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The types and function of closed depressions in modern loess landscape of Nałęczów Plateau (Lublin Upland, E Poland)

Typy i funkcja zagłębień bezodpływowych we współczesnym lessowym krajobrazie Płaskowyżu Nałęczowskiego (Wyżyna Lubelska, Polska wschodnia)

Keywords: closed depressions, loess landscape, land use, water conditions, Nałęczów Plateau
Słowa kluczowe: zagłębienia bezodpływowe, krajobraz lessowy, użytkowanie terenu, warunki wodne, Płaskowyż Nałęczowski

INTRODUCTION

The Nałęczów Plateau is characterised by the presence of a peculiar complex of loess relief forms, among which closed depressions are the most characteristic features (Maruszczak 1958). 1,761 closed depressions were documented within the Nałęczów Plateau (Kołodyńska-Gawrysiak, Chabudziński 2012). They are small landforms with peculiar distribution and morphometric characteristics such as the dimensions of their longer axis and their size. The longer axis of more than half of the depressions (51.39%) is within the narrow range from 25 to 50 m. The size of 70% of all forms does not exceed 1,500 m^2. These forms are also typified by a characteristic distribution in relation to the elements of loess relief. Their greatest concentration is on the plateau tops where 72% of all forms were documented. Closed depressions also occur in denudation troughs (16% of the forms), bottoms of erosion-denudation valleys (5%) and slopes (7%). Areas of concentration with 30–40 forms per km^2 can be clearly distinguished in the spatial arrangement. Eleven areas of concentration, referred to as closed depression microregions, were identified in the study area (Kołodyńska-Gawrysiak, Chabudziński 2012).

So far, the origins of closed depressions in the loess areas in Poland have been linked with the development of piping processes within initial depressions associated with the dynamics of the loess cover sedimentation (Maruszczak 1954). The

most recent research indicates that the development of closed depressions may have been determined by cryogenic processes (Kołodyńska-Gawrysiak et al. in print). In Poland, closed depressions were studied in the loess areas of the Lublin Upland (Maruszczak 1954; Konecka-Betley, Maruszczak 1993; Kołodyńska-Gawrysiak, Chabudziński 2012; Kołodyńska-Gawrysiak et al. 2012), Sandomierz Upland (Czarnecki, Lewartowska-Urbańska 1987; Czarnecki, Solnceva 1992) and Carpathian Foothills (Wojtanowicz 1997). Closed depressions were also studied in France (Pissart 1958), the United Kingdom (Prince 1961), central Belgium (Gillijns et al. 2005; Vanwalleghem et al. 2007; Etienne et al. 2011) and Russia (Zanin 1952).

The landscape of the Nałęczów Plateau is determined not only by the peculiar land relief but also the type of land use – which is determined by the former (Zgłobicki, Baran-Zgłobicka 2012). In terms of land use, agricultural landscape dominates in the Nałęczów Plateau. More than 82% of the region is covered by agricultural land, mostly arable fields accounting for more than 53%. Forest areas have been preserved in the form of small complexes covering a total of 4,239 ha, i.e. 8.5% of the region (Corine Landcover 2006).

STUDY OBJECTIVE AND METHODS

The study objective was to attempt to classify closed depressions in the Nałęczów Plateau based on their basic external characteristics, and to identify the function performed by these forms in the modern loess landscape.

For the purposes of this study, we used a database containing morphometric characteristics and data on the spatial distribution of closed depressions in the Nałęczów Plateau (Kołodyńska-Gawrysiak, Chabudziński 2012). The database was supplemented with data on land use within the depressions, prepared based on an ortophotomap and verified on site. Four types of depressions were distinguished according to the manner of use: forested, used for agriculture, excluded from agricultural use and located within built-up areas. Due to their strong anthropogenic transformation, depressions located within built-up areas have lost their function in landscape. Therefore, 55 forms of this type were excluded from further study.

The morphological types of closed depressions were determined based on their size and shape. In terms of size, four types of depressions were distinguished: small-, medium-, large- and very large-sized. In terms of shape, three types were distinguished: bowl-shaped, saucer-shaped and fossil depressions. The types of depressions according to the hydrologic regime were identified based on on-site observations conducted from 2010 to 2013.

MORPHOLOGICAL TYPES OF CLOSED DEPRESSIONS

Small-sized depressions, covering 1,000 m^2, are very numerous: 886 such forms, 50.3% of all depressions, were documented in the study area.

The area of **medium-sized depressions** ranges from 1,000 to 2,500 m^2; 629 such forms, 35.7% of all depressions, occur in the study area.

