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Original article

## Landscape transformations in the alluvial fan of the River Little Vistula (Mała Wisła) in Poland from the 18<sup>th</sup> century to the present

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### ABSTRACT

Development within the River Little Vistula valley undoubtedly started at the very beginnings of the Polish state. At that stage, human activity focused on finding and adapting sites that were suitable for permanent settlement and also on utilising the resources found in the valley and afforded by the river such as fishing and shipping opportunities. The shape of the River Little Vistula alluvial fan also allowed the construction of numerous canals branching from the river channel, on which mills, fulleries and sawmills were established. The characteristics of the landscape changes which have taken place in the study area have been presented on the basis of analyses of large-scale (1:28,800) topographic maps from the mid-18<sup>th</sup> and 19<sup>th</sup> centuries, modern topographic maps and also from visits to the study area (General-Mappa des Merzogthums Ober-Schleisien 1763–1764 and Übersicht der Militar Aufmahme von Mähren und Schlesien, 1839-1840). It was found that landscapes of the River Little Vistula alluvial fan are “landscapes of valleys and plains subject to water accumulation and floods”. Such areas are characterised by the presence of groundwater at low depths and are subject to periodic flooding by river waters, which are rich in mineral substances. Their habitats include riparian forests and flood meadows, which have often been transformed into arable fields. Characteristic types of soils in these areas include alluvial soils and peats, and typical elements of the landscape are water bodies, mainly fish ponds.

**KEY WORDS:** Little Vistula Valley, alluvial fan, human impact, land use changes

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### 1. Introduction

For many centuries, watercourses have been of interest to settlers and therefore traces of human presence can be found in almost every major river valley. In those areas, villages, settlements and cities have been situated and also intensive farming has taken place because valleys offer fertile soil and rivers provide the water required for domestic and agricultural purposes. River valley development processes intensified in the 17<sup>th</sup> century when large complexes of fish ponds began to be constructed alongside a network of ditches (mill races) that extracted energy from water in order to drive the waterwheels of mills, sawmills and fulleries.

The rapid development of industry and urbanisation, referred to as the Industrial Revolution, resulted in river valley development processes intensifying. Many industrial centres were located in river valleys and the towns that had existed there for hundreds of years expanded.

While taking advantage of the benefits provided by rivers both in the past and in the present, humans have always been aware of the great danger associated with flowing water. Therefore, since the times of early settlements built on river banks, hydraulic engineering structures were constructed in order to secure sufficient amounts of water in the event of drought or, conversely, protect from the devastating effects of floods.

This study analyzes the shaping of the Vistula alluvial fan and the history of its development dating back to the 16<sup>th</sup>-18<sup>th</sup> centuries. Based on detailed topographical maps from the 18<sup>th</sup>, 19<sup>th</sup> and 20<sup>th</sup> century, changes in the layout of particular landscape types are presented.

Although high water stages, especially extreme ones, have played a decisive role in shaping the river channel and river valley, hydraulic engineering measures such as regulating and straightening the river channel, the construction of weirs, gates, check dams, groynes, etc. have been important factors as well. During high water stages, these structures may initiate erosion and accumulation processes, in turn causing changes to the shape of the valley and the layout of the surface hydrographic network. The construction of large complexes of fish ponds has been of considerable importance in shaping the landscape of river valleys.

Development within the River Little Vistula valley (Dolina Małej Wisły) undoubtedly started at the very beginnings of the Polish state (10-11<sup>th</sup>). At that stage, human activity focused on finding and adapting sites that were suitable for permanent settlement and also on utilising the resources found in the valley and offered by the river such as fishing and shipping opportunities. The shape of the River Little Vistula alluvial fan also allowed the construction of numerous canals branching from the river channel, on which mills, fulleries and sawmills were established. New development directions were initiated in the 17<sup>th</sup> century when the construction of a system of fish ponds began; up until modern times, these have been a characteristic feature of alluvial fan areas.

