APPLICATION OF GIS IN ANALYSIS OF CHANGES IN FOREST COVER IN BUKOWE HILLS

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Abstract

The mesoregion of the Bukowe Hills, located close to the Szczecin agglomeration, was originally covered with the primeval beech forest. Location of nearby city caused that as early as in renaissance region was deforested. From the end of 18th century Prussian administration planned to restore the original forest cover. This paper presents results of research on forest cover transformation in the area during the last two centuries. The land use was reconstructed based on the archival maps with the ArcInfo software. Authors also identified the land forms shown on the archival city views and compared with the present day DEM. Such comparison allowed the reconstruction of the landscape without forest cover in the period with topographical maps (17th-18th century).

The forest cover was most probably presented on the analyzed views of the city from 16th-18th century in a fashion similar to the reality. The greatest deforestation (3 500 ha) took place between 1780 and 1900. The greatest afforestation took place between 1960 and 2000.

Introduction

Archival topographical maps are an important source of information about the changes in particular elements of landscapes. Analyses of the archival cartographic materials may concern changes in land use, hydrology network and settlement. Comparison of the historical data with the modern cartographic materials makes it possible to assess the changes in landscape. Geographic Information Systems (GIS) are especially useful here. Thanks to the software it is possible to process the maps of the state and changes of the environment as well as create and use digital elevation models (DEM).

Szczecin, the old capital of the Western Pomerania, has got a large collection of views and maps of the town and its surroundings. Most of them include the Bukowe Hills, which is a proof that they were considered an important element of the landscape.

Over the centuries the image of the Hills in the archival materials underwent various changes. Nowadays computer technology helps to follow these changes and to make a more objective assessment.

The aim of this study was to assess the usability of the archival cartographic materials in the GIS analysis of the changes in the forest cover of the Bukowe Hills. Digital elevation model was used to assess the changes in the forest cover in relation to the hypsometric diversification.

Materials and methods

DEM was based on topographical maps in the scale 1:10 000 from the end of the 1960s, published by the GEOKART United Geodetic-Cartographic Companies according to the state co-ordinate system 1965. The model was built with the ArcInfo and Idrisi for Windows.

The digital map of the changes in the forest cover was based on the cartographic documentation (Ziarnek 2002) using “Historischer Atlas von Pommern” and “Dynamics of changes in landscape of Szczecin Landscape Park”. Maps documenting the state of forest cover from 1780, 1900, 1960 and 2000
were scanned and the forest polygons were digitalized with the ArcInfo software. The data were exported to the Idrisi software in which rasterization of the polygons took place. The study also presented the example of views of Szczecin (Braun and Hogenberg, 1594) which was compared with the digital elevation model.

**Research area**

The Bukowe Hills is a range of towering moraine hills east of Szczecin. They are popularly called the Bukowa Forest. Kondracki (2000) in his physico-geographical division defined the hills with the adherent area as a separate mesoregion called the Bukowe Hills. The length of the main moraine massif spreading in the NW-SE direction is 15 km and its width ranges from 4 to 6 km (Fig. 1.). The area of the hills themselves is 7 800 ha and the whole research area covered by the DEM was 17 000 ha. It is believed that the Bukowe Hills are a glaciectonically dislocated upland, structures whose had already existed before the Baltic glaciation. The massif formed during the Vistulian glaciation and was crossed and its structures were dislocated by the glacier expanding southwards (Musielak 1993).

Geological structure and the variety of the surface formations results in the high diversification of the soil cover. The types of the soil have the transitory character: from the brown earth to the rusty soil. Despite the very good soil the area is mainly covered with forest. It is due to the very diversified topography which makes it difficult to use the land for agricultural purposes. Nowadays the area of the Bukowe Hills is the massif cut with ravines. The hills have a high true height and various slope. The very varied topography makes the slopes very steep. The considerable height of the Bukowe Hills (the highest hill Bukowiec - 147m) and the proximity of plains results in the hills being the dominating element of the landscape south of Szczecin. Their height results in different climatic and hydrologic conditions with many specific and precious plant societies.

The composition of species in the forests of the Bukowe Hills was mostly influenced by the early stage of the sub-Atlantic period. The convenient ecological conditions of that time facilitated the expansion of the beech-tree in the area; it is still the dominating species in various areas of the Bukowa Forest (Celiński 1962).
Results and discussion

The image of the forest and the profile of the area in historical views

The presence of the Hills in the views of Szczecin suggests that for ages the area was considered an important element of the landscape. However, the image of the Bukowe Hills presented on the past maps and views may differ from the actual state since the perspective available today was possible in those days. On the Lubinus map (1618) the western part of the Bukowe Hills is presented as hillocks and the eastern part as a uniform area completely covered with a forest (Fig. 2). The lack of forest in the western part, similarly to the views from the contemporaries, is a proof of the varied cover of the area. The actual diversification of the topographic profile is presented in the DEM (Fig. 3).
Fig. 2. Bukowe Hills on Lubinus map of Pomerania (1618)

Fig. 3. Digital elevation model

Also the town view by Braun and Hogenberg (1594), the first ever plan of Szczecin and its surroundings, depicts the Hills with no forest cover in the Western part (Gwiazdowska 2001). The Bukowe Hills were presented as a range of subsequent massifs (Fig. 4).
In the present study ridges of the massifs were marked with lines that were also drawn in the model of the area. Comparison of the ridges from the illustration with the model suggests that the work of Braun and Hogenberg is relatively true when it comes to the actual profile of the area.

