Acta Sci. Pol.
Formatio Circumiectus 17 (1) 2018, 115–123
ENVIRONMENTAL PROCESSES

www.formatiocircumiectus.actapol.net/pl/ ISSN 1644-0765 DOI: http://dx.doi.org/10.15576/ASP.FC/2018.17.1.115

ORIGINAL PAPER Accepted: 1.03.2018

# TLM METHOD AND SGI INDEX AS AN INDICATOR OF GROUNDWATER DROUGHT

Justyna Kubicz✉

Institute of Environmental Engineering, Faculty of Environmental Engineering and Geodesy,
Wrocław University of Environmental and Life Sciences, ul. Grunwaldzka 55, 50-357 Wrocław

**ABSTRACT**

Previous studies of drought in Poland practically neglected the aspect of groundwater shortage, focusing on atmospheric, agricultural and hydrological drought. Therefore, the aim of this work was groundwater drought analysis in selected sites of South-Western Poland, based on the analytical methods used in other European countries. The intermediate objective was to assess the possibility of using the TLM method and the SGI for monitoring groundwater drought based on data from the National Geological Institute – National Research Institute. Investigations demonstrated that both methods gave results that complemented existing information on droughts in Poland in the last 30 years. Studies show that in the 1990s there was groundwater drought, not only atmospheric and agricultural drought described by Bąk and Łabędzki (2002), Bobiński, Meyer (1992, 1992), Bartczak (2014).

**Keywords:** groundwater drought, Standardized Groundwater Index SGI, Threshold Level Method

## INTRODUCTION

There are many definitions of drought in the scientific community, depending on different reasons for their formulation (Hayes et al. 2010). Usually, drought is defined as a period of significantly reduced precipitation, which results in limited accessibility to water (Wilhite and Glantz 1985, Tallaksen and van Lanen 2004, Mishra and Singh 2010). In temperate latitudes an intensity of a drought is related to high air temperature and increased evaporation (Feyen and Dankers 2006, Lehner et al. 2006, van Loon 2015).

Shortage of precipitation and intensive evaporation lead to depletion of water resources in the soil. The beginning of soil drying then can be observed. In the next phase, water content in lower layers decreases until the groundwater level drops. When the extracted groundwater resources are not renewed by infiltrating precipitation, groundwater level in wells also drops, and water supply to the sources and watercourses decreases. This process in interrupted when the resources are replenished by an abundant and long-lasting precipitation, which feeds the aquifer through infiltration (Strzebońska-Ratomska 1994). The rate of replenishment of groundwater resources is also influenced by other non-meteorological factors. These are mainly physical properties of a terrain, hydraulic properties of an aquifer and anthropogenic factors, especially the water abstraction rate (Chen et al. 2002, Whittemore 2016, Leelaruban et al. 2017).

In recent years, research on groundwater droughts was conducted with a variety of methods producing different results – among them the Threshold Level Method and the method of standardised drought indicators. The first method is referred to as TLM. Initially, it was used for determining low flows in rivers, over time its application was extended to groundwater level. According to TLM, drought is a period, in which the level of

✉e-mail: justyna.kubicz@upwr.edu.pl

the groundwater table is equal to or lower than the assumed limit level (Hisdal et al. 2004, Fleig et al. 2006, van Loon 2013, 2015). Among the index methods, most commonly used is SGI (Standardized Groundwater Level Index), calculated on a basis of long-term sequences of groundwater position measurements (Bhuiyan et al. 2006, Bloomfield and Marchant 2013).

Determining drought cycles is of great importance in water management during shortage of water or in preceding periods. The application of aforementioned methods provides with a basis for setting the information thresholds i.e. a threat of drought, drought occurrence, or a critical situation. Water management teams from Netherlands, Italy and the United Kingdom set an example for improving operations by these methods (Rijkswaterstaat 2014, Arpa CIMA 2005, von Christierson et al. 2011).

The aim of this paper was to analyse groundwater droughts in selected time periods in the observation points of south-west Poland, by applying analytical methods used in other European countries. The findings of the analysis will broaden available knowledge about past droughts in Poland. Previous studies on drought in this country practically neglected groundwater shortage, and focused on atmospheric, agricultural and hydrological droughts. The intermediate objective of the study was to assess the potential of TLM method and SGI indicator to monitor groundwater droughts in regard to data from the state environmental monitoring carried out by National Geological Institute – National Research Institute. The analysis of the history of groundwater droughts allows to fully assess the impact of climate volatility on groundwater and facilitate the determination of areas that are particularly exposed to droughts (Kubicz and Stodolak 2017).

