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Interaction of surface water and groundwater in Nida valley, Poland

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Abstract: The study area of the Nida valley was examined to investigate variations in groundwater and surface water levels, as well as the interaction between them. In the valley, there were three branches. The two actives were the Nida River itself and the Smuga Umianowicka branch while the Stara Nida branch was dry during the measurement session. Over a 12-month period from June 2021 to June 2022, 7 monitoring points were equipped with piezometers, comprising 5 groundwater points and 2 surface water points. The monitoring frequency was set to 30 minutes. The results of this research indicate that there are significant differences in the water level at the same observed point at different times. This study demonstrates seasonal changes in both surface water and groundwater levels with higher levels in autumn and winter and lower levels in spring and summer, which are closely tied to the changes in meteorological conditions during the research period, such as precipitation and air temperature. The study results also indicate that during summer and winter at the Nida River and its riparian area, losing stream is the primary process occurring in the studied reach. Conversely, during autumn and spring, the main process is gaining stream. At the human-maintained Smuga Umianowicka branch and in its riparian area, losing stream is the main process during summer and autumn, and gaining stream is the main process during spring. During winter, losing stream and gaining stream processes can occur simultaneously, and neither process takes place mainly.

Keywords: groundwater, interaction, Nida valley, piezometer, surface water, transition zone

INTRODUCTION

Surface water (SW) and groundwater (GW) bodies have been studied extensively by hydrogeologists. These two resources are traditionally viewed as separate entities and can be studied independently. However, a transition zone exists at the bottom of the rivers between the two, where various processes occur that affect the transportation, decomposition, and absorption of substances. This exchange of organic matter and other substances between SW and GW can significantly alter the water quality of either system (Findlay, 1995; Phan, Strużyński and Kowalik, 2023). The transition zone is an important area, as it helps to neutralise the different pollutants of SW and GW. It is characterised by permeability of sediments, saturation state and filtration velocities, making it similar to terrestrial aquifers. In streams, however, this region may contain some portion of GW due to infiltration, resulting in unique characteristics of water bodies. Ecologists refer to transition volume as the hyporheic zone and consider it crucial for the metabolic processes of stream biota and stream metabolism (Hynes, 1983; Brunke and Gonser, 1997).

Interactions between GW and SW occur in two main ways: GW flows into streams (gaining stream), and stream water infiltrates into the groundwater (losing stream). The direction of flow exchange is dependent on the hydraulic head, with gaining reaches having a higher GW table elevation than the stream stage, and losing reaches having a lower GW table elevation. Disconnected streams, where the GW table is below the streambed and the stream is separated from the GW system by an unsaturated zone, are a special type of losing stream. Seasonal changes in precipitation and single precipitation events can also affect the GW tables and stream stages, leading to changes in the direction of exchange flows. On a smaller scale, flow into and out of the streambed can be caused by pressure variations resulting from geomorphological features such as pool-riffle sequences, slope discontinuities, or streambed obstacles (Savant, Reible and Thibodeaux, 1987; Hutchinson and Webster, 1998; Nowicka *et al.*, 2015; Borek and Drymajło, 2019; Kubicz, 2019). Additionally, the movement of sediment grains on the streambed can result in trapped stream water in the sediment interstices and the release of interstitial water to the stream (Elliott and Brooks, 1997).

Saha *et al.* (2017) studied the dynamics of SW-GW interactions under climate change by examining the time-averaged contribution of GW to SW. Their findings indicate that these contributions vary monthly, seasonally, and annually due to changes in precipitation. However, these interactions are complex and have been thoroughly outlined by Sophocleous (2002) who presented the key controls and mechanisms of GW-SW exchange.

