	7.9	7.7	1.2
Oe	88–100	-	14.2	-	-	0.9
Cl3	100–128	loamy sand	2.03	8.0	7.7	4.1
Cl4	>128	clay	0.608	8.4	7.5	9.4
Profile 2 – Rheic Sapric Histosol (Calcaric. Epifluvic. Limnic. Orthomineralic)						
AL1	0–14	sandy loam	11.8	8.1	7.4	14.3
AL2	14–33	sandy loam	12.4	8.1	7.5	17.3
Lcm	33–56	-	27.1	7.8	7.5	21.4
Lc	56–74	-	41.2	7.2	6.9	3.2
Lm	74–94	-	13.6	7.9	7.9	41.1
Cl1	94–105	sand	2.91	7.9	7.5	4.4
Cl2	105–120	sand	0.16	8.5	8.1	0.5
Cl3	>120	-	0.684	8.1	7.6	3.8

RESULTS AND DISCUSSION

Mill pond sediments are characterised by considerable variability in transects along the axis of the former reservoirs. It is connected with the paralimnic sedimentary environment that occurs in such types bodies of water. This diversity resulted in an increasing content of both organic matter and the smallest mineral particles from the proximal to the distal parts of the ponds. Surface horizons of soils developing from pond sediments also show large variability [23, 25]. Moisture, pH, and electrical conductivity are closely related to the organic matter content. The pH values also depend on the content of calcium carbonate in the studied paralimnic sediments. These three values can thus serve as useful proxy data in their characteristics. Differentiation of moisture, pH, and electrical conductivity shows variability in the surface layer of the sediments accumulated in the former mill pond basin (Tab. 2–4, Fig. 2.).

TABLE 2. VARIABILITY OF SM_a, pH AND EC_a IN THE PROXIMAL PART OF MILL POND BASIN

Plot No.	SM_a [%]	pH	EC_a [dS m-1]
1	47.0	7.0	0.22
2	27.6	7.7	0.37
3	56.3	7.4	0.29
4	47.1	6.9	0.29
5	45.3	6.9	0.18
6	85.6	6.9	0.38
7	50.9	6.7	0.37
8	69.0	6.9	0.42
9	47.4	6.9	0.23
10	37.3	6.8	0.16
11	53.2	6.7	0.36
mean	51.5	7.0	0.30
min-max	27.6–85.6	6.7–7.7	0.16–0.42

Moisture is characterized by the largest variability. The means calculated for this feature increase from the proximal part of basin to the distal one (Tab. 2–4, Fig. 2). This may be a result of increasing content of organic matter, mentioned above. The highest values (6, 21, 30, 40, 44 and 46) occurred in the immediate vicinity of seepages (effusions) which are common in the described basin [25]. On the other hand, the lowest values are associated with the colluvial material, which covers mill pond sediments at the edges of the former pond (16, 23, 29) and levees along the stream bank (2, 35). Formation of such forms in the period following the functioning of the pond was also described in the Krzyżówka Mill Pond by Szwarczewski [27].

TABLE 3. VARIABILITY OF SM_a, pH AND EC_a IN THE MIDDLE PART OF THE MILL POND BASIN

Plot No.	SM_a [%]	pH	EC_a [dS m-1]
12	43.2	7.2	0.17
13	47.2	6.7	0.17
14	40.9	6.9	0.22
15	67.2	7.1	0.41
16	27.4	6.8	0.57
17	38.7	6.8	0.19
18	50.9	7.1	0.20
19	78.4	7.1	0.39
20	55.0	7.2	0.33

TABLE 3. CONTINUATION

21	85.5	7.4	0.36
22	51.6	7.2	0.22
23	32.2	7.0	0.15
24	77.8	7.3	0.46
25	68.1	6.9	0.53
26	45.2	7.4	0.20
27	47.2	7.2	0.20
28	73.9	6.9	0.42
29	31.3	7.5	0.06
30	84.0	7.1	0.48
31	62.4	7.2	0.32
mean min-max	55.4 27.4–85.5	7.1 6.7–7.5	0.30 0.06–0.57

TABLE 4 . VARIABILITY OF SM_a, PH AND EC_a IN THE DISTAL PART OF THE MILL POND BASIN

Plot No.	SM_a [%]	pH	EC_a [dS m-1]
32	62.6	6.8	0.27
33	46.3	7.2	0.30
34	47.5	7.0	0.19
35	32.0	7.0	0.19
36	64.2	7.3	0.32
37	30.7	7.6	0.16
38	70.1	7.3	0.34
39	78.3	7.5	0.45
40	85.2	7.2	0.36
41	44.4	6.4	0.22
42	39.6	5.8	0.18
43	55.3	7.0	0.38
44	85.6	6.9	0.38
45	63.6	7.1	0.19
46	82.4	7.0	0.43
47	46.6	7.3	0.32
48	47.1	7.1	0.11
49	46.2	7.1	0.17
mean min-max	57.1 30.7–85.6	7.0 5.8–7.6	0.28 0.11–0.45

Mean values of pH do not differ from each other (Tab. 2–4). The reaction of surface sediments is close to neutral or slightly alkaline in almost the entire basin. The highest values are connected with layers containing large amounts of calcium carbonate which is a common component of the gyttja-like materials occurring mainly in the central part of the basin. Acidic reaction in some places (42) is associated with low pH of the seepage water. It is significantly lower (pH 5.6) then the pH measured in the water of the Struga Rychnowska river (pH 8.0).