## METHODOLOGY

There is not one universal method for assessing groundwater droughts. Therefore, this paper puts to work two different and currently most common methods in the international literature. The first one – TLM (Treshold Level Method) – determines the threshold level of groundwater table allowing to learn the periods of groundwater droughts (Hisdal et al. 2004, Fleig et al. 2006, van Loon 2013, 2015). According to TLM method, a threshold level for drought is related to an element of an environment or the economy sector affected by the drought, for example, the amount of water needed for proper functioning of water-dependent ecosystems, the amount of water needed for irrigation of agricultural areas, as well as for industrial and energy purposes, or the demand for drinking water (Hisdal et al. 2004, Lloyd-Hughes 2014). Due to lack of relevant information, determining drought levels for each of these elements would be extremely difficult. That is why for practical reasons the threshold values are set for the analysed area or research point. Usually, it is the 75–90 percentile range for long-term observations of low levels (Hisdal et al. 2004, Fleig et al. 2006, Tallaksen et al. 2009). An average low water table level for long-term period (*SNG*) was adopted in the study as a threshold level. It is recommended by Kazimierski and others (Kazimierski et al. 2009, Kubicz and Dąbek 2016). A drought can be indicated, when the groundwater table has repeatedly and systematically dropped below the adopted *SNG* value. It is assumed that a groundwater drought can be identified, when the average monthly water table level for at least 3 months drops below the *SNG* level (Tarka and Staśko 2010). Shorter period is defined as a low flow. Kazimierski et al. (2009) added that the conditions ranging from medium low to the half-way between medium low and the lowest of the low ones observed in the long-term period $SNG \geq AG > ½ (SNG + NNG)$, indicate an occurrence of shallow drought. In turn, the position of water table below half of that distance $AG \leq ½ (SNG + NNG)$ indicates an occurrence of deep drought (where: *WNG* – the highest position out of the lowest water table positions (i.e. the highest of the low position defines the upper limit of the low positions zone), *SNG* – a medium low water table position, *NNG* – the lowest water table position, so-called the lowest of low positions).

The paper also employed an index method known as *SGI* (Standardized Groundwater Level Index) calculated by groundwater level (Bloomfield and Marchant 2013, Musuuza et al. 2016). *SGI* is an equivalent to *SPI* (Standarised Precipitation Index) used to evaluate precipitation shortages proposed by McKee et al. (1993, 1995) and *SWI* (Standarised Water Level Index), which was introduced by Bhuiyan (2006) to monitor the shortages of surface waters and groundwater. The value of the used indicator is a standardized deviation of groundwater level from median values in the studied time period. In order to match normally distributed homogeneous data strings, the recommended in the literature 2-parameter logarithmic function ln was used (Ozga-Zielińska and Brzeziński 1994, Vicente-Serrano et al. 2012). The correspondence of distribution of the transformed variable *f (X)* with a normal distribution was examined using the Pearson's $\chi 2$ test. The positive value of the test allowed to calculate the values of the grounds of the equation (1):

$$SGI = \frac{f(X) - \mu}{\delta} \quad (1)$$

where:

*f(X)* – standardised average level of groundwater position,

$\mu$ – average value of a standardised sequence of groundwater table position *X*,

$\delta$ – standard deviation of standardised average level of groundwater position.

According to McKee et al. (1993, 1995) all values of the *SGI* indicators are negative during droughts and also in at least one month these values are smaller than or equal to –1,0. A drought breaks when the indicator value rises above zero. For indicators that meet the condition $X < 0$, a common 4-grade drought intensity assessment was adopted (see: Table 1).

**Table 1.** Classification of drought intensity acc. to McKee et al. (1993, 1995)

| SGI | Intensity of drought |
|---|---|
| < –2,0 | extreme drought |
| –1,99 ÷ –1,5 | severe drought |
| –1,49 ÷ – 1,0 | moderate drought |
| –0,99 ÷ 0,0 | mild drought |

## MATERIAL AND FIELD OF RESEARCH

The analysis included measurements of groundwater table levels in five measurement points belonging to research and observation network of the National Geological Institute – National Research Institute (PIG – PIB). The measurement points were in following localities of the Lower Silesian Voivodeship: Piława Górna in the Sudeten Foreland, Białobrzezie in the Silesian Lowlands and Słup in the Silesian-Lusatian Lowlands; and in the Opole Voivodeship: Dobrzeń Mały and Łącznik in the Silesian Lowlands (Kondracki 2002) (see: Fig. 1). By the hydrogeological division the gauge stations Piława Górna, Słup, Białobrzezie and Łącznik are located in the 15th hydrogeological region (Wrocław region), Dobrzeń Wielki in the 12th region (Silesian-Cracow region) (Paczyński 1995). All points are situated in the basin of the Odra River. The average monthly values of groundwater level position were calculated for the analysis based on the measurement of water table depth in test wells performed once a week on Mondays at 600 UTC. The data covered years from 1987 to 2014 at the station in Piława Górna, 1989–2014 in Białobrzezie and Słup, and 1987–2014 in Dobrzeń Mały and Łącznik. A summary of basic information about measurement points is shown in Table 2.