In order to preserve water resources, it is crucial to comprehend and quantify the exchange processes and pathways between GW and SW. Woessner (2000) highlights the importance for hydrogeologists to broaden their scope and examine water exchange within the context of riparian management using multiple methods. This approach was practised to analyse the interaction between SW and GW (Lee, 1977; Kalbus, Reinstorf and Schirmer, 2006). Early methods primarily focused on measurement techniques (Lee and Cherry, 1979) which are based on the SW-GW interactive flux observation scale, or on the results from multipoint measurements that can be extrapolated to a larger scale and are ideal for precise field-scale studies. Hydraulic gradient methods were used to identify the direction of groundwater flow and determine whether a stream reach is losing or gaining groundwater by comparing the hydraulic head between piezometers and stream water level (Freeze and Cherry, 1979; Baxter, Hauer and Woessner, 2003). Environmental monitoring techniques are commonly utilised to assess the interaction between SW and GW. Examples include the use of stable isotopes (deuterium and oxygen) as per Negrel *et al.* (2003) and Xu *et al.* (2017), radioactive isotopes like strontium (Hakam *et al.*, 2001), radium (Cook *et al.*, 2003), and radon (Unland *et al.*, 2013; Oyarzún *et al.*, 2014). Wang *et al.* (2013) applied hydro-chemical analysis to examine water availability and the GW replenishment process in the Ejina basin and found that shallow and deep GW have distinct compositions, with differences becoming more pronounced with the length of shallow GW flow paths. Martinez, Raiber and Cox (2015) highlighted the importance of combining hydro-chemical data with environmental monitoring when investigating SW-GW interactions in real-world scenarios. Numerical simulation is a widely used approach in studies of the interaction between SW and GW at various spatial scales, as demonstrated by the works of Frei *et al.* (2009), Boano, Revelli and Ridolfi (2010), and Jin *et al.* (2010). These methods have proven effective not only for small-scale studies (Jones, Sudicky and McLaren, 2008; Guay *et al.*, 2012), but also for regional studies (Jutebring Sterte *et al.*, 2018; Wang *et al.*, 2018). The combination of numerical simulation with field measurement techniques, hydrochemistry, and isotopes has been particularly successful.

In this study, the hydraulic gradient method (piezometer method) was used to analyse the interaction between SW and GW. The piezometer method provides precise measurements of the hydraulic pressure and it is quick and easy to install. This method is ideal for small-scale projects and facilitates an in-depth examination of the variability of subsurface flow conditions. However, groundwater movement can vary over time. Hence, all hydraulic pressure measurements should be taken contemporaneously at the study site, and the resultant contour and flow maps are representative only of that specific time (Winter, 1995). The use of pressure transducers and data loggers installed in piezometers or pressure probes buried beneath the saturated subsurface can aid in monitoring the temporal variations of the changes in the water level.

MATERIALS AND METHODS

STUDY AREA

The object of interest is located in the Nida valley in Poland, Europe. This lowland river valley is characterised by plains, wetlands, and flooded forests and it has a typical ground structure of sand with a thin layer of mud on the top. The valley was formed by the Nida River near the town of Pińczów. The floodplain serves as a natural storage area for water and sediment, reducing the risk of flooding along the river (Lajczak, 2004). The measurement section lies within the Nadnidziański Landscape Park and it is a part of an ecological corridor (Strużyński *et al.*, 2015). The study area extends from the Nida to the Smuga Umianowicka branch, located between the Pińczów and Kije communes in the Pińczów district (Fig. 1). The Nida valley floodplain is regularly flooded during spring and occasionally in summer, with inundation lasting from 2 to 5 months per year. The floodplain is widest (up to 3.5 km) near Umianowice. While the flow of water in the Nida changes in accordance with the laws of nature, the Smuga Umianowicka is supplied naturally from partial catchments, but also to a large extent with water taken from the Nida at the weir in Rębów.

The flow of the Nida has been altered multiple times due to flood control measures. Some sections of the river have had their flow artificially shortened. From the 1960s to the 1990s, the channel of the Nida near Kowala below Pińczów was regulated, resulting in a shortened stretch. However, the rivers further downstream still maintain their natural flow. In 1970, also the Nida near Pińczów was artificially regulated. In the 1990s, the branch network of the Nida in the Umianowice floodplain was negatively impacted when a new artificial channel was created and large areas were drained. The channel incision reaches 2 m, and additionally, some branches have been overgrown. As a result of these changes, the Nida valley has lost its ecological function and is almost completely drained, with only fragments of oxbow lakes and other surface waters remaining. In the early 20th century, the two other sections of the Nida near Pińczów and upstream of the Wiślica village were also decommissioned. This is where the positive and negative effects of previous flood control measures can be seen. Some of the negative effects include a permanent increase in the groundwater table depth in the valley bottom and the disappearance of some river branches, altering the ecological function of certain areas (Żelazo, 1993; Lajczak, 2004).

