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TRANSFORMATIONS OF RIVER VALLEY SANDY LANDSCAPES ON THE EXAMPLE OF NATURA 2000 SITES IN THE VALLEY OF THE LOWER RIVER BUG[1]

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Summary. The paper presents an attempt at identification of the scale and direction of transformation of the numerous in the Bug valley landscapes of sandbars, open sand fields, sand dunes and other similar forms that are present there, both on the flood terraces and the upland terraces. The study area is a fragment of two Natura 2000 sites: PLH 140011 and PLB 140001, with a surface area of 3930.8 ha, situated in the valley of river Bug. The area of the study included also the Nature Reserve Kózki. The source materials used in the study were two orthophoto maps of the area, created from aerial photographs taken in 1953 and 2006. Manual vectorisation of the orthophoto map from 1953 was performed to determine the spatial reach of open sands and over-sand swards. Next, the authors investigated what forms of land use replaced them in 2006. The measurements of the areas of land use forms of the study area permit the conclusion that over 60% of the sandy areas had been artificially afforested. Only 7.75% of the sand areas remained relatively unchanged over the period of 53 years. Those are areas situated nearly exclusively within the boundaries of the Kózki Nature Reserve. The transformations of the landscape of the studied section of the river Bug valley took place primarily under the effect of human activity, including the pine afforestation conducted intensively during the nineteen sixties and seventies.

Key words: Natura 2000 sites, fluvial landscapes, sandy habitats, Bug river valley

OBJECT AND AREA OF THE STUDY

In Poland the landscapes of open sands and over-sand swards appear primarily in coastal regions and in the valleys of major rivers. The largest areas of this type include the Słowiński National Park and the Hel Peninsula Dunes Nature Reserve. In the nineteen fifties they included also a complex of inland

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dunes, the largest in Europe, situated in the Kampinoski National Park, but at the beginning of the 21st century open sands and over-sand swards already constituted as little as 0.1% of the area of the Park [Andrzejewski (ed.) 2003]. Inland sandy habitats are also an inseparable element of the landscape of the river Bug valley. A fragment of the valley of that river was the area of the study of the processes of transformation of river valley sandy landscapes that took place there in the period of 1953–2006.

The section of the valley of river Bug selected as the study area has a surface area of 3930.8 ha and includes fragments of two Natura 2000 sites: the habitat refuge PLH 14001 and the bird refuge PLB 140001. In the central part of the study area there is the Nature Reserve Kózki, situated as a whole in the Podlaski Gap of River Bug Landscape Park (Fig. 1).

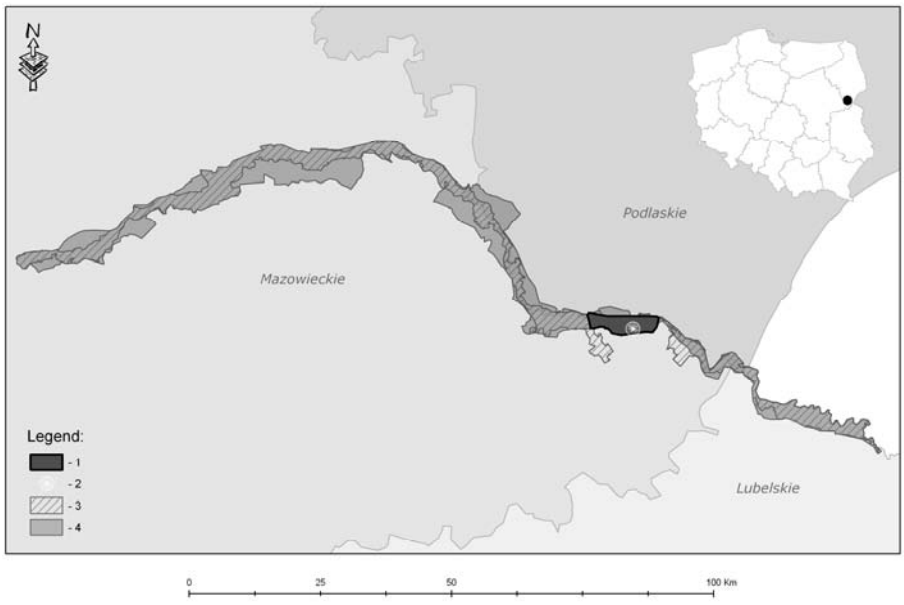

Fig. 1. Situation of the study area: 1 – study area, 2 – Nature Reserve Kózki, 3 – Natura 2000 site PLH 140011, 4 – Natura 2000 site PLB 140001