**Table 2.** Summary information about the measurement points

| Point number | | II/601/1 | II/633/1 | II/636/1 | II/692/1 | II/732/1 |
|---|---|---|---|---|---|---|
| Site | | Piława Górna | Łącznik | Dobrzeń Mały | Słup | Białobrzezie |
| Stratygraphy | | Pt | Q | Q | Pg+Ng | Q |
| Lithology | | gneiss | sands | medium-grained sands | basalts | sands |
| Groundwater level in the analyzed period, m a.s.l. | mean | 16,16 | 7,41 | 3,18 | 10,99 | 2,74 |
| | min | 24,61 | 7,98 | 4,03 | 13,98 | 5,61 |
| | max | 10,86 | 6,16 | 2,37 | 10,35 | 1,82 |
| Footwall depth relative to soil surface, m a.s.l. | | 45 | 21 | 9 | 15,2 | 12 |
| Water table met during drilling, m a.s.l. | | 13,5 | 5,3 | 1,5 | 12,65 | 1,2 |

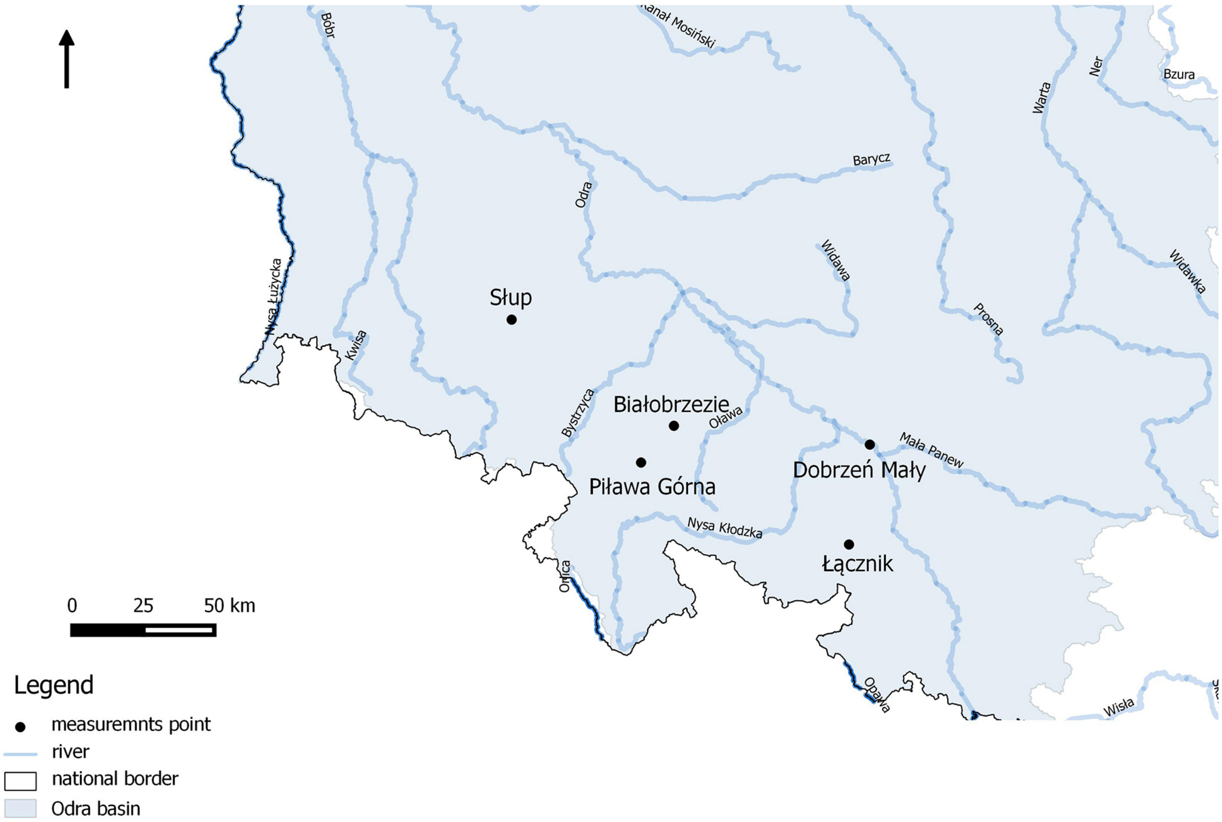


**Fig. 1.** Location of measurement points against the main tributaries of the Odra basin

## RESULTS

The variability of groundwater table position at the measurement points are shown in Figure 2. The horizontal line indicates the threshold level that marks an occurrence of a low flow (in case of short periods of decrease) or droughts (for periods of at least a 3-month decrease of water table level) in accordance with TLM methodology. For observations in Piława Górna the threshold level, marked as *SNG*, was 16.16 m b.g.l. In Łącznik this level was set at 7.41 m b.g.l., in Dobrzeń Mały – 3,18 m b.g.l., in Słup – 10,99 m b.g.l. and in Białobrzezie – 2,74 m b.g.l. This method allowed to distinguish from 2 (Piława, Dobrzeń Mały, Białobrzezie) to 7 (Słup) periods of drought in groundwater. All measurement points registered droughts during the period from 1990 to 1996. Groundwater droughts at the observation point in Słup were interrupted in this period by 2 short episodes (3–4 months) and one 23-month long. The longest and uninterrupted drought occurred in Piława Górna. In years that followed a few more droughts were reported. The most significant were groundwater droughts at the observation points in Słup (in 2000–2001, 2003–2005) and in Łącznik (in 2002–2005) (see: Figures 2, 3).