The area of **large-sized depressions** ranges from 2,500 to 5,000 m^2. There are 163 forms of this type, accounting for 9.3% of all depressions.

The area of **very large-sized depressions** exceeds 5,000 m^2. Eighty-three forms of this type, 4.7% of all depressions, were recorded within the Nałęczów Plateau.

The small- and medium-sized depressions occur mainly within the plateau tops where they account for 87% of all forms; 362 such forms, 20.9.% of all depressions in the region, were found in the denudation troughs and slopes. Large and very large depressions are located outside plateau tops, usually in the bottoms of erosion-denudation valleys.

The closed depressions in the Nałęczów Plateau are characterised by gentle outlines resulting from the lack of distinct boundaries separating the individual morphological elements (slopes and bottoms) of the depressions. This natural characteristic of closed depressions can be observed in all of the forms, regardless of their present-day manner of use. Maruszczak (1954) distinguished two morphological types of closed depressions: bowl-shaped and saucer-shaped (Fig. 1). This classification can be complemented with the third type: fossil depressions.

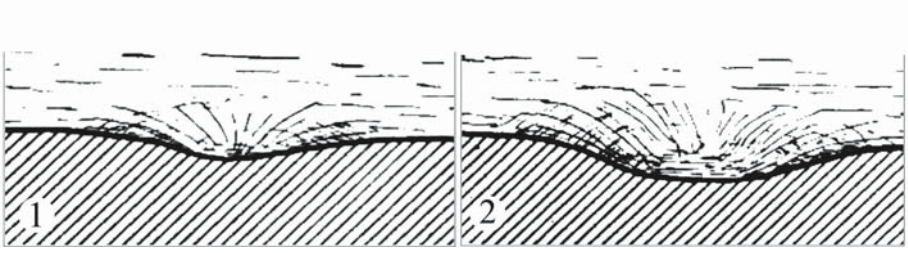

Fig. 1. Morphological types of closed depressions according to Maruszczak (1954).
1 – bowl-shaped, 2 – saucer-shaped

The slopes of **bowl-shaped depressions** are subject to gradual transition into a concave bottom. The boundary between the morphological elements is blurred. These forms are usually small- or medium-sized (Fig. 2).

Fig. 2. A bowl-shaped closed depression at Żabie Duki: N 51019’9.11’’, E 22017’19.97’’

The bottoms of **saucer-shaped depressions** are flat and clear-cut (Fig. 3). This group consists of medium- to very large-sized forms. In the light of on-site observations, this type is the most numerous.

Fig. 3. A saucer-shaped closed depression in the vicinity of Ożarów: N 51017’48.2’’, E 22017’10.9’’

Fossil depressions are currently not discernible in the relief due to their complete infilling by colluvial sediments originating from the denudation of soils. Their presence can only be discerned in early spring or late autumn when darker

oval-shaped stains of humus-rich colluvial material infilling the forms can be observed on the surface of arable land devoid of vegetation. Furthermore, these forms "manifest" themselves in exposures (road gullies, road cuttings, excavations for construction projects) due to the very distinct humic horizon of the buried Holocene soil, marking the original bottom surface of the depressions (Fig. 4). These depressions are quite numerous and small, their diameter being between 10 and 15 metres.

Fig. 4. A fossil closed depression at Kolonia Dąbrowica, exposed in the road cutting within the Lublin Ring Road under construction (July 2012)

TYPES OF CLOSED DEPRESSIONS ACCORDING TO THEIR MANNER OF USE

Closed depressions used for agriculture represent the majority (87.7%) of all closed depressions in the Nałęczów Plateau. In some parts of the plateau tops, they are the only element that adds diversity to the almost flat plateau tops. In the areas with a high concentration of depressions, where they are close to each other and boundaries between them are not distinct, the plateau top relief attains a peculiar microrelief. In agricultural landscape, the presence of small forms does not create special conditions for the development of the vegetation cover; hence it does not influence the character of the crops. Due to periodically more humid habitats, a greater share of weeds in the crops or later ripening of cereals can occur in the bottoms of small- and medium-sized depressions. Sometimes, during long-lasting rainfall, water accumulates in the bottoms of these depressions for short

periods (several days). If grain grows in such depressions, the stalks are bent and the bottoms become silty (Fig. 5).

