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THE ROLE OF LOCAL WATER CONDITIONS IN DISTRIBUTION OF RAISED BOGS IN MOUNTAINOUS AREAS: CASE STUDY OF THE POLISH CARPATHIAN MOUNTAINS

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SUMMARY

It has been often argued that the formation of peat bogs, especially of the raised type, is predominantly influenced by a humid climate (precipitation greatly exceeds evaporation during the vegetation growth season). In many areas, even in mountains, where precipitation during vegetation growth season is greater than evaporation, raised bogs do not cover all gently sloping areas and valley bottoms and often develop within certain landforms with specific hydrological conditions. In the flysch Carpathian Mountains local water conditions determined by land relief and bedrock structure are the most crucial factor in the development of peat bogs. This study covers bogs in selected areas in the Polish Carpathians: intra-mountain basins, floors of river valleys and mountain ridges (slopes, passes). The paper is based on an analysis of maps produced over the 20th century, on aerial photographs taken since 1965 and on the newest data (LiDAR). Fieldwork included the geomorphological and hydrographic mapping of specified landforms with peat bogs studied using GPS methods as well as the field measurement of water infiltration. Peat bogs of the Polish Carpathians demonstrate that bogs, irrespective of altitude and total precipitation, develop most frequently in concave landforms, where outcrops of poorly permeable rocks offer numerous low-capacity but stable outflows of groundwater that continuously humidifies the slopes lying below thus supporting the formation of habitats for hydrophilic plants. Thus, the common belief that raised bogs with well-grown domes in the areas of the Polish Carpathians under study are fed exclusively by rainwater must be questioned, as throughout the development of such bogs, an integral part, i.e. the fringe zone, is largely fed also by groundwater outflows.

***Keywords**: raised bogs, peat substratum, low-capacity groundwater outflows, Polish Carpathians*

INTRODUCTION

It has been often argued that the formation of peat bogs, especially of the raised type, is predominantly influenced by a humid climate (precipitation exceeds evaporation during the vegetation growth season). By many authors for a bog to develop specific geological, geomorphological, hydrographic and hydrogeological conditions must also be met (e.g. Cooper, McCann, 1995, Ilnicki, 2002). In mountain areas where precipitation greatly exceeds evaporation during this season, vast blanket bogs develop, covering ridges, slopes and the feet of the slopes (e.g. Shaw *et al.*, 1997, Bragg, Tallis, 2001). In many areas, even in mountains, however, where precipitation during vegetation growth season is greater than evaporation, bogs (especially of the raised type) do not cover all gently sloping areas and valley bottoms and often develop within certain landforms with specific hydrogeological conditions and stream network. In the Carpathian Mountains local water conditions determined by land relief and structure are the most crucial factor in the development of peat bogs (Łajczak, 2014).

The goal of the presentation is to discuss the impact of water conditions on distribution of raised bogs in different geomorphological locations in Polish part of the Carpathian Mountains.

METHODS

This study is based on an analysis of maps produced over the 18th-20th centuries, on aerial photographs taken since 1965 and on the newest LiDAR data. Fieldwork included the geomorphological and hydrographic mapping of specified landforms with peat bogs studied using GPS methods as well as the field measurement of water infiltration and discharge of groundwater outflows.

RESULTS

In the Polish part of the Carpathian Mountains bogs (including the raised bogs with well-developed domes) are concentrated in two areas named as The Carpathian Peatlands: The Orawa - Nowy Targ Basin (intramountain basin) and the Bieszczady Mountains (floors of two deep valleys). In that areas eight geomorphological situations were distinguished in which expanding raised bogs changed the land relief on a local scale. The locations featuring the groups of bogs that have been distinguished are discussed in order from those lying on the highest ground to those lowest bogs lying in valley and basin bottoms. The following situations are distinguished in terms of the pattern of bog development: (1) watershed bogs, (2) bogs in spring niches of shallow erosion-induced incisions, in the bottom of these incisions and on their slopes, (3) bogs in palaeochannels, (4) bogs on high various-age Quaternary terraces near the base of a higher terrace, (5) bogs on evenly inclined fragments of the terrace formed during the last glaciation in spots with numerous groundwater outflows, (6) bogs fully developed on an alluvial fans, (7) bogs on the edges of single or neighbouring alluvial fans, (8) bogs on the post-glacial terrace between an inactive levee and undercut flysch slope, locally at former oxbows. The development of bogs in situations (1), (5) and (6) leads to a gradual local increase in the terrain height difference. In the other situations, as the low bog develops, the terrain levels out, and then, as the peat dome builds up, local height differences increase. Thus, hollow forms in the mineral substratum of the bogs are replaced by convex forms made of peat. The most significant changes in the relief occur in situation (3), where an extensive peat dome may even grow on top of several fossilised channels of former neighbouring watercourses. In such a situation, local watersheds shift.