Droughts were noted the most often in the Piława Górna (37.5%) and the least, 19.9%, in Białobrzezie (see: Table 3). By assuming the intensity of a drought as a criterion for division, it was shown that at all the measurement points the frequency of shallow droughts prevailed over deep droughts. At the measurement points in Piława Górna, Dobrzeń and Słup the frequency values for shallow droughts were similar and came in the range of 21.3–23.5%. The shallow droughts occurred the most often in Słup. The measurement point in Białobrzezie is characterised by the least total time of shallow droughts (10.6%). In the case of deep droughts, these were recorded most fre-

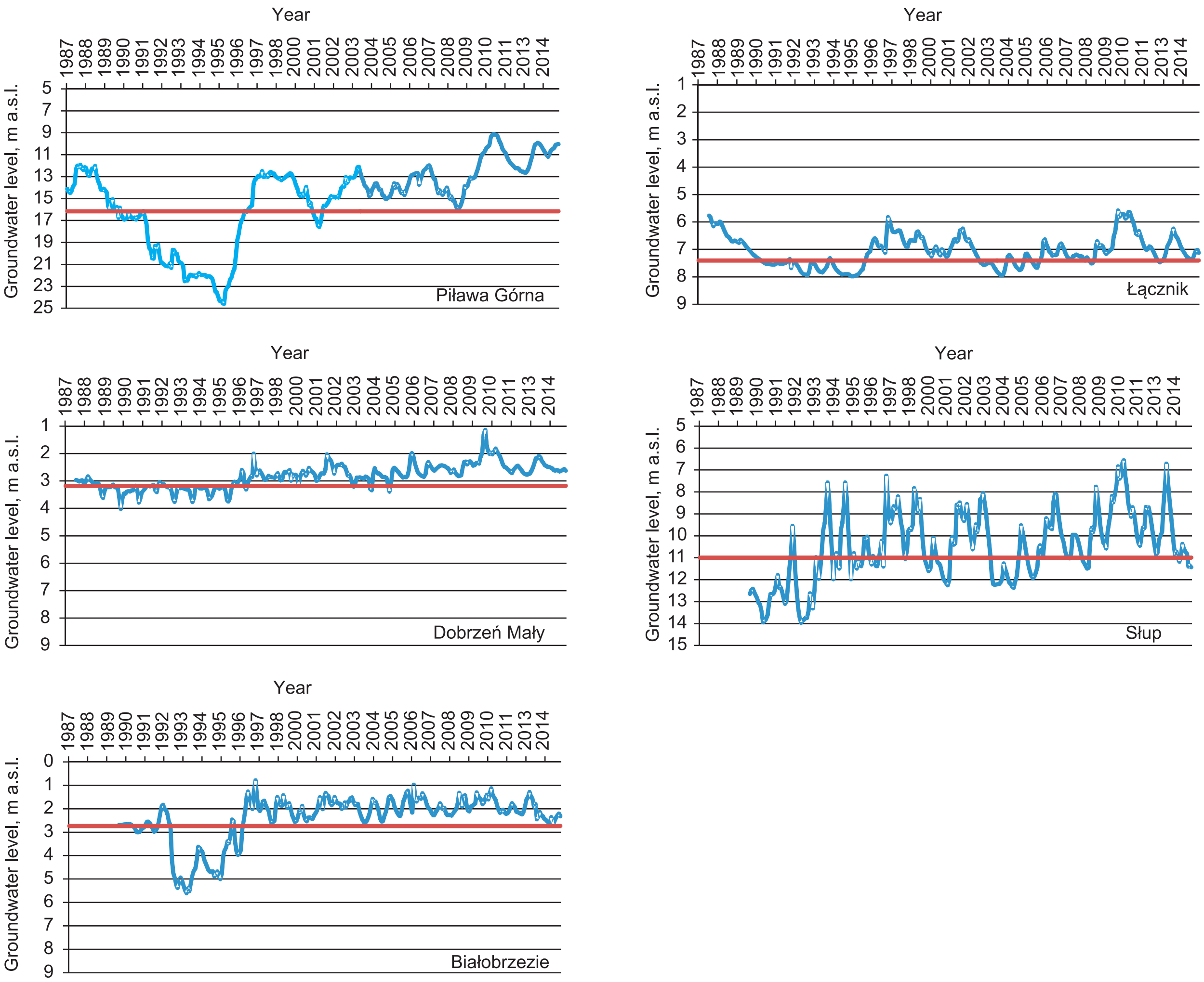


**Fig. 2.** Histograms showing the variability of groundwater level in the measurement points with a marked limit value below which a hydrological drought is noted