Fig. 5. Episodically stagnant water in closed depressions is the cause of damage to the crops in the summer. Smugi near Jastków: N 51019'36.44'', E 22028'18.65'', July 2013

Some medium- and large-sized forms, periodically filled with water, stand out in the agricultural landscape due to the different kind of crops growing there: usually these are grasslands, root crops, vegetables or fruit shrubs. If cereals are grown in such depressions, they are soaked during the spring thaw and long-lasting rainfall. In these periods, the oval-shaped bottom surfaces of such depressions where the grain stalks are less robust, not very dense and unripe, stand out in the arable field landscape.

Depressions excluded from use (wasteland) are forms that have been excluded from agricultural use due to frequent or long-lasting water logging. Thirty-eight (2.2%) of such closed depressions were recorded within the Nałęczów Plateau. Distinctive herb vegetation or trees and shrubs growing in these depressions differentiate these isolated enclaves from the surrounding areas. They are usually covered by trees constituting "islands" of forest vegetation in the midst of vast deforested loess plateau top surfaces (Fig. 6).

Tree-covered depressions. Due to the considerable deforestation of the Nałęczów Plateau, less than 7% of the depressions are in forest areas. The size of these forms varies but small- and mid-sized forms predominate (86.7%). Closed depressions are not very distinct in a forest landscape, particularly during the peak of the growing season when they are "camouflaged" by thick forest undergrowth. The vegetation growing in the bottoms of some depressions has a greater share of

Fig. 6. A closed depression excluded from agricultural use at Sadurki: N 51^{0}17’26.98”, E 22^{0}17’8.09”. Such forms constitute peculiar “islands” of forest vegetation on deforested plateau tops

herb vegetation, shrubs and, sometimes, tree species that tolerate variable humidity conditions, e.g. the poplar. These forms are most distinct in early spring, before the vegetation develops in full (Fig. 7).

Fig. 7. A closed depression in a forest near Jastków (February 2013): N 51019’56.38”, E 22027’11.66”

TYPES OF CLOSED DEPRESSIONS ACCORDING TO THE HYDROLOGIC REGIME

A distinguishing feature of some closed depressions is that during the spring thaw and long-lasting rainfall in the warm season, they are filled with precipitation water. The duration of water retention in the depressions varies depending on the seasonal variation of meteorological conditions and size of the individual depressions. At present, water can be retained even for several weeks. In the contemporary landscape of the Nałęczów Plateau, four types of closed depressions can be distinguished based on the hydrologic regime: a) permanently filled with water, b) periodically filled with water, c) episodically filled with water, d) dry. The first two types were identified by Maruszczak (1954), who conducted observations of closed depressions in the first half of the 20th century.

Depressions permanently filled with water are rare in contemporary landscape: four forms of this kind were recorded in the entire region. Two are located in Płouszowice Kolonia, and the other two in Czesławice (Fig. 8, 9). Two of these depressions are located in denudation troughs, one in the upper part of an erosion-denudation valley, and one in the low plateau top area between the Czechówka and Ciemięga rivers. These are medium- and large-sized forms in agriculturally used areas. The water table in these depressions is surrounded by humid habitat vegetation such as *Cladium mariscus*, *Phragmites australis*, *Juncus*, willow shrubs, poplar tree and willow tree.

Fig. 8. A closed depression permanently filled with water in the village of Płouszowice Kolonia (February 2014): N 51^{0}15’54.9’’, E 22^{0}24’11.78’’

Fig. 9. A closed depression permanently filled with water in the village of Czesławice (February 2014): N 51^{0}18'7.97'', E 22^{0}17'1.04''

According to Maruszczak (1954), there were many more depressions filled with "permanent water" at the turn of the 20th century than in the 1950s when he conducted his observations. As Maruszczak noted: "According to residents of various areas, 20–30 years ago, numerous depressions, now ploughed over and filled with water for relatively short periods, used to be filled with water permanently or for a considerable part of the year. Cattle swam in these depressions, fish were bred and people rode boats there". The drying of the depressions, observed by Maruszczak (1954), was a process linked with the changes in hydrologic regimes occurring in the Lublin Upland over the last several decades as a result of human activity (Michalczyk 1993). The changes were mainly related to lower groundwater levels. The surface runoff conditions also changed due to the intensification of agricultural use of the land.

Depressions periodically filled with water retain water even for several weeks during the spring thaw and/or long-lasting rainfall. One or several periods of water retention occur in such forms per year, from early spring to autumn. Due to the periodic presence of water, these forms are excluded from agricultural use. They are home to turf vegetation, *Cyperaceae*, *Phragmites* or tree and shrub species that tolerate variable humidity conditions, i.e. willow shrubs, alder, poplar and birch (Fig. 10, 11).