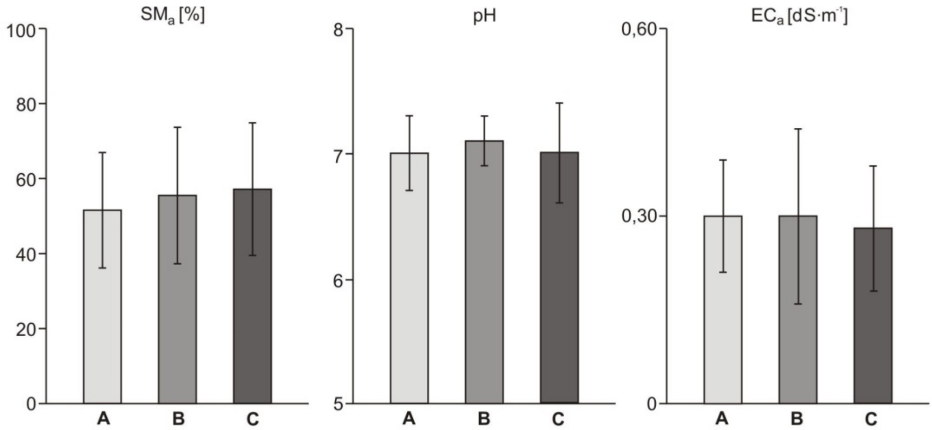

Fig. 2. Means and standard deviations of actual soil moisture, pH and bulk soil electrical conductivity in the proximal (A), middle (B) and distal (C) parts of the basin.

Conductivity, which can be a measure of salinity, as well as the pH, does not show any clear trend (Fig. 2). Values of the bulk soil electrical conductivity can be considered as relatively low. The small salt content in the studied sediments may originate from mineral fertilizers, which are used on arable land bordering the basin on the eastern side [11].

CONCLUSIONS

1. The surface layer of the sediments accumulated in former Oleszek Mill Pond basin does not show differences with regard to the division of the basin into the proximal, middle and distal parts.

2. The observed variability of spot-occurring extreme values are associated with the microrelief formed after the period of mill pond functioning (levees) or caused by local factors strongly modifying the surface of the biogenic plain within the basin, such as the seepages of water at the edge of the former body of water.

3. The studied basin is not characterised by the model system observed in other mill pond basins on the Polish territory.

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ZRÓŻNICOWANIE PRZESTRZENNE WILGOTNOŚCI AKTUALNEJ, pH I PRZEWODNOŚCI ELEKTRYCZNEJ GLEB W NIECCE BYŁEGO STAWU MŁYŃSKIEGO OLESZEK

Celem badań było określenie zróżnicowania przestrzennego wilgotności aktualnej (W_a), pH i przewodności elektrycznej (EC_a) w powierzchniowych poziomach glebowych w niecce byłego stawu młyńskiego Oleszek. Młyny wodne to jedne z pierwszych budowli hydrotechnicznych w Polsce. Pojawiły się już na przełomie XI i XII wieku, natomiast upowszechniły się w XIII wieku. Budowa i funkcjonowanie młynów wodnych znacznie wpłynęła na przekształcenie środowiska przyrodniczego w ich otoczeniu, przede wszystkim na zmiany rzeźby terenu i warunków wodnych. Badania obejmowały pomiary W_a, pH i EC_a w powierzchniowej warstwie gleby (0–30 cm). Pomiary wykonano za pomocą metody TDR aparatem Field Operated Meter – Easy Test FOM/mts w 49 punktach zlokalizowanych w obrębie niecki byłego stawu młyńskiego Oleszek. Zróżnicowanie wyników W_a, pH i EC_a wskazuje na znaczną zmienność przestrzenną powierzchniowej warstwy osadów zakumulowanych w niecce byłego stawu młyńskiego. Powierzchniowa warstwa osadów budujących analizowaną nieckę nie wykazuje jednak różnic w odniesieniu do podziału niecki na część proksymalną, środkową i dystalną. Zaobserwowane różnice mają postać punktowo występujących wartości ekstremalnych związanych z mikrorzeźbą powstałą po zakończeniu funkcjonowania stawu (wały brzegowe), lub wywołane są z lokalnymi czynnikami silnie modyfikującymi powierzchnię równiny biogenicznej w obrębie niecki takimi jak wysięki wód w strefie krawędziowej niecki.