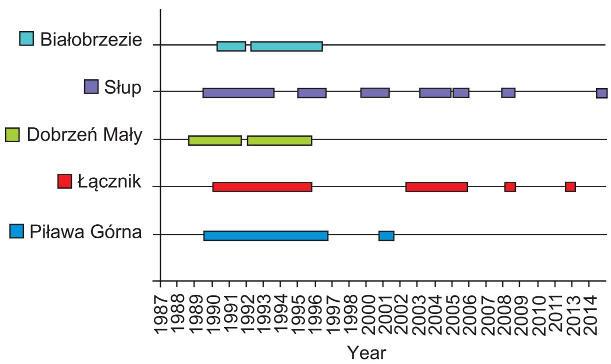


**Fig. 3.** Groundwater drought periods according to TLM method in selected measurement points

quently in Piława Górna (14.6%), and least – in Dobrzeń Mały (4.3%) (see: Table 3).

The variability course of SGI was presented in Figure 4, while the periods of droughts at the measurement points were indicated in Figure 5. According to the adopted classification of the calculated index *SGI* at the measurement points from 1 (Piława Górna, Dobrzeń Mały, Białobrzezie) to 3 (Słup) periods of groundwater droughts were distinguished. A simultaneous occurrence of a drought at four of the five measurement points was observed in the period 1990–1996. In the period between October 1992 and November 1993 drought appeared in all locations (see: Fig. 5).

**Table 3.** Number of months and frequency of groundwater drought with different intensity according to the TLM method

| Site, observation period | Shallow drought | | Deep drought | | Total | |
|---|---|---|---|---|---|---|
| | number of months | frequancy % | number of months | frequancy % | number of months | frequancy % |
| Piława Górna 1987–2014 | 77 | 22,9 | 49 | 14,6 | 126 | 37,5 |
| Łącznik 1987–2014 | 58 | 17,6 | 42 | 12,8 | 100 | 30,4 |
| Dobrzeń Mały 1987–2014 | 70 | 21,3 | 14 | 4,3 | 84 | 25,5 |
| Słup 1989–2014 | 71 | 23,5 | 32 | 10,6 | 103 | 34,1 |
| Białobrzezie 1989–2014 | 32 | 10,6 | 28 | 9,3 | 60 | 19,9 |