Fig. 10. A closed depression at Sadurki, periodically filled with water and featuring reed vegetation (February 2014): N 51^{0}17’27.9’’, E 22^{0}19’57’’

Fig. 11. A closed depression periodically filled with water at Kolonia Miłocin (February 2014): N 51^{0}15’26.73’’, E 22^{0}20’12.71’’

Depressions episodically filled with water occur only in areas used for agriculture. Their size varies from small to large. Water stagnation occurs in these depressions rarely and for short periods (several days) (Fig. 12, 13).

Fig. 12. A closed depression episodically filled with water at Cholewianka (March 2011): N $51^0$18'37.85'', E $21^0$57'28.01''

Fig. 13. A closed depression periodically filled with water in the village of Smugi near Jastków (February 2012): N $51^0$19'36.44'', E $22^0$28'18.65''

The accumulation of water in these depressions is determined by geomorphological factors (size of the catchment), soil properties and weather conditions. Conducive conditions occur when the snow thaws in the spring due to the slowly

increasing temperature and low level of insolation or when it is accompanied by rainfall. In such conditions, the ground remains frozen, which prevents the water from infiltrating deeper into the soil and thus leads to the stagnation of water on the ground surface. In the summer and autumn, the arrival of humid air masses may occasion long and intensive rainfall (lasting several days). Some depressions, particularly those with medium- and large-sized catchments, become filled with water then. The catchment sizes determines the amount of water that will flow to the bottom of a depression. During summer and autumn rainfall, episodic water retention in the depressions is determined by the morphological characteristics of Luvisols developed on loess. The presence of the Luvisol illuvial horizon (Bt), containing a clayey fraction, compact and almost impermeable, prevents the infiltration of water deeper into the soil and increases the proportion of surface runoff on the slopes.

Dry depressions are the most numerous group of closed depressions in the region and occur in forests and arable fields. It is the only type of depressions occurring in forest areas because forest vegetation stabilises the hydrologic regime by restricting surface runoff and facilitating infiltration. The bottoms of dry depressions show greater humidity in some periods (during the thaw and rainfall). In the spring, the darker colour of the soils differentiates them from the arable land (Fig. 14). In the growing season, thanks to their greater humidity, these depressions offer better conditions for crop cultivation, which is reflected in better crops in certain locations (denser cereals, large root vegetables).

Fig. 14. A closed depression in the fields belonging to the village of Marianka Ożarowska. The bottom of the depression has a distinct dark colour owing to the presence of humus colluvia and greater humidity (February 2014)

THE FUNCTIONS OF CLOSED DEPRESSIONS IN LANDSCAPE

Closed depressions have various functions in the contemporary landscape of loess areas. These functions can be viewed from the geomorphological, ecological and aesthetic perspective. Local residents indicate that in the past, closed depression also had a utilitarian function, mainly as watering places for cattle and fishing sites. Depressions located in the neighbourhood of residential buildings were used for domestic purposes (washing clothes). They have already lost that utilitarian function due to the contamination of water with fertilisers and pesticides washed out from arable fields by rainwater. The number of closed depressions permanently filled with water has clearly fallen over the last few decades also due to anthropogenic changes in the hydrologic regime. From the geomorphological perspective, the role of the closed depressions depends on their location in relation to other elements of the loess relief. The most significant role in landscape is played by depressions located within the loess plateau tops. Closed depressions are usually the only landform that adds variety to the monotonous land relief, which makes them one of the most distinctive types of loess landscapes. The parts of plateau tops where numerous depressions occur are marked by unique geomorphological characteristics manifested in a strongly undulating relief (Fig. 15). The landscape of plateau tops with an abundance of depressions can be compared to badlands in the areas subjected to intensive erosion. The landscape role of depressions in certain parts of plateau tops can thus be quite significant and can justify the distinction of subtypes of loess landscape.

The ecological function of closed depressions is related to their manner of use that depends on the hydrologic regime occurring there (Borcz, Pogodziński 1994). In this respect, the small number of depressions permanently and periodically filled with water play a considerable function in landscape.

Fig. 15. The characteristic undulating relief of the plateau top with abundant closed depressions. The vicinity of Marianka Ożarowska

The presence of such depressions has an impact on the biological diversity of areas used for agriculture (Markuszewska 2001). Depressions permanently filled with water provide habitats and feeding grounds to many water animal and waterfowl species (Juszczak 2001; Koc et al. 2001). Most of the depressions periodically filled with water feature complexes of arborescent plants, with a large proportion of shrubs, which is conducive to enhanced species richness. They provide shelter, nesting places and breeding grounds to many species of mammals, birds, amphibians and insects.