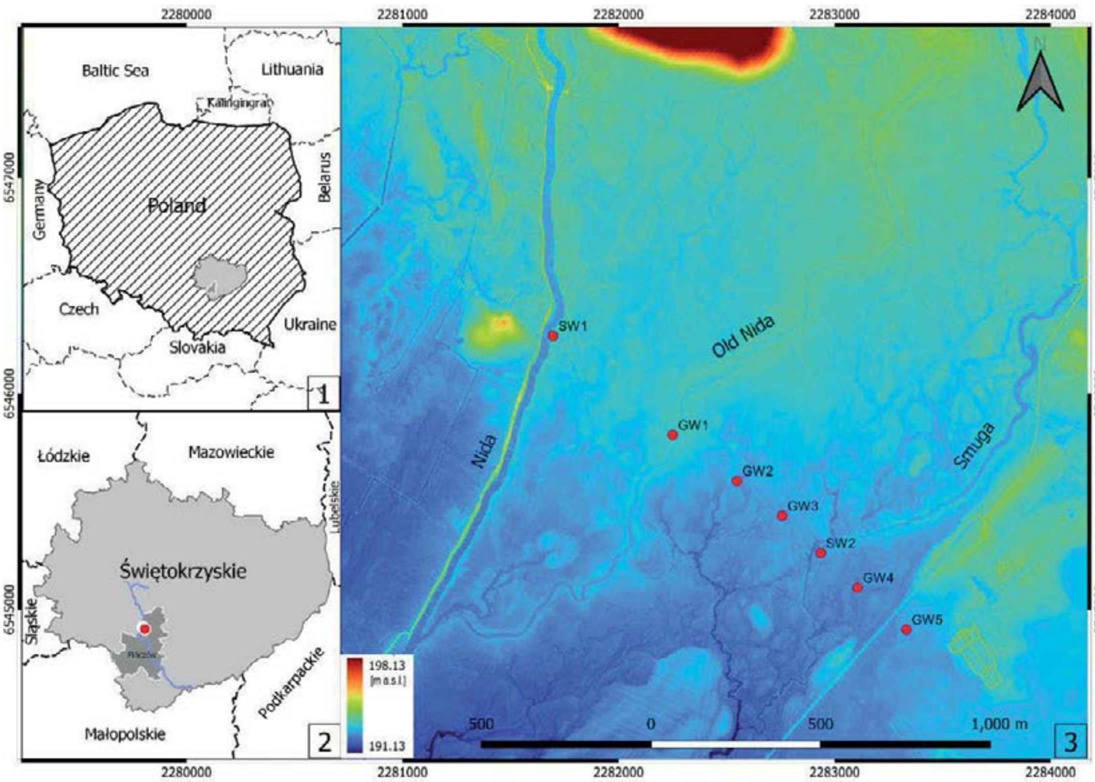

Fig. 1. Map of study area and sampling sites in the Nida valley; red points = installed piezometer locations; source: own elaboration using Digital Terrain Model available at: geoportal.gov.pl

HYDRAULIC GRADIENT METHOD (PIEZOMETER METHOD)

A total of 7 piezometers have been placed in a section formation. There, 5 piezometers were installed in the riparian zone to measure groundwater level (GW1, GW2, GW3, GW4, GW5) and 2 piezometers were organised near the Nida River (SW1) and Smuga Umianowicka branch (SW2) to measure surface water level, as illustrated in Figures 1 and 2. The piezometers are put into the pipes installed vertically below the terrain surface to measure the hydraulic pressure at a particular location. Measurement frequency has been set to 30 min. The length of the pipes is 2 m. The distances between the pipes range from 150 to 400 m. Water level data recorded in the network of pipes was read for the period from June 2021 to June 2022.

In this study, the piezometer used is the Onset HOBO Water Level Logger U20L-01. It has an operation range or a full scale (FS) of 0–207 kPa, which corresponds to approximately 0–9 m of water depth at sea level, or 0–12 m of water depth at an altitude of 3,000 m. The water level accuracy of the piezometer is as follows: for typical error, it is ±0.1% FS, equivalent to 1.0 cm of water, and for the maximum error, it is ±0.2% FS, equivalent to 2.0 cm of water. Regarding the raw pressure accuracy, it is ±0.3% FS with a maximum error of 0.62 kPa.