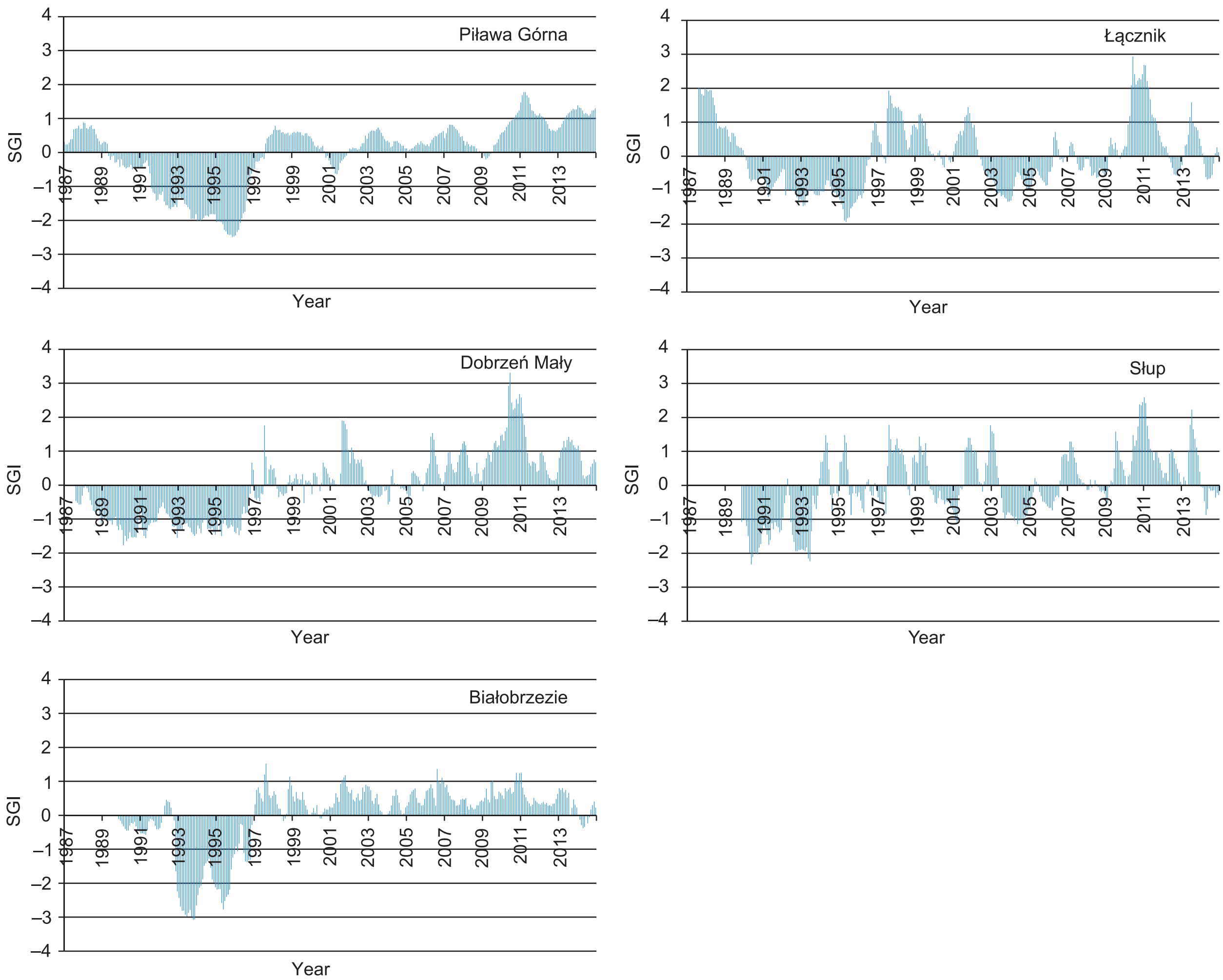


**Fig. 4.** Histograms showing the variability of the SGI in the measurement points

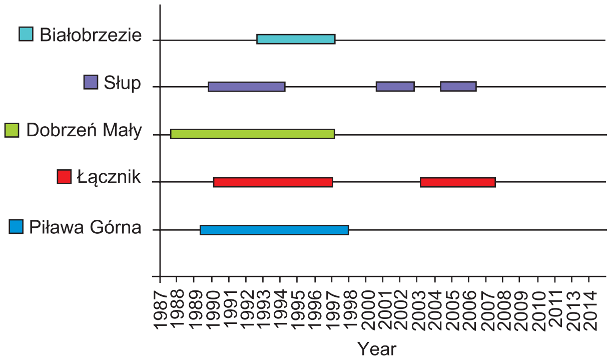


**Fig. 5.** Groundwater drought periods according to SGI method in the measurement points

The frequency of periods of drought according to *SGI* was from 30.1% to 39.5% (see: Table 4). The frequency of periods with mild drought ranged from 9.1% in Dobrzeń Mały to 21.9% in Łącznik, with moderate drought from 4% in Białobrzezie to 19.5% in Dobrzeń Mały. Whereas, most frequently a severe drought came in the range from 1.8 (Łącznik) – 8.6% (Piława Górna); and an extreme drought from 0% (Łącznik, Dobrzeń Mały) to 8.6% (Białobrzezie). The SGI index showed that the most severe drought held in Piława Górna from January 1995 to April 1996. It was a period of 16 months of extreme drought that was preceded by 6 years of drought with intensity from mild to severe. Additionally, attention was drawn to two periods of extreme drought in Białobrzezie (12.1992–03.1994 and 12.1994–09.1995), being part of a longer water shortage period in 1992–1996 (see: Fig. 4).

The analyses refer to existing research on droughts in Poland. According to studies of Bobiński and Meyers (1992, 1992), Bąk and Łabędzki (2002) and Bartczak (2014) in the last fifty years deep droughts occurred in the following years: 1951, 1953, 1959, 1963, 1964, 1969, 1971, 1976, 1982–1984, 1988–1995, 2000–2003. The mentioned authors focused on atmospheric, agricultural and hydrological droughts. This paper provides with calculation and analysis revealing that in the 1990s the drought also reached groundwater level at all posts. Its extension until the end of 1996 was noted, too. No groundwater drought was recorded in 2000–2003, while it is pointed out that at some measurement points this drought appeared only late in 2002 and lasted until 2006. Similar results were obtained in studies of groundwater shortage in Western Pomerania (Kubicz and Stodolak 2017).

## CONCLUSIONS

1. The analysis proves that the TLM method and SGI indicator can be applied to drought research in Poland based on measurement data from National Research Institute.
2. Obtained results complement existing knowledge on droughts in Poland in the last thirty years. The analyses showed that in the 1990s not only there was atmospheric and agricultural drought,

**Table 4.** Number of months and frequency of groundwater drought with different intensity according to the SGI

| Site, observation period | Mild drought | | Moderate drought | | Severe drought | | Extreme drought | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | number of months | frequancy % | number of months | frequancy % | number of months | frequancy % | number of months | frequancy % | number of months | frequancy % |
| Piława Górna 1987–2014 | 40 | 11,9 | 14 | 4,2 | 29 | 8,6 | 18 | 5,4 | 101 | 30,1 |
| Łącznik 1987–2014 | 72 | 21,9 | 52 | 15,8 | 6 | 1,8 | 0 | 0,0 | 130 | 39,5 |
| Dobrzeń Mały 1987–2014 | 30 | 9,1 | 64 | 19,5 | 9 | 2,7 | 0 | 0,0 | 103 | 31,3 |
| Słup 1989–2014 | 47 | 15,6 | 25 | 8,3 | 15 | 5,0 | 6 | 2,0 | 93 | 30,8 |
| Białobrzezie 1989–2014 | 64 | 21,2 | 12 | 4,0 | 6 | 2,0 | 26 | 8,6 | 108 | 35,8 |