Enclaves of trees growing in depressions periodically filled with water are among the factors that shape the microclimate and regulate the hydrologic regime by reducing evaporation and the melting rate of the snow cover. They also improve the circulation of water in the soil and reduce the intensity of winds, thus mitigating aeolian erosion in agricultural areas (Koc 2010). The above functions are spatially restricted to the immediate neighbourhood of such depressions; hence they have a local character.

The presence of closed depressions also raises the aesthetic value of landscape. Depressions permanently or periodically filled with water have a particular importance in this respect (Niedźwiecka-Filipek 2001). The former are very distinct in landscape because the complex of water- and humidity-loving vegetation growing in these depressions distinguishes them from the surrounding fields. Most of the depressions periodically filled with water feature complexes of arborescent plants, with a large proportion of shrubs. These enclaves of shrubs strongly contrast with the highly deforested agricultural areas of the Nałęczów Plateau (Fig. 16).

Fig. 16. Forest enclaves formed by shrub vegetation growing in closed depressions contrast with arable fields. A depression at Moszenki: N $51^0$18’12.63’’, E $22^0$20’30.42’’

Closed depressions episodically filled with water have a unique aesthetic function in landscape. This function is limited to a short period (several days), usually in early spring before the culmination of the growing season. The water-filled depressions, usually small but occurring in groups, are a unique landscape feature of loess areas, particularly the plateau tops with scarce surface streams (Fig. 17).

Fig. 17. Closed depressions periodically filled with water are a unique landscape feature of loess plateau tops. Jastków, February 2012

CONCLUSIONS

The present-day functions of closed depressions in the landscape of the Nałęczów Plateau are based on natural values. These functions can be viewed from the geomorphological, ecological and aesthetic perspective.

In geomorphological terms, closed depressions enhance the geodiversity of loess areas. They form a unique microrelief that adds variety to the relief of the plateau tops. Colluvial material containing chemical elements and pollutants accumulates in these forms.

Closed depressions, particularly those permanently and periodically filled with water, have a favourable impact on the biodiversity of areas used for agriculture. Thanks to the forest vegetation and water- and humidity-loving plants growing next to the arable field vegetation, these depressions enrich the landscape with natural contrasts and habitat diversity that is conducive to species diversity.

Depressions periodically filled with water constitute peculiar "islands" whose vegetation contrasts with the surrounding arable fields. Clusters of trees and

shrubs are characteristic landscape features enhancing the aesthetic value of the monotonous, highly deforested plateau tops.

In periods of water retention, closed depressions clearly stand out in the landscape of arable fields and constitute a characteristic landscape feature in loess areas with scarce surface streams.

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STRESZCZENIE

Zagłębienia bezodpływowe należą do głównych, a jednocześnie osobliwych elementów rzeźby obszarów lessowych. Celem badań była próba klasyfikacji zagłębień na podstawie ich cech zewnętrznych oraz określenie funkcji, jaką formy te pełnią we współczesnym krajobrazie obszarów lessowych Płaskowyżu Nałęczowskiego. Klasyfikacji zagłębień dokonano w oparciu o kryteria geomorfologiczne, hydrograficzne oraz użytkowanie terenu.

Zagłębienia bezodpływowe, mimo iż są to drobne formy rzeźby, pełnią ważną funkcję we współczesnym krajobrazie Płaskowyżu Nałęczowskiego. Funkcję tę można rozpatrywać w aspekcie geomorfologicznym, ekologicznym oraz estetycznym. Z punktu widzenia geomorfologicznego, funkcja zagłębień wyraża się w ich wpływie na georóżnorodność obszarów lessowych. Na terenie wierzchowin tworzą one specyficzny mikrorelief, który urozmaica rzeźbę. W aspekcie ekologicznym, zagłębienia bezodpływowe korzystnie wpływają na bioróżnorodność obszarów użytkowanych rolniczo. Największe znaczenie pod tym względem mają zagłębienia z wodą stałą oraz periodyczną. Dzięki porastającej je roślinności leśnej oraz wodno- i wilgociolubnej bezpośrednio sąsiadującej z roślinnością pól uprawnych, wprowadzają one do krajobrazu kontrasty przyrodnicze oraz zróżnicowanie siedlisk, wpływające korzystnie na różnorodność gatunkową.

Zagłębienia periodycznie wypełniające się wodą stanowią swoistego rodzaju wyspy kontrastujące typem roślinności z otaczającymi terenami pól uprawnych. Kępy drzew i zarośli stanowią osobliwe dominanty w krajobrazie monotonnych, silnie odlesionych wierzchowin lessowych, podnosząc ich walory estetyczne.