## 2. Source materials and research methods

A cultural landscape is considered to be a landscape shaped by man as a result of the development of civilisation and is an evolutionary succession of the natural landscape (MYGA-PIĄTEK, 2010). In order to assess the extent of natural and anthropogenic changes to the landscapes of the River Little Vistula alluvial fan, archival materials were mainly used alongside modern topographic and aerial photographs. Of great value were descriptions of floods, including deep and long-lasting low water stages, violent storms and cold and snowy winters. In fact, what was most important were the hydrological, geomorphological and economic effects of those events. First reports of flooding in the upper reach of the River Vistula date back to the 13<sup>th</sup> century, and detailed descriptions of events which specify the time of their occurrence, duration and the magnitude of

economic losses have been preserved from the 15<sup>th</sup> and 16<sup>th</sup> centuries (SZEWCZUK, 1939; GIRGUŚ & STRUPCZEWSKI, 1965). Particularly important information was also present in archival drawings, plans and the first topographic maps. Moreover, the documents available in archives include expert opinions, plans and permits for the construction of hydraulic engineering structures such as mill races, ponds, groynes, weirs, etc. Drawings and topographic maps from the 18<sup>th</sup> and 19<sup>th</sup> centuries were subjected to cartometric analyses, taking into account the errors resulting from both the inaccuracy of the measuring instruments used at the time when the map was created and from the control network provided by photographs, drawing techniques, reproduction, etc. (CZAJA, 2017). Detailed verification of maps and plans was also necessary due to the fact that various units of measurement and zero reference levels were used in the Austrian Empire during the levelling works carried out at the time (KONIAS, 1995).

Gauging station measurements in the upper River Vistula River catchment started in the second half of the 19<sup>th</sup> century, so starting from that period, we have fairly accurate information about high water stages and floods. Until the catastrophic flood of July 1997, it was believed that the most significant high water stages in terms of both wave height and territorial reach were the floods which occurred in August 1813, also in July 1844 and in July 1903 (MEMEL & PREGEL... 1899; FISZER, 1995). Subsequent significant high water stages occurred in 1816, 1839, 1876, 1925 and 1934 (CZAJA & RAHMONOV, 2017). In modern times, floods have not resulted in permanent changes to the landscape of the River Vistula alluvial fan. The main reason is that the impact of high water stages has been limited by hydraulic engineering structures such as weirs, groynes and check dams. Of importance has also been the straightening of the river channel and the construction of levees. These works were already started at the turn of the 20<sup>th</sup> century, but it was only in the 1920s and 1930s that new structures covered the entire length of the River Vistula channel within its alluvial fan.

The aim of this study was the reconstruction of changes to the landscape of the River Little Vistula alluvial fan from its "base" in the area of Ustroń down to Strumień and Zabłocie in the western part of the Oświęcim Basin (Kotlina Oświęcimska) limited by the Silesian Foothills from the south and the edge of the Silesian – Cracovian Upland from the north. The alluvial fan area (study area) is around 114 km<sup>2</sup> and from the late 16<sup>th</sup> and the early 17<sup>th</sup> centuries, it was already developed for fish farming purposes. The landscape was dominated

by numerous large ponds, which occupied around 15% of the area by the middle of the 18<sup>th</sup> century. After large floods, the distribution and sizes of the ponds changed significantly in many cases. After dykes had been destroyed, many ponds were transformed into arable fields, while others were rebuilt and their shapes and surface areas changed. Periodic changes in pond numbers and areas also resulted from the operation of the traditional carp breeding industry. Bottoms of water bodies were lined with the metabolic waste substances produced by the fish farmed in ponds. At the same time, silts and organic sediments provided an excellent natural fertiliser which increased agricultural yields in these areas. Most drained ponds were used as meadows and pastures, and some of them as arable land. After a few (3–5) years, pond bottoms were cleaned, refilled with water and then restocked.

Characteristic changes to the landscapes of the River Little Vistula alluvial fan have been presented on the basis of analyses of large-scale topographic maps. The oldest such map, with a 1:28,800 scale, was produced between 1763 and 1764. It is known as the first military photograph of Cieszyn Silesia (Śląsk Cieszyński). This map contains numerous errors of distance, area and angle, which vary between individual sheets ([GENERAL-MAPPA...](#), 1763-1764).

These errors were estimated in detail by [KONIAS](#) (2000), and thus the map can be used to analyse changes to landscapes in the study area. Another map used in the study was the topographic photograph of Cieszyn Silesia with a 1:28,800 scale from 1839–1840. This was the so-called “*Second military photograph of Cieszyn Silesia and Galicia*” ([ÜBERSICHT DER MILITÄR...](#) 1839–1840). The use of new, improved and more accurate mapping methods (the plane-table survey) enabled the development of maps which can be compared with maps from the mid-20<sup>th</sup> century in terms of their accuracy.

### 3. Transformations of the landscape of the River Vistula alluvial fan

The River Little Vistula alluvial fan extends from the broader section of the valley where the River Vistula flows from the Silesian Beskids within the Cieszyn Foothills, which are also referred to as the Silesian Foothills, into the western part of the Oświęcim Basin. Within the foothills, the River Vistula valley becomes noticeably broader, reaching a width of almost 2 km in the vicinity of Ustroń. The depression is lined with Quaternary alluvial formations of the River Vistula and of its tributaries,

which form the base of the alluvial fan. The low, slightly convex terrace extends northwards like a fan; already in the area where the River Brennica enters the River Vistula, it covers the entire width of the four kilometre broad valley. From the boundary between the Cieszyn Foothills and the Oświęcim Basin, the River Vistula valley becomes broader again, and the change is disproportionate to the width of the river itself. In the vicinity villages of Drogomyśl and Strumień, its floor is already between 8 and 10 km wide. Here the valley floor is clearly convex. It is built of sands and gravels and covered with alluvial loams. It is the front of the River Vistula’s extensive alluvial fan, which reached up to 10 metres in height during the last glaciation and is dissected with marginal channels. In the western channel, the contemporary River Vistula flows, lining its two kilometre wide floodplain with fresh depositions. To the east of the fan, there are flysch foothills, and to the west, there is a plateau which consists of Quaternary sediments ([STARKEL](#), 2001).

An important part of the landscape of the River Vistula alluvial fan, apart from the formations of its substrate and land forms, is its vegetation cover. Its current state is the result of climate changes and the progress of soil-forming processes. The development of contemporary vegetation cover was also significantly influenced by human economic activity, which had already started in the study area in the 11<sup>th</sup> and 12<sup>th</sup> centuries. Today, in forests and tree stands pine monocultures dominate, often with an admixture of spruce and silver birch. Aquatic and swamp vegetation in the alluvial fan area has undergone significant transformations which were related to the regulation of the River Vistula channel, the construction of a network of ditches and mill races as well as fish ponds. Changes to the aforementioned plant communities were also caused by the periodic, or permanent terrestrialisation, of ponds. Permanent grassland communities (meadows and pastures which account for around 9–14% of the alluvial fan area) are mostly used for economic purposes. The meadows are fertilised and regularly mown, and thus their plant composition is more varied ([MICHALIK](#), 1991). The surface of the alluvial fan, which was elevated from 10 to 12 metres above the River Vistula valley floor, was a convenient area for settlement (mainly of a dispersed nature). Additionally, as a result of the construction of the network of ditches which fed water to ponds and mill races, the River Vistula erosion base level was lowered and many elevations emerged on the alluvial fan. The large villages which were established had the shape of irregular multi-street settlements (Zaborze, Czuchów, Gołysz, Młyn).

Less numerous were long villages (waldhufendorfs) situated perpendicularly, or in parallel, to the River Vistula channel. Settlements of this type were established in the valleys of the streams which fed the River Vistula, usually on upper alluvial fan terraces; examples include the settlements of Ustroń and Drogomyśl (Fig. 1).

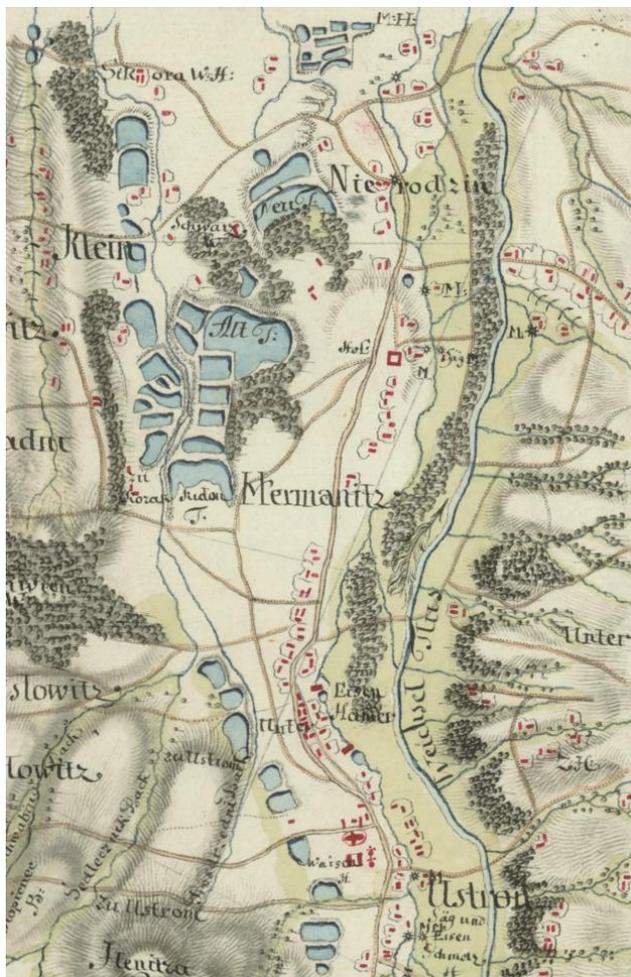


Fig. 1. The Ustroń settlement (of the waldhufendorf type) situated on a meadow terrace and the complex of ponds in the River Vistula valley (according to General-Mappa des..., 1763–1764)

Landscapes of the River Little Vistula alluvial fan should be classified as “landscapes of valleys and plains subject to water accumulation and floods”. Such areas are characterised by the presence of groundwater at low depths and are subject to periodic flooding by river waters, which are rich in mineral substances. Their habitats include riparian forests and flood meadows, which are often transformed into arable fields. Characteristic types of soils in such areas include alluvial soils and peats. Other typical elements of the landscape are water bodies, mainly fish ponds.

The contemporary landscape of the area described is the result of man-made transformations which have occurred on a large scale since the

end of the 16<sup>th</sup> and the beginning of the 17<sup>th</sup> century. The main reason was the shift from an agricultural economy towards a carp-breeding industry. Such activities were conducted until the mid-19<sup>th</sup> century, and the pace of transformation accelerated in the 20<sup>th</sup> century. The scope of the use of arable land was adapted to the conditions of the natural environment (mainly land forms and the hydrographic network) and thus modern landscapes of the alluvial fan replicate naturally ordered structures. Unfortunately, in some parts of the alluvial fan, as a result of the construction of levees, the regulation of watercourses and drainage works, the natural linear structures have been simplified or even entirely obliterated.

#### 4. Landscape change directions

In the description and classification of the landscapes of the River Little Vistula alluvial fan, the criterion of dominant land use has been adopted. Therefore, examination of the direction of the landscape transformations from the mid-17<sup>th</sup> century until the present time required a detailed analysis of changes in the size (area) and distribution of dominant landscape elements: arable land and dispersed development, meadows and pastures, ponds and canals and finally forests and tree stands.

##### 4.1. Agricultural landscapes

From the mid-18<sup>th</sup> century until the present, the dominant form of land use in the study area has consisted of arable lands, meadows and pastures. Owing to this manner of land use, these areas can be classified as agricultural landscapes of the field-meadow-pasture type. This type of landscape is a remnant of the late medieval economy where settlements were concentrated around rivers, and considerable parts of the valley were already deforested and used for agriculture. At that time, most of the land was transformed into meadows and pastures, while drier areas higher up became arable lands. The original riparian forest was preserved along the River Vistula channel and also in places on wetlands within the valley. Permanent settlement rarely took place on the valley floor because of the threat of floods. Apart from defensive strongholds, people avoided siting settlements on major rivers. Forest felling in the River Vistula valley took place in the late 15<sup>th</sup> and early 16<sup>th</sup> centuries when economic development in Poland resulