

Forest expansion on the boulder fields of the Mt. Łysica massif in the 19th and 20th centuries - analysis of historical sources, archival maps and contemporary aerial photos

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The aim of the research was to assess the rate of forest expansion on the boulder field on the Mt. Łysica massif in the Świętokrzyskie Mountains in the 19th and 20th centuries. In the above-mentioned period, large changes in the forest area took place, caused by deforestation for agriculture, as well as forest succession caused by climate change. Historical sources were used in the research, including archival maps, as well as archival and contemporary photogrammetric materials. Field surveys of the forest range boundaries were also performed, using the tacheometric measurement method and the photogrammetric flight using the UAV. The boulder fields are a distinctive element of the landscape of the Świętokrzyskie Mountains (Fig. 1). They are rock rubble not covered by forest, occurring in the top plateau parts of the Łysogóry and Jeleniowskie ranges, built of quartzite sandstones. They differ from the rubble and rock debris typical of higher mountains, because they occur inside the forested areas with relatively gentle slopes, at a height of approximately 500 – 600 m.a.s.l. The influence of the periglacial climate in the late Pleistocene is most often considered as the main factor that contributed to their formation.

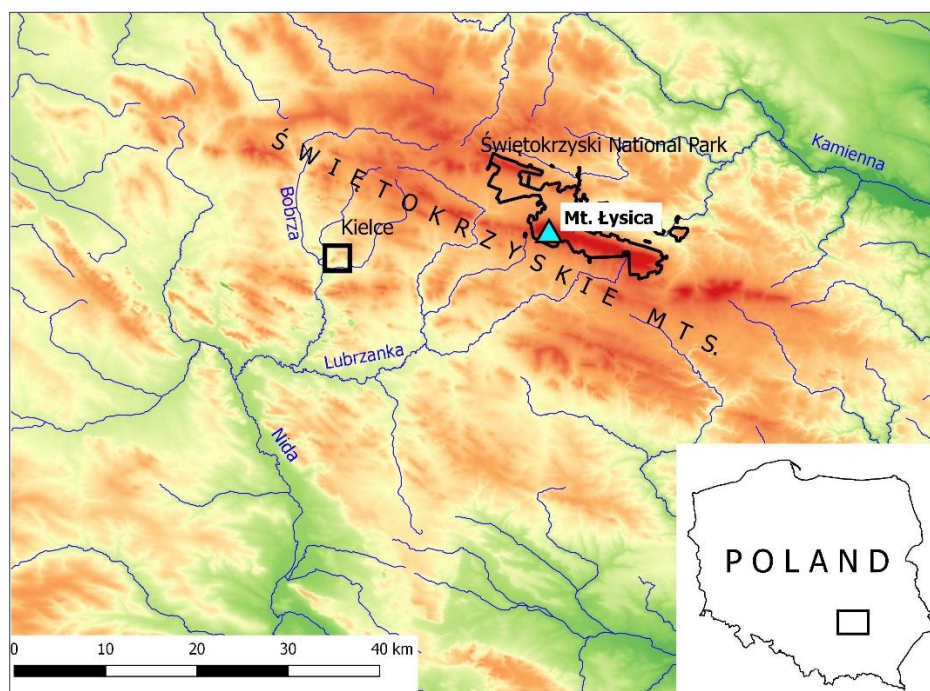


Figure 1 Location of the studied area.

The vast majority of the boulder fields occur on the northern slopes of the aforementioned mountain ranges, which means a coincidence with the climatic conditions (Łajczak et al., 2020).

The analysis of historical sources present significant changes in the forest cover of the Łysica Massif during the 19th century. According to the report from triangulation net survey from 1828-1829 (Armiński, 1830), the entire area of the Łysica top plateau was unforested, what allowed for triangulation in all directions from the top, using a stone platform elevated about 2 meters above ground level, and made this place convenient as the start point of local reference system. The report also includes a detailed physiographic description of the Łysica Massif, where the boulder fields are characterized as natural deforested areas. In later studies on the genesis of boulder fields (Sedlak, 1964), natural deforestation also is assumed, even taking into account ancient remains of economic activity (prehistoric iron metallurgy), which are quite common in the adjacent areas, but were found to be absent in this area. The analysis of cartographic materials from the 19th century also does not confirm forestry activity in the Łysica top plateau, despite the fact that deforestation in the adjacent areas - mainly valleys and slopes - is well documented (Ciupa et al. 2016). Therefore, it should be assumed that deforestation was not caused by human activity on the Łysica plateau but rather was a result of natural causes (e.g., climate change) in the analyzed period. The triangulation survey mark from Armiński's measurements was damaged in 1830, and in 1834 it was rebuilt and raised to the height about 9 m above ground level (Banasik, Bujakowski 2018), and was used for the surveys of Russian military topographical services in 1846 – 1848. In the report from 1904 (Dybczyński, 1909), it was found that the top of Łysica was completely covered with forest, except for a narrow glade to the north-east. Also, a military observation tower at the top, 20 meters high is described there, which collapsed in the mid-1890s due to the decay of the wooden structure. The necessity of building of this tower means, that it was no possibility to observe the areas surrounding from the ground level at least 15 or 20 years earlier than the fact of collapse of the structure. This may indicate the expansion of the forest to the top of Łysica around the middle of the 19th century. There, the eastern peak of Łysica (Agata's Rock) was also mentioned, as the place without any view or other interesting objects. Actually, in the present time there are steep rocks (outcrops), and boulder field there, but it's difficult to spot them from the track, due to presence of dense forest. Therefore, it can be assumed, that the situation was the same in the beginning of 20 century. The eastern top of Łysica is located 700 meters away from main top and even higher by nearly 0,5 m than the main top, though its terrain conditions are inconvenient to the surveys (Hajdukiewicz, Romanyszyn, 2017). It is located on the line of sight connecting the main top and the triangulation point on the tower of the monastery on the Łysiec mt., that was mentioned as the main angular reference of the triangulation of 1828 – 1829, so it can be concluded, that in 1829 this part of the Łysica top plateau must had been unforested, otherwise it would obstruct the sight.