The Orawa - Nowy Targ Basin with the largest Carpathian peatland has an area of 600 km^2. The Basin lies between the high-mountain massif of the Tatra Mts and the Beskidy Mts and is inclined northwards. Thirty raised bogs in the Basin developed on glaciofluvial fans, on river terraces and on small alluvial fans at altitudes of 590-770 m a.s.l., lying from 5 to 40 m above river channels. The bogs cover a poorly permeable 2-metre thick layer of clay, sitting on strongly hydrated Quaternary gravels. The formation of bogs in the Basin is enhanced by its cool and humid climate (precipitation of approx. 1000 mm). Despite the substantial shrinkage of peatland in the last 500 years, as a result of peat extraction and drying, the peat-covered area in the Basin can nevertheless be compared with some of the largest peat-covered areas in other massifs in Europe. The bottoms of river valleys in the Polish part of the Bieszczady Mts feature remnants of 17 raised bogs. The bogs in that mountain are much smaller and surrounded by narrower post-peat areas. Bogs are at an altitude of 550-700 m a.s.l. and extend over post-glacial terraces and alluvial fans, lying from 5 to 8 m above river channels. The bog substratum is formed by a layer of silt atop gravel. The precipitation in the area is 1000-1200 mm. Most bogs located at the feet of flysch slopes are recharged by groundwater seepage.

In the Polish Carpathian Mountains many small bogs, including raised bogs, are located in the Tatra Mountains with typical glacial morphology and in numerous places in the flysh Beskidy Mountains. Bogs in the Tatra Mountains are developed in U-shaped valleys on substratum overlain by moraines. Most frequently, they are present between the ridges of lateral moraines and the valley slopes and between the ridges of recessional moraines. Many of these places previously functioned as a small post-glacial lakes. Thus the parent material of these bogs is formed by poorly permeable (fine grained) lake material deposited on moraine debris. Peat bogs on slopes occur above moraine ridges and in depressions formed by the melting of dead ice. In the Beskidy Mountains, peat bogs are found on slopes in the following situations: on flat areas and in landslide niches, in depressions surrounding springs, at mountain ridge passes and on cryoplanation terraces – mostly at the base of steep slopes. The substratum of bogs on slopes is formed by locally deposited fine-grain eluvium, which, in the Flysch Carpathians, is located on shale rock outcrops. The above morphological situations always involve outflows of groundwater, even minute ones, which hydrate the area surrounding the peat bogs and the nearby hydrophilic vegetation habitats not yet undergoing the peat-bog forming process.

Peat bogs of the Polish Carpathian Mountains demonstrate that bogs, irrespective of altitude, develop most frequently in concave landforms, where outcrops of poorly permeable rocks offer numerous low-capacity but stable outflows of groundwater that continuously humidifies the slopes lying below thus supporting the formation of habitats for hydrophilic plants.

Locally, the number of bogs in the study area is large enough for their location to be analysed on the basis of the lithological, geomorphologic and, especially, hydrogeological properties of the substratum. Most bogs in the Polish Carpathians have an area of less than 1 ha, with only a few being larger than 100 ha. In intramountain basin they occur from hilltops to the old-Holocene terraces, in valley floors on alluvial fans especially. The bogs developed on mountain ridges are located on slopes, passes and locally at the tops. The bogs located on ridges with very varied relative altitude are for the most part ombrogenous in nature; while the more numerous slope bogs are soligenous (hanging bogs). The lowest located bogs are topogenous and fluviogenous and also limnogenous. The above types of bogs are transformed into ombrogenous ones.

By analysing the relief of raised bogs in the Polish Carpathians some of the characteristics of bogs were examined which had not been previously addressed. Considering the geomorphological criteria for their occurrence, all the bigger bogs examined are of the valley type, although they developed within different mesoforms. Raised

bogs in the areas under investigation do not solely occur, as claimed by other authors, on clearly visible watersheds, but mainly in locations that are topographically lower than these. Raised bogs with an extensive dome may develop across the range of altitudes of the areas under study, yet hollow landforms, such as spring niches, palaeochannels, scarp bases of higher terraces and alluvial fan edges are favored in this respect. Stable outflows of shallow groundwater, which are the most intensive in such places, guarantee the development of low bogs, and then, as raised bogs expand, they keep the fringe area highly humidified.

The formation of raised bogs, not only in the initial phase of their growth, but also during the growth of the dome, is largely determined by the system of watercourses, which transform with time into fringe watercourses (Łajczak, 2007). High levels of dampness of the soil in the vicinity of such watercourses fed by the nearby outflows of groundwater guarantee the continuation of the peat-forming process in the fringe zone, and in the marginal zone of the peat domes, which is a prerequisite for their further expansion. Examples of a dense system of fringe watercourses in the vicinity of the largest peat domes in the Orawa – Nowy Targ Basin before the initiation of the drainage activity are shown by the maps produced at the turn of the 18th and 19th centuries.

CONCLUSION

The common belief that raised bogs with well-grown domes in the peatland areas of the Polish Carpathians under study are fed exclusively by rainwater must be questioned, as throughout the development of such bogs, an integral part, i.e. the fringe zone, is largely fed also by groundwater outflows (Łajczak, 2007, 2009).

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