The objective of the study was to determine the scale and direction of transformations of river valley sandy landscapes in the studied section of the valley of river Bug. In the nineteen fifties, sandbars, open sand fields, dunes and patches of over-sand swards were a characteristic and indispensable element of that landscape. And dunes formed extensive, mostly semi-circular ranges with lengths of several hundred metres, extending from the banks of the riverbed onto the farm areas. On the aerial photographs of the area from 1953 used in the study one can see not only farms situated wholly on open sands, but also those par-

tially submerged under windborne sand. The largest complexes of sand dunes were situated in the neighbourhood of the villages Ogrodniki and Binduga. Due to intensive artificial afforestation and through natural succession of shrub and grass communities the landscape of the valley fundamentally changed its character. Fragments of open sand fields and sand dunes with no vegetation remained only within the area of the Nature Reserve Kózki, where they are subject to the process of active conservation.

METHOD

Determinations of the temporal variability of the reach of occurrence of various forms of land cover frequently employ the methods of contemporary geomatics. Michałowska, Głowienka [2007], and Michałowska, Hejmanowska [2008] describe in detail the possibilities of application and the methods of processing of archival remote-sensing data in studies on the spatial reach of sand dunes. The methodology of the study of multi-period transformations of sand dune landscapes, on the example of data for the Błędowska Desert, is also described by Maryniak and Drzewiecki [2010]. The applicability of satellite imaging in studies on changes in the spatial reach of sandy areas is also referred to by Zonneveld [1999].

Original remote-sensing images have a number of radiometric and geometric distortions, and all of those require correction. The process of such correction comprises two stages – radiometric correction and geometric correction. Only after those operations have been performed digital images can be directly compared and merged into larger images [Adamczyk and Będkowski 2007].

In this study the source materials included 28 panchromatic photographs in a scale of approximately 1 : 10 000, taken in 1953, and a digital colour (RGB) orthophoto map from 2006, with the field resolution of one pixel of 0.5 m. The archival aerial photographs were characterised by very good quality for this type of material, and did not require radiometric correction. The geometric correction was performed on the basis of GCP points located on the digital orthophoto map from 2006 in numbers not less than 30 per a single photograph. Altitude data at the GCP points were taken from a DEM created on the basis of a drawing of isohypses of a topographic map at the scale of 1 : 25 000 (ed. 1984). The fitting into the PUWG 92 system was performed with an RMS error not exceeding 2 m for an individual photograph. That value falls within the intervals of location accuracy of an object on a map at a given scale, recommended by Urbański [2008].

The high scanning resolution of the archival materials (714 pixels/cm) permitted the obtainment of an orthophoto map with the field resolution of one pixel of 0.2 m. Due to the large size of the initial file and the greater value of one pixel in the data from 2006, with which the material was to be compared, the orthophoto map created from the archival materials was converted with the Nearest Neighbour method to pixels with field resolution of 0.3 m. In the process of

placing linework, as much as possible the linework was placed along axes of roads and along boundaries of large forest complexes. The whole orthophoto was saved as a TIFF file of 821 MB.

The data from 2006 were purchased already in the form of a digital colour (RGB) orthophoto map with the field resolution of one pixel of 0.5 m, fitted into the PUWG 92 system. The data were characterised by very good quality and high thematic resolution, with the consecutive stages of succession well visible in the photographs. On dunes, white and light grey colours corresponded to sandy elevations with initial stages of colonisation of open patches of sand by individual plants and lichens, gradually passing into a more advanced stage, when the surface of sandy soil totally disappears beneath light-grey thalluses of lichens. Equally well visible in the photograph were the consecutive stages of succession, with domination of grey hair-grass represented by grey-green colour passing into violet [Jarzombkowski *et al.* 2011].