as described by Bąk and Łabędzki (2002), Bobiński and Meyer (1992, 1992), but groundwater drought, too.
3. The analyses indicated a possible shift in time of groundwater drought in relation to the other types of droughts. For further research on droughts in Poland the author recommends taking into account the delayed reaction of the aquifer system to the shortage of precipitation, causing in the first place atmospheric and agricultural drought.
4. The SGI indicated fewer droughts than the TLM method, which was more sensitive to short-term droughts. The indicator method did not register temporary fluctuations in groundwater level.
5. Both methods indicated the greatest water shortages in Białobrzezie in 1992–1995.

## REFERENCES

Arpa CIMA (2015). Guidelines for the use of the out-put of models for low-flow management in the po river, www.cimafoundation.org/wp-content/uploads/doc/magre.pdf (dostęp 20.02.2017).

Bartczak, A., Glazik, R., Tyszkowski, S. (2014). Identyfikacja i ocena intensywności okresów suchych we wschodniej części Kujaw. Nauka Przyr. Technol., 8(4), 46.

Bąk, B., Łabedzki, L. (2002). Assessing drought severity with the relative precipitation index [RPI] and the standardised precipitation index [SPI]. J. Water Land Develop., 6, 29–49.

Bhuiyan, C., Singh, R.P., Kogan, F.N. (2006). Monitoring drought dynamics in the Aravalli region (India) using different indices based on ground and remote sensing data. International J. Applied Earth Observation and Geoinformation, 8(4), 289–302.

Bloomfield, J.P., Marchant, B.P. (2013). Analysis of groundwater drought building on the standardised precipitation index approach. Hydrol. Earth System Sci., 17, 4769–4787.

Bobiński, E., Meyer, W. (1992a). Drought in Poland in the years 1982–1992. A hydrologic assessment. Wiadomości Instytutu Meteorologii i Gospodarki Wodnej, 15(4).

Bobinski, E., Meyer, W. (1992b). Hydrologic drought in the years 1989–1992 in Poland against the years 1982––1992. Gosp. Wodna, 12.

Chen, Z., Grasby, S.E., Osadetz, K.G. (2002). Predicting average annual groundwater levels from climatic variables: an empirical model. J. Hydrology, 260(1), 102–117.

Feyen, L., Dankers, R. (2009). Impact of global warming on streamflow drought in Europe. J. Geophysical Res.: Atmospheres, 114(D17).

Fleig, A.K., Tallaksen, L.M., Hisdal, H., Demuth, S. (2006). A global evaluation of streamflow drought characteristics. Hydrol. Earth System Sci., 10(4), 535–552.

Hayes, M., Svoboda, M., Wall, N., Widhalm, M. (2011). The Lincoln declaration on drought indices: universal meteorological drought index recommended. Bull. American Meteorological Society, 92(4), 485–488.

Hisdal, H., Tallaksen, L., Clausen, B., Peters, E., Gustard, A. (2004). Hydrological drought characteristics. Developments in Water Science, 48(5), 139–198.

Kazimierski, B., Cabalska, J., Mikołajczyk, A., Pilichowska-Kazimierska E. (2009). Ocena zagrożenia suszą hydrogeologiczną (gruntową) na obszarze Polski. Materiały XVIII Ogolnopolskiego Sympozjum Zintegrowanego Monitoringu Środowiska Przyrodniczego.

Kondracki, J. (2002). Geografia regionalna Polski. Wydawnictwo Naukowe PWN, Warszawa.

Kubicz, J., Dąbek, P. (2016). Zróżnicowanie częstości występowania nizówek hydrogeologicznych na obszarze Pomorza Zachodniego. Acta Sci. Pol., Formatio Circumiectus, 15 (4), 279–293.

Kubicz, J., Stodolak, R. (2017) . Metoda obrazowania niskich stanów wód podziemnych w przestrzeni jednolitych części wód podziemnych The method of low groundwater flow charting in space of groundwater bodies. Przegl. Nauk. Inżynieria i Kształtowanie Środowiska, 26(1), 15–27.

Leelaruban, N., Padmanabhan, G., Oduor, P. (2017). Examining the Relationship between Drought Indices and Groundwater Levels. Water, 9(2), 82.

Lehner, B., Döll, P., Alcamo, J., Henrichs, T., Kaspar, F. (2006). Estimating the impact of global change on flood and drought risks in Europe: a continental, integrated analysis. Climatic Change, 75(3), 273–299.

Lloyd-Hughes, B. (2014). The impracticality of a universal drought definition. Theoretical and Applied Climatology, 117(3–4), 607–611.

McKee, T.B., Doesken, N.J., Kleist, J. (1993). The relationship of drought frequency and duration to time scales. Proc. 8th Conference on Applied Climatology, 17–22 Janvier, Anaheim. American Meteorological Society, Boston, 179–183

McKee, T.B., Doesken, N.J., Kleist, J. (1995). Drought monitoring with multiple time scales. Proc. 9th Conference on Applied Climatology. American Meteorological Society, Dallas – Boston, 233–236.