Fig. 2. The terrain of a cross-section through the research locations; source: own study

DATA AND STATISTICAL ANALYSIS

The data from the piezometers were processed to create daily graphs of water level changes. Besides, the Shapiro–Wilk test (α = 0.05) was used to check whether the variables were in accordance with normal distribution. In order to estimate the significance differences between data taken at different times, non-parametric analysis (Kruskal–Wallis test at α = 0.05) was conducted.

The correlation between the groundwater and surface water level was determined by computing Pearson's correlation coefficients (r) and creating a correlation matrix. The significance of the coefficients was established using the r-value and a level of significance of 0.001. Furthermore, cluster analysis was employed for the normalised data with Ward's method, using squared Euclidean distances as a measure of similarity. The hierarchical cluster analysis was used to identify the similarity of water level fluctuations between different observation points. The analysis was performed using R version 4.1.2, free software on GNU license. In order to determine whether there is a hydraulic connection between a stream and surrounding terrain, hydraulic pressure measured in a piezometer profile was analysed.

Precipitation and air temperature monitoring data in the study area were obtained from the website (https://hydro.imgw.pl). These data were recorded at the Kielce-Suków monitoring station and utilised to investigate the correlation between water levels and meteorological factors. Figure 3 illustrates the monthly variations in precipitation and air temperature throughout the study period.

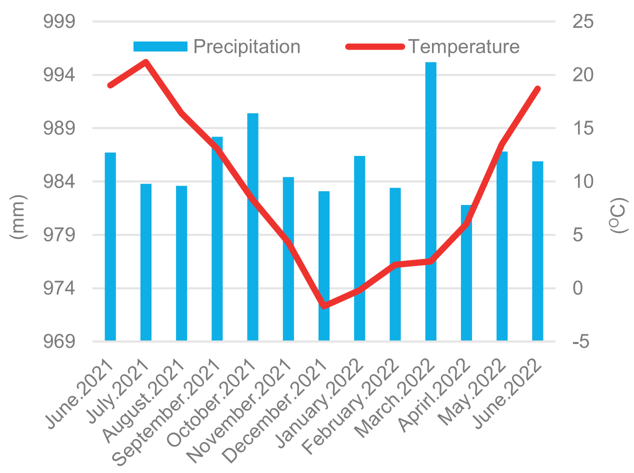

Fig. 3. Annual mean values of temperature and precipitation in the study area; source: own elaboration based on data of IMGW-PIB available at: https://hydro.imgw.pl

RESULTS AND DISCUSSION

THE VARIATIONS OF GROUNDWATER AND SURFACE WATER LEVEL

The Kruskal–Wallis test was performed and the results are presented in Table 1, which includes the chi-squared value, degrees of freedom, and p-values. The p-value was found to be less than 2.2e–16 for all observation points, indicating that there are statistically significant differences between the water level values registered within the measurement period.

Table 1. The results of the Kruskal–Wallis test for each observation point (p-value < 2.2e–16)

Observation point	Chi-squared	*df*
SW1	16,411	5,448
SW2	12,363	5,448
GW1	16,598	5,448
GW2	16,764	5,448
GW3	15,338	5,448
GW4	11,497	5,448
GW5	18,488	5,448

Explanation: *df* = degree of freedom.
Source: own study.

Figure 4 displays the surface water level fluctuations on the Nida River (SW1) and the Smuga Umianowicka branch (SW2) at the study site over the observation period. Additionally, the average water levels observed in summer, autumn, winter and spring were presented in Table 2. At the Nida River, notable high water levels were recorded on February 2nd, 2022 (194.11 m a.s.l.) and September 9th, 2021 (193.98 m a.s.l.), while the lowest level was recorded on August 6th, 2021 (192.26 m a.s.l.). In both June 2021 and June 2022, there was a recorded decrease in the water level. Besides, notable high water levels on the Smuga Umianowicka branch were recorded on June 20th, 2022 (192.59 m a.s.l.), January 4th, 2022 (192.53 m a.s.l.), and February 25th, 2022 (192.50 m a.s.l.), while the lowest levels were recorded on August 4th, 2021 (191.13 m a.s.l.) and July 8th, 2021 (191.20 m a.s.l.). There were initial variations recorded in the water level between June 2021 and June 2022. While the water level tends to decrease gradually in June 2021, the opposite trend takes place in June 2022.