The forests are on the ridges of all the hills. If the hills had been covered with trees, it would have been impossible to notice the particular massifs; therefore one may suppose that the aforementioned illustration reflected the actual state of the land cover at the time.

No forests are shown also on the view of the Bukowe Hills by Kotte and Rollos (1625). The illustration shows small patches of forests covering only the ridges and the feet of the hills. On the hills, beside the deer, there are some pigs, which suggests the agricultural activities on the area.

The view by Seutter from the middle of the 18th century presents the Bukowe Hills completely covered with trees (Fig. 5).
One can notice four main ridges of the range. The profile of the area is invisible because the area is completely covered with trees.

The analysis of the views of Szczecin indicates that between the second half of the 17\textsuperscript{th} century and the first half of the 18\textsuperscript{th} the western part of the hills became completely afforested.

**Changes in forest cover between 1780 and 2000**

The archival cartographic materials show that the Western part of the Bukowe Hills range was relatively little afforested between the 16\textsuperscript{th} century and the first half of the 18\textsuperscript{th} century. According to the digital maps based on the “Historischen Atlas von Pommern” (1963), the forests covered over 60\% of the research area. The forests dominated mainly in the area of the massif where it reached 78\% (Fig. 6). Between the end of the 18th and the beginning of the 20th century the acreage of forests markedly decreased (by almost 20\%) which resulted from the inclusion of the forest stand into the forestry scheme (Ziarnek 2002). However, the changes did not affect that much the hills themselves where the area covered with trees decreased by nearly 11\% (Fig. 7).

No significant changes were found between 1900 and 2000. Both on the hills and their feet only a small increase in the forest area was noticed. The acreage of the afforested areas exceeded the one of the deforested areas (Fig. 8).

![Fig. 6. Changes in forest cover in the years 1780-1900](image-url)

Forest cover in relation to the slope of the area

Changes in the forest cover on the Bukowe Hills between 1780 and 1900 depended on the slope of the area (Tab. 1). Between the end of the 18th and the beginning of the 20th century the forest cover decreased mainly in the areas of the lowest slope. The reason of the deforestation was both the elevated demand for timber and increasing the acreage of grasslands at the expense of forests (Tab. 2). The distinct decrease in the forest cover took place also on the steep slopes. More than 30% of trees were cut down on the slopes with the slope higher than 26°. The decrease in forest cover was not connected with the agricultural activity but purely for timber.

Between 1780 and 1900 there was no increase in the forest cover on the slopes with the highest slope. However, in the later period (1900-1960) the mentioned areas witnessed an increase in forest cover. Afforestation increased the forest cover by 20.5% on the slopes with the slope higher than 26°. Therefore one could say that between 1780 and 1900 water erosion increased and after the 1900 the erosion was inhibited due to the domination of the forest cover.
Table 1. Forest cover on the research area in classes of slope

<table>
<thead>
<tr>
<th>Slope [°]</th>
<th>Years</th>
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<tr>
<td></td>
<td>1780</td>
<td>1900</td>
<td>1960</td>
<td>2000</td>
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<tr>
<td>&lt;1</td>
<td>54.8</td>
<td>33.1</td>
<td>35.7</td>
<td>40.0</td>
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<td>1 – 5</td>
<td>60.1</td>
<td>41.3</td>
<td>43.6</td>
<td>47.4</td>
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<td>6 – 10</td>
<td>83.7</td>
<td>69.2</td>
<td>69.8</td>
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<td>84.1</td>
<td>86.7</td>
<td>88.5</td>
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<td>93.0</td>
<td>93.8</td>
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<tr>
<td>21 – 25</td>
<td>98.8</td>
<td>82.3</td>
<td>89.5</td>
<td>90.1</td>
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<tr>
<td>&gt;25</td>
<td>99.3</td>
<td>68.1</td>
<td>78.7</td>
<td>80.8</td>
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Table 2. Changes of forestation in classes of slope

<table>
<thead>
<tr>
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<th>Area [ha]</th>
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<th>afforestation</th>
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<td>1780/190</td>
<td>1900/196</td>
<td>1960/200</td>
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<tr>
<td>&lt;1</td>
<td>23.4</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>1 – 5</td>
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<td>0.9</td>
<td>0.8</td>
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<tr>
<td>6 – 10</td>
<td>16.9</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>11 – 15</td>
<td>9.7</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>16 – 20</td>
<td>8.8</td>
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<td>0.6</td>
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<td>21 – 25</td>
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<td>1.4</td>
<td>0.7</td>
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<td>&gt;26</td>
<td>32.8</td>
<td>2.0</td>
<td>0.0</td>
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</table>

Conclusions

1. The studied archival views of Szczecin depicted the forest cover of the Bukowe Hills according to the actual situation at the time. It is indicated by the presented hypsometry (similar to the actual profile of the area) which would have been very difficult to obtain in the case of the area being completely covered with forest.

2. Prepared digital maps made it possible to determine the changes in forest cover in the Bukowe Hills area. The greatest deforestation (3 500 ha) took place between 1780 and 1900. The greatest afforestation took place between 1960 and 2000 (by about 600 ha).

3. Between 1780 and 1900 deforestation included the areas adherent to the massif of the Bukowe Hills. Also the areas with the slope higher than 21° which increased the exposure to the water erosion. The steep slopes were afforested again between 1900 and 2000.

Bibliography