Work on the photointerpretation of remote sensing materials was preceded with field studies during which detailed data on the land cover were acquired. The field studies were conducted primarily in the Nature Reserve Kózki where the greatest number of sand dune forms have remained. During the field studies data were collected with the use of a GPS receiver, the measurements being made with a sub-metre accuracy.

In the central part of the photograph from 2006 traces of a fire in the reserve Kózki could be discerned in the form of a brown spot. In the course f the field study conducted in 2011 it was decided that those areas will be charted as meadows.

Both orthophto maps (from 1953 and 2006) were subjected to manual vectorisation which, though it requires a notable input of human effort, is still the most reliable method in the case of cartographic work and ensures high quality of results [Adamczyk 2008]. In the photograph from 1953 the reach of sand dunes was identified on the basis of the lightest photophone. Probably (the limited thematic resolution of panchromatic images does not permit this to be stated with certainty) those were purely sandy areas, without any larger patches of lichens and grass vegetation. Additionally, vectorisation was also performed for the waters of the riverbed of Bug.

On the basis of the data from 2006 and thanks to the GPS measurements in the field a vector map of land use was created, comprising 19 categories: Riverbed of the Bug; Ox-bow lakes (lakes remaining from abandoned channel of Bug); Reeds (patches of reed communities, related mainly with the ox-bow lakes on Bug and with the banks of its present channel); Dunes (sandy areas with no vegetation); SwardsN (over-sand swards with no grassland vegetation); SwardsT (over-sand swards with distinct succession of grassland communities); Water courses; SzZW (artificial reservoirs); Meadows; Alder; Riverside carr; Forest (other types of forest including blanks); Upgrowth (areas of natural forest succession, not including individual trees on dunes); Orchards; Fields (arable fields and fallows); Scrub_comm (scrub communities, mainly osier); Hard-surfaced roads;

Dirt roads (so-called trodden paths were not charted); Plots with buildings (this category comprises whole farms as well as individual detached buildings).

The map of transformation of river valley sandy landscapes was obtained by clipping data on land cover in 2006 with the vector of the reach of sandy forms (Dunes and SwardsN) from 1953. The values of the calculated surface areas were given in hectares.

RESULTS

In 1953 sandy forms occupied an area of 263.02 ha, which constitutes 6.7% of the whole study area. It was assumed that in 2006 that type of landscape was created by open sand fields and sand dunes with areas of over-sand swards*, which corresponds to two of the categories of land cover adopted in the study: Dunes + SwardsN. During the period of 53 years the area of those categories shrank from 263.02 ha to 20.4 ha, which means a decrease in area by 92.25%.

The percentage of the area of sandy forms transformed in 2006 into other forms of land use is presented in Table 1. A map illustrating the forms of land cover on the area of former sandy forms is presented in Fig. 2.

Table 1. Percentage share of forms of land cover occupying in 2006 the areas of the former sandy forms

Form of land use	% of area occupied by a given land use form on the area of the former open sand fields and sand dunes
Forests (deciduous and coniferous, including alders and riverside carrs)	63.22
Meadows	13.94
Riverbed of Bug	4.6
Arable fields and fallows	3.26
Plots with housing	2.73
Over-sand swards with a share of grassland vegetation	1.43
Roads (surfaced and dirt)	1.32
Areas of natural forest succession	0.79
Other forms of land use	0.96

* due to the limited thematic resolution of panchromatic photographs it is not possible to determine whether, and if yes – to what degree, sand dunes were covered with lichens and vegetation typical for over-sand swards.

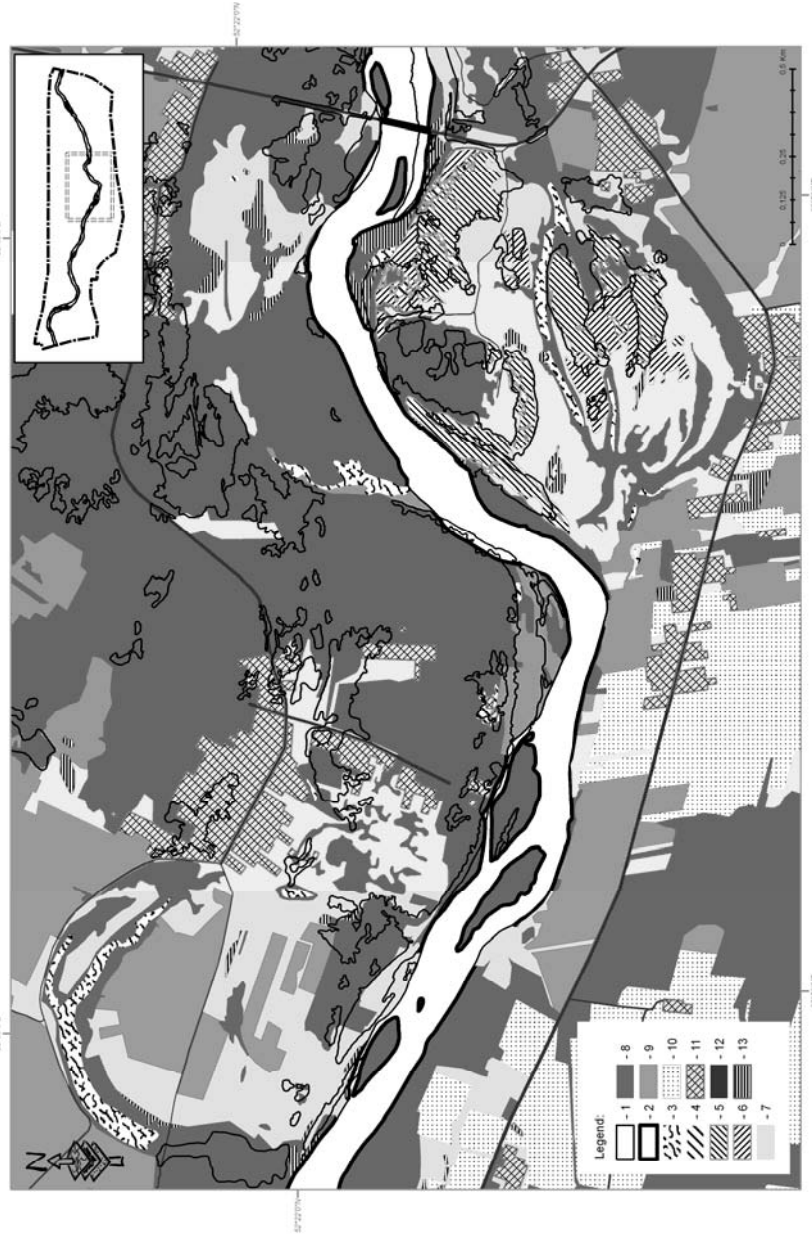

Fig. 2. Fragment* of photointerpretative map of land use forms in 2006 with marked out reaches of sand dunes of 1953: 1 – reach of occurrence of sand dunes in 1953, 2 – waters of river Bug, 3 – ox-bow lakes, 4 – sand dunes, 5 – over-sand swards, 6 – over-sand swards with succession of meadow communities, 7 – meadow communities, 8 – forests (including alders and riverside carrs), 9 – arable fields and fallows, 10 – orchards, 11 – plots with buildings, 12 – roads, 13 – other forms of land use

*due to the balck-and-white character of the publication, the map is presented in generalised form (12 out of 19 identified forms of land use) and in a fragment covering the nature reserve

Open sand fields and sand dunes, numerous in the nineteen fifties, have been largely overgrown by forests. This is primarily a result of intensive afforestations. As much as 60.23% of the area of open sand fields and dunes have been transformed in pine plantations, while the process of natural succession of forest communities covered only 2.98% of the area of sandy forms.