The factors influencing changes in river water levels are multifaceted and can be attributed to a combination of natural and anthropogenic causes. Among the key factors that impact river water levels during the study period are precipitation, climate change, human activities, topography and geology, and seasonal changes.

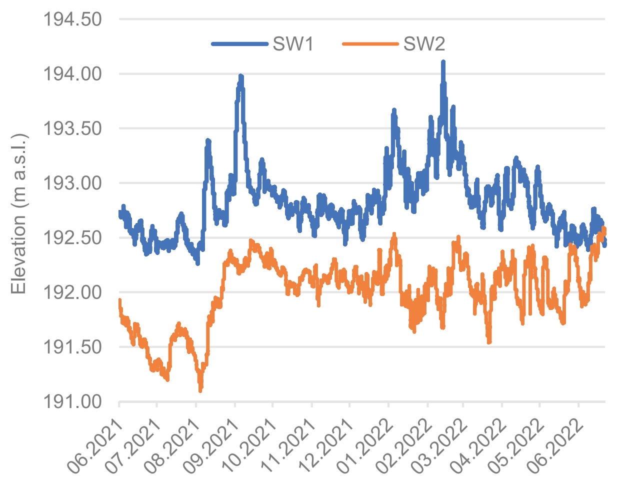

Fig. 4. Fluctuations of surface water level in the Nida (SW1) and the Smuga Umianowicka branch (SW2) point; source: own study

Table 2. The average value of the seasonal water level at the observation points

Period	Value in point (m a.s.l.)						
	SW1	SW2	GW1	GW2	GW3	GW4	GW5
Summer	192.60	191.63	192.53	192.22	192.31	191.54	192.59
Autumn	192.91	192.19	192.94	192.47	192.39	192.03	192.83
Winter	193.03	192.08	192.97	192.50	192.50	192.08	192.81
Spring	192.84	192.07	192.86	192.41	192.41	192.14	192.69
Minimum	192.26	191.13	192.07	191.75	191.71	191.04	192.18
Maximum	194.11	192.59	193.71	193.18	193.07	192.56	193.19

Source: own study.

In Poland, heavy rainfall during autumn or snow melting in winter can lead to sudden water level increases, sometimes even causing flooding. Conversely, prolonged dry periods in summer can result in a drop in water levels (Kubicz, 2019; Ahmad *et al.*, 2021; Belemtougri *et al.*, 2021; Merz *et al.*, 2021). The global climate patterns, particularly precipitation and air temperature, have a notable effect on river water levels (Dettinger, Diaz, 2000; Chang *et al.*, 2016; Ghotbi *et al.*, 2020; Wei *et al.*, 2020; Lv *et al.*, 2021; Bao, Ding and Han, 2022; Li *et al.*, 2023). The data obtained from meteorological monitoring stations on precipitation and air temperature in the study area, as shown in Figure 3, align well with the measurements recorded by the piezometer. This consistency in the data helps to elucidate that changes in water levels in both the Nida River and the Smuga Umianowicka branch are predominantly influenced by precipitation.

Human activities, such as the construction of dams, have been widely documented to have significant impacts on river water levels (Grant, 2012; Chang *et al.*, 2016; Wang *et al.*, 2018; Wei *et al.*, 2020; Słowik *et al.*, 2021; Bao, Ding and Han, 2022; Li *et al.*, 2023). The variation in water level observed between the Smuga Umianowicka branch and the Nida River can be attributed to the water level regulation facilitated by the dam constructed on the Smuga Umianowicka branch.

Additionally, the topography and geology of the surrounding landscape play a crucial role in influencing water flow, thereby impacting river water levels (Schumm and Spitz, 1996; Detty and McGuire, 2010; Grant, 2012; Rinderer, Meerveld van and Seibert, 2014; Trevisan *et al.*, 2020; Dai *et al.*, 2021). Notably, the topography of the study area, characterised by a slope from the Nida River side to the Smuga Umianowicka branch, contributes to the abnormal increase in water level observed at the Smuga Umianowicka branch during periods of heavy rainfall. Furthermore, the seasonal changes, as evident in Figure 3, including the rainy and dry seasons experienced in Poland, play a significant role in explaining the notable variations in river water levels (Dettinger and Diaz, 2000; Ahmad *et al.*, 2021). These natural fluctuations in precipitation and water availability contribute to the dynamic nature of river water levels in the region.

Groundwater level fluctuations were observed at five different points: GW1, GW2, GW3, GW4, and GW5, along the riparian Nida River and Smuga Umianowicka branch at the study site. Figure 5 shows the groundwater level fluctuations at each of these points during the observation period. The average water level was measured at these five points during four seasons and it was presented in Table 2. The highest water levels were recorded on September 5th, 2021, at GW1 (193.71 m a.s.l.), GW5 (193.19 m a.s.l.), GW2 (193.18 m a.s.l.), and GW3 (193.07 m a.s.l.) points. The lowest water levels were recorded on August 8th, 2021 (191.04 m a.s.l.) at GW4 point, on June 30th, 2022, at GW2 (191.75 m a.s.l.), GW3 (191.71 m a.s.l.), GW1 (192.07 m a.s.l.), and at GW5 (192.18 m a.s.l.). Initially, the water level trend was repeated in June 2021 and June 2022 at points GW1, GW2, GW3, and GW5. However, an opposite trend was observed at the GW4 point.

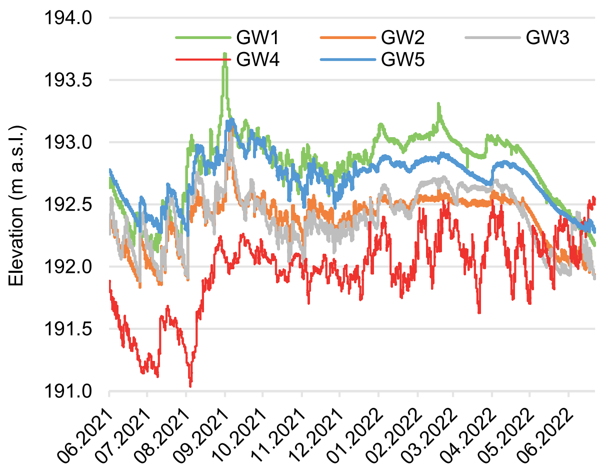

Fig. 5. Fluctuations of groundwater level in the riparian area at GW1, GW2, GW3, GW4, GW5 points; source: own study

Groundwater levels can be influenced by various factors, including precipitation, surface water bodies, soil characteristics, and human activities (Grajewski, Miler and Okoński, 2014). The amount and frequency of precipitation in a region play a significant role in affecting groundwater levels. Heavy rainfall enhances groundwater recharge rates, while prolonged dry periods can lead to a decrease in groundwater levels (Jan, Chen and Lo, 2007; Thomas, Behrangi and Famiglietti, 2016; Azizi *et al.*, 2021). In the study area, fluctuations in groundwater levels align with the recorded heavy rainfall at meteorological observation stations, particularly during autumn in Poland, which explains the observed increase in groundwater levels. The soil's permeability, porosity, and texture also influence groundwater levels. In the Nida valley, where the typical ground structure consists of sand with a thin layer of mud on top (Strużyński *et al.*, 2015), the high porosity and permeability allow for the storage and transmission of more water, leading to higher groundwater levels (Orfánus *et al.*, 2016; Gomboš *et al.*, 2018). Human activities, such as flow regulation to control flooding in the Nida valley, can cause a decline in groundwater levels (Żelazo, 1993; Lajczak, 2004). Additionally, groundwater levels can be affected by the proximity and characteristics of surface water bodies, like rivers and wetlands. In the study area, two branches flow through the valley, combined with low-lying terrain to create a large flooded area. These water bodies can act as recharge areas for groundwater or as sources of groundwater discharge. The interaction between groundwater and surface water will be further explored in the subsequent part of this study.

THE CORRELATION AND INTERACTION OF GROUNDWATER AND SURFACE WATER

Parameters conducive to the flow of water over the surface of the terrain, but also the filtration process, are the terrain slope as well as the type of soil (Listyani, Prabowo and Suparta, 2023). Statistical analyses of connections between water levels in piezometric wells in the profile covering both the Nida River bed, its dried oxbow lakes and the cleaned and functioning oxbow lake called Smuga Umianowicka were carried out. Table 3 shows the correlation coefficients (r) and their corresponding significance levels (p values) for all locations studied. Positive correlations were observed in all cases. Strong positive correlations were found between SW1 and GW1 (r = 0.718, $p < 0.001$), GW2 (r = 0.775, $p < 0.001$), GW3 (r = 0.759, $p < 0.001$), and GW5 (r = 0.781, $p < 0.001$). Additionally, strong positive correlations were observed between GW1 and GW2 (r = 0.872, $p < 0.001$), GW3 (r = 0.737, $p < 0.001$), and GW5 (r = 0.867, $p < 0.001$). Moreover, strong positive correlations were found between GW2 and GW3 (r = 0.878, $p < 0.001$), GW5 (r = 0.932, $p < 0.001$), between GW3 and GW5 (r = 0.800, $p < 0.001$), and between SW2 and GW4 (r = 0.912, $p < 0.001$).

Table 3. Correlation coefficients (r) and their corresponding significance levels (p-values) for all variables

Point	SW1	GW1	GW2	GW3	SW2	GW4	GW5
SW1	1.000						
GW1	0.718*	1.000					
GW2	0.775*	0.872*	1.000				
GW3	0.759*	0.737*	0.878*	1.000			
SW2	0.382	0.479	0.445	0.251	1.000		
GW4	0.413	0.471	0.423	0.288	0.912*	1.000	
GW5	0.781*	0.867*	0.932*	0.800*	0.440	0.372	1.000

* correlation is significant at the 0.001 level.
Source: own study.

Besides, the dendrogram (Fig. 6) presented the correlation between observation points. Ward's association method and squared Euclidean distance were used and showed 2 statistically significant clusters. The first cluster covers 5 points (SW1, GW1, GW2, GW3, GW5). The second cluster contains the observation points of SW2 and GW4. This result also was presented on the correlation coefficients (r).

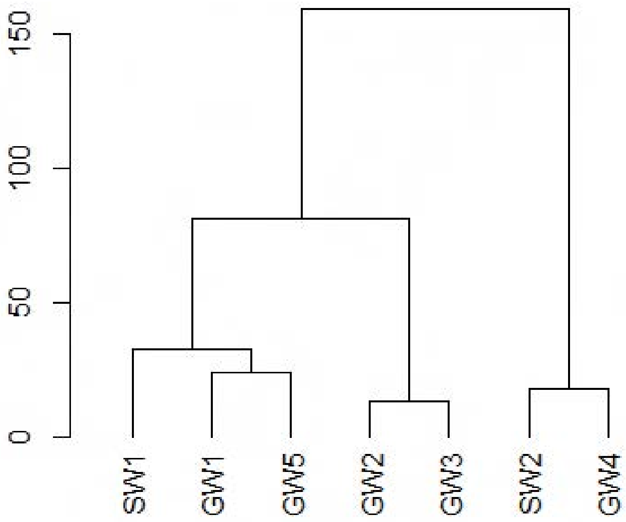

Fig. 6. Cluster analysis dendrogram of observation points (SW1, SW2, GW1, GW2, GW4, and GW5); source: own study

The study results demonstrate strong correlations between SW1, GW1, GW2, GW3, and GW5, as well as between SW2 and GW4. The positive correlations observed between SW1, GW1, GW2, GW3, and GW5 can be explained by the topography of the monitoring points. The terrain generally slopes downward from the Nida River towards the Smuga Umianowicka branch. This means that the Nida (SW1) and Stara Nida (GW1) areas are at a higher elevation and slope downward at GW2 and GW3 points. On the right side, there is a lower terrain in the form of a bowl-shaped valley (SW2, GW4) through which the Smuga Umianowicka flows. The elevation increases at GW5 and is separated by high ridges of land. The expected direction of filtration, in a cross-section view, is from the Nida River, through Stara Nida, and towards the Smuga Umianowicka branch (Fig. 1, 2). Additionally, similar weather conditions in the same area, including precipitation, temperature, and evaporation, may also contribute to these correlations. On the other hand, the correlation between SW2 and GW4 can be explained by the basin topography of the area from the GW4 location to the Smuga Umianowicka branch of SW2 location, where the terrain is lower than that of the surrounding areas, potentially creating reservoirs (Fig. 1, 2). Furthermore, a dam built adjacent to the SW2 location on the Smuga Umianowicka branch, aimed at regulating the flow, may contribute to the accumulation of water in this reservoir.