The analysis of cartographic materials (Białokur, 1935) in comparison with the data of the Świętokrzyski National Park spatial information system (forest economical map, updated in mid 1950's and digitized) demonstrated that in the 1930s the boulder field covered a much larger area than nowadays. Moreover, the visibility analysis indicated that the degree of afforestation at the top plateau of Łysica was lower than that described by Dybczyński, in turn on the basis of an update from the 1950s, it was found that the surface of boulder fields was about 10% larger than that found on the map performed 20 years earlier. A comparison of aerial photos from 1969 and 1973, orthophotos from 1997, 2003 and 2015 showed that the areas indicated as boulder field on the forest economical maps were partially forested already at the end of 1960's. In the period 1969-2015 the deforested area has decreased by 15%, but the survey performed on the archival photogrammetric material of different quality is very uncertain. All the images show area oscillating about 50% smaller than indicated on the forest

economical map of 1935. On the images of 1997, 2003 and 2015 the small boulder fields are recognizable, that wasn't indicated on the forest economical maps.

The verification of the accuracy of the measurements was carried out on selected boulder fields in 2017, by field survey using GNSS and tachimetric method and comparison to the survey on the orthophotomap of 2015 with a resolution of 0.25 m. As a result of field measurement, the area of boulder field was 25% larger than as a result of measurement performed on the aerial orthophotomap. Taking into account the correction for the thus estimated measurement error, it can be concluded that the area of the deforested boulder fields decreased by 55% in the period 1935 – 2017. Comparison of the reaches of the forests in 1829, mid of the 1950's (described as 1955), 2015 and from control survey of 2017 is depicted in Fig. 2. Estimating the forest expansion in the period 1828-1935 required the determination of the presumed extent of the forest at the beginning of this period. On the basis of Armiński's information about the lack of obscuring the horizon, and the measurements of the average height of trees surrounding the contemporary boulder field carried out using UAV photogrammetric survey, the minimum range of the deforested area in 1828 was determined approximately on the level of the contour of 595 m above sea level. The area delimited this way covers 13 hectares, of which nowadays only 8% is covered by the boulder fields, while in 1935 it was about 15%.

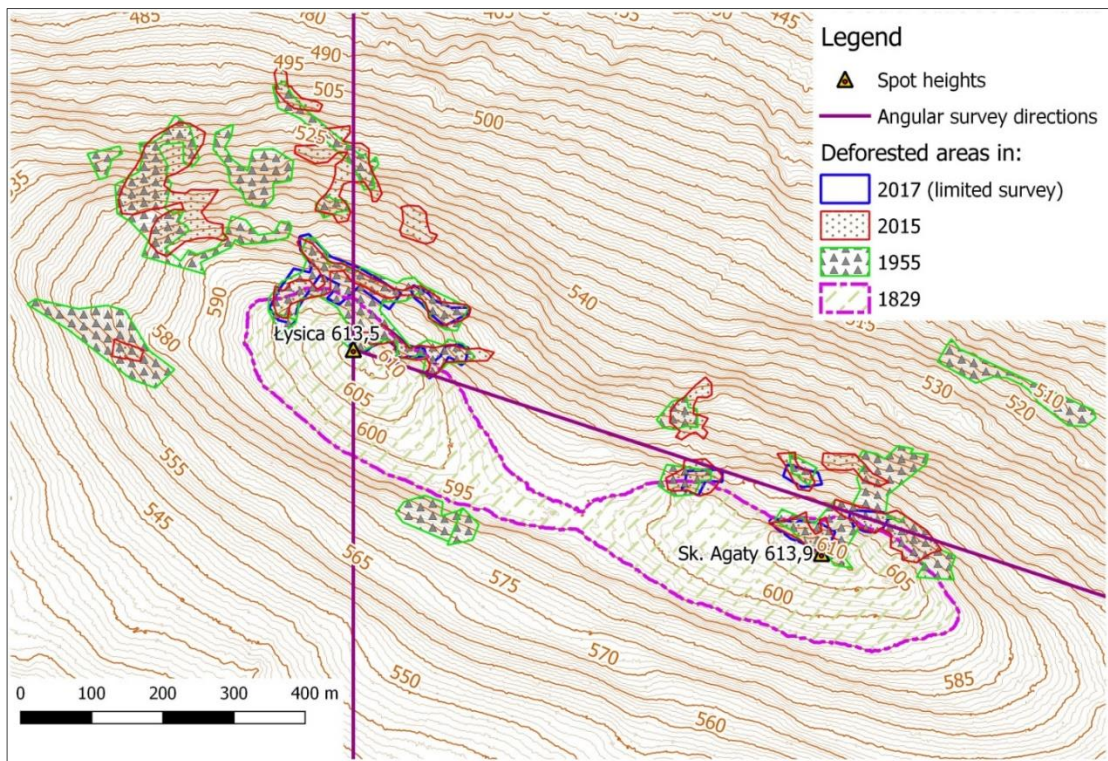


Figure 2 Changes of the deforested area of Łysica massif in XIX – XXI centuries.

To conclude, according to the analysis of the described materials, two periods of intensive forest succession on the Łysica Massif can be distinguished: between 1829 and 1904 and between mid of 1950's and present time, while the rate of forest expansion in the first of these periods was much higher than in the later period. This indicated the climate changes as a main cause of forest cover changes in the peak parts of Łysica massif during the last 200 years rather than human activity.

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