13.6% of the pen sands area gradually succumbed to the succession of plant communities typical of over-sand swards (reindeer cup-moss *Cladonia rangiferina,* grey hair-grass *Corynephorus canescens* L.), and subsequently – of grassland communities (1.43%). The fire noted in 2006, at a spot currently occupied by grassland communities, also had a slight effect on the process.

Moreover, over the 53-year period, on the analysed section of the Bug river valley there was noted a maximum local shift of the river bank, amounting to 85 metres, and a number of smaller shifts with values of 20–30 m. This is related with erosion of the sandy banks by the waters of the meandering river. That process affected 4.6% of the area of the sandy forms.

The mosaic of pine monocultures, arable fields and meadows covers now almost the whole area of the study. The exception is the small nature reserve Kózki (86.4 ha), where sandy habitats are under active conservation (Natura 2000 habitat No. 2330) [EU Habitat Directive 1992]. The cutting of the pine upgrowth, conducted there since 2010, and the introduction of sheep grazing on areas of succession of grassland communities, effectively contribute to the conservation of sand forms with exceptional landscape values, and of the inseparable over-sand swards with high nature value.

CONCLUSIONS

The presented numerical values indicate that the transformations of the landscape of the studied section of the valley of river Bug took place primarily under the effect of human activity. A considerable part of the extremely attractive, in terms of landscape values, open sands and over-sand swards, a habitat protected under the EU Habitat Directive of 1992 with the symbol 2330, has been transformed into monoculture pine plantations. That certainly limited the phenomenon of migration of sand, a burden to the inhabitants (the photos from 1953 clearly show sand-bound farm households), but it also totally changed the unique character and the ecological and tourism potential of the valley.

The procedures of active conservation of over-sand habitats implemented in the nature reserve Kózki since 2010 provide good protection for the last preserved habitats No. 2330 in the studied part of the Natura 2000 area No. PLH 140011.

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PRZEMIANY PIASZCZYSTYCH KRAJOBRAZÓW DOLINNYCH NA PRZYKŁADZIE OBSZARÓW NATURA 2000 W DOLINIE DOLNEGO BUGU

Streszczenie. W artykule podjęto próbę określenia skali i kierunku przekształceń licznie występujących w dolinie Bugu krajobrazów piaszczystych łach, pól, wydm itp. form występujących tu zarówno na tarasach zalewowych, jak i nadzalewowych. Obszar badań stanowił fragment dwóch obszarów Natura 2000: PLH 140011 oraz PLB 140001 o powierzchni 3930,8 ha, położony w dolinie Bugu. W granicach obszaru badań znajduje się także rezerwat przyrody Kózki. Jako materiały źródłowe wykorzystano dwie ortofotomapy tego obszaru wykonane ze zdjęć lotniczych pozyskanych w 1953 r. oraz 2006 r. W drodze manualnej wektoryzacji ortofotomapy z 1953 r. określony został przestrzenny zasięg otwartych piasków i muraw napiaskowych. Następnie zbadano, jakie formy użytkowania terenu w 2006 r. zajęły ich miejsce. Przeprowadzone pomiary powierzchni form użytkowania terenu pozwalają stwierdzić, że ponad 60% powierzchni obszarów piaszczystych uległo sztucznemu zalesieniu. Zaledwie 7,75% powierzchni piasków przez okres 53 lat pozostało względnie niezmienionych. Są to obszary położone prawie wyłącznie w obrębie rezerwatu przyrody Kózki. Przekształcenia krajobrazu badanego odcinka doliny rzeki Bug odbyły się głównie pod wpływem działalności człowieka, w tym intensywnie wprowadzonych w latach 60–70 XX w. zalesień sosnowych.

Słowa kluczowe: obszary Natura 2000, krajobrazy dolinne, siedliska piaszczyste, dolina rzeki Bug