Mishra, A.K., Singh, V.P. (2010). A review of drought concepts. J. Hydrology, 391(1), 202–216.

Musuuza, J. L., Van Loon, A. F., Teuling, A. J. (2016). Multiscale evaluation of the Standardized Precipitation Index as a groundwater drought indicator. Hydrol. Earth System Sci., 20(3), 1117.

Ozga-Zielińska, M., Brzeziński, J. (1994). Hydrologia stosowana. PWN, Warszawa.

Paczyński, B. (1995). Atlas hydrogeologiczny Polski w skali 1 : 500 000. Systemy zwykłych wód podziemnych, Zasoby, jakość i ochrona zwykłych wód podziemnych.

Rijkswaterstaat (2014). Drought report (in Dutch: "Droogtebericht"). Watermanagementcentrum Nederland Landelijke Coördinatiecommissie Waterverdeling.

Strzebońska-Ratomska, B. (1994). Metodyka oceny intensywnosci i zasiegu suszy hydrologicznej Cz. I: Susza hydrologiczna na Podkarpaciu w latach 1961–1990. Wiadomości Instututu Meteorologii i Gospodarki Wodnej, 17(4), 15–41.

Tallaksen, L.M., Hisdal, H., Van Lanen, H.A. (2009). Space–time modelling of catchment scale drought characteristics. J. Hydrology, 375(3), 363–372.

Tallaksen, L.M., Van Lanen, H.A. (red.). (2004). Hydrological drought, 48: Processes and estimation methods for streamflow and groundwater. Elsevier, Amsterdam.

Tarka, R., Staśko, S. (2010) Wahania zwierciadła wod podziemnych jako odzwierciedlenie ekstremalnych sytuacji pogodowych. [W:] Wyjątkowe zdarzenia przyrodnicze na Dolnym Śląsku i ich skutki. Red. P. Migoń. Uniwersytet Wrocławski, Wrocław, 241–255.

Van Loon, A.F. (2013). On the propagation of drought: how climate and catchment characteristics influence hydrological drought development and recovery. PhD thesis, Wageningen University, Wageningen.

Van Loon, A.F. (2015). Hydrological drought explained. Wiley Interdisciplinary Reviews: Water, 2(4), 359–392.

Vicente-Serrano, S.M., Beguería, S., Lorenzo-Lacruz, J., Camarero, J.J., López-Moreno, J.I., Azorin-Molina, C., Revuelto, J., Moran-Tejeda, E., Sanchez-Lorenzo, A. (2012). Performance of drought indices for ecological, agricultural, and hydrological applications. Earth Interactions, 16(10), 1–27.

Von Christierson, B., Hannaford. J., Lonsdale, K., Parry, S., Rance, J., Wade, S., Jones, P. (2011). Impact of long droughts on water resources. Report SC070079/R5, Environment Agency.

Wilhite, D.A., Glantz, M. H. (1985). Understanding: the drought phenomenon: the role of definitions. Water International, 10(3), 111–120.

Whittemore, D.O., Butler Jr, J.J., Wilson, B.B. (2016). Assessing the major drivers of water-level declines: New insights into the future of heavily stressed aquifers. Hydrological Sci. J., 61(1), 134–145.

## METODA TLM ORAZ WSKAŹNIK SGI JAKO WYZNACZNIKI SUSZY W WODACH GRUNTOWYCH

### ABSTRAKT

Dotychczasowe badania suszy na terenie naszego kraju praktycznie pomijały aspekt niedoboru wód gruntowych, a koncentrowały się na suszach atmosferycznej, rolniczej i hydrologicznej. Dlatego jako cel niniejszej pracy przyjęto przeprowadzenie analizy występowania susz wód gruntowych w wybranych punktach Polski południowo-zachodniej, w oparciu o metody analityczne stosowane w innych krajach europejskich. Celem pośrednim była ocena możliwości wykorzystania metody odcięcia TLM oraz wskaźnika SGI do monitorowania suszy wód gruntowych na postawie danych z państwowego monitoringu środowiska prowadzonego przez Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy. Wynikiem badań jest stwierdzenie, że zaproponowana metoda i wskaźnik mogą być wykorzystane w analizach dotyczących suszy w Polsce. Uzyskane wyniki stanowią uzupełnienie dotychczasowych informacji na temat susz w Polsce w ostatnim 30-leciu. Analizy wykazały, że w latach 90. XX wieku wystąpiła nie tylko susza atmosferyczna i rolnicza opisywana przez Bobińskiego i Meyera (1992a, 1992b), Bąka i Łabędzkiego (2002), Bartczaka (2014), ale także susza w poziomie wód gruntowych.

**Słowa kluczowe:** susza wód gruntowych, standaryzowany wskaźnik poziomu wód gruntowych SGI, metoda odcięcia TLM