These findings suggest that there is a significant interaction between groundwater in the riparian area at GW1, GW2 and GW3 locations and the surface water of the Nida River where SW1 is located. Furthermore, there is a significant interaction between groundwater at the GW4 location and the surface water in the Smuga Umianowicka branch at the SW2 location. Combined with the results in Table 2, the average water levels at points SW1, GW1, GW2, and GW3 observed in four seasons, demonstrate that there are seasonal variations in the water levels. In summer, the water level at SW1 is higher than at GW1, GW2, and GW3. In autumn, the water level at SW1 is lower than at GW1. In winter, the water level at SW1 is higher than at GW1, GW2, and GW3, while in spring, the water level at SW1 is lower than at GW1. This indicates that during summer and winter, the surface water level in the Nida River is usually higher than the groundwater level in the riparian areas. This leads to a difference in hydraulic gradient between the stream and the groundwater, with losing stream being the main process occurring in the studied reach. Conversely, during autumn and spring, the water level in the Nida is usually lower than in the riparian areas, resulting in a reverse hydraulic gradient difference and the main process being gaining stream (Freeze and Cherry, 1979; Baxter, Hauer and Woessner, 2003).

In addition, Table 2 presents the average water levels at points SW2 and GW4 observed in four seasons, which indicate that during summer and autumn, the water level at SW2 is higher than at GW4. In winter, the water levels at SW2 and GW4 are equivalent, while in spring, the water level at SW2 is lower than at GW4. These findings suggest that during summer and autumn, the surface water level in the Smuga Umianowicka branch is usually higher than the groundwater level in the riparian areas, leading to a difference in the hydraulic gradient between the stream and the groundwater. Losing stream is the main process occurring in the studied reach during these seasons. Conversely, during spring, the water level in the Smuga Umianowicka branch is usually lower than in the riparian areas, resulting in a reverse hydraulic gradient difference and the main process being gaining stream. However, in winter, the water levels at the Smuga Umianowicka branch and GW4 are strongly interrelated, indicating that there is a one-way relationship between SW2 and GW4. It means losing stream and gaining stream processes can occur simultaneously, and neither process takes place mainly (Freeze and Cherry, 1979; Baxter, Hauer and Woessner, 2003).

CONCLUSIONS

This study used the piezometer method to observe the fluctuations of groundwater and surface water levels and their interactions according to the seasons in the Nida valley, Poland. The research results show that: there are significant differences between the water level at different times within the same observed point.

Seasonal changes in surface water and groundwater levels have been shown in this study. Consequently, water levels exhibit significant variations across different seasons throughout the year, which are closely tied to the changes in meteorological conditions during the research period, such as precipitation and air temperature. For surface water, high water level is recorded in autumn and winter, lower in spring and the lowest in summer. At the Nida, in both June 2021 and June 2022, there was a recorded decrease in the water level. There was a difference in the recorded water levels between June 2021 and June 2022 at the Smuga branch. While the water level tends to decrease gradually in June 2021, the opposite trend takes place in June 2022. As for the groundwater level, high elevation is also recorded in autumn and winter and lower in spring and lowest in summer. Initially, the water level trend was repeated in June 2021 and June 2022 at points GW1, GW2, GW3, and GW5. However, an opposite trend was observed at the GW4 point. The period of spring is one of the wettest parts of the year within the Mediterranean climate zone however it's also very random.

The study results demonstrate that during summer and winter at the Nida and its riparian area, losing stream being the main process occurring in the studied reach. Conversely, during autumn and spring, the main process being gaining stream. In addition, at the Smuga Umianowicka branch and its riparian area, losing stream is the main process occurring in the studied reach during summer and autumn. Conversely, the main process is gaining stream during spring. However, losing stream and gaining stream processes can occur simultaneously in winter, and neither process takes place mainly.

This study provides preliminary findings, and ongoing research is planned in the near future to further validate and corroborate the results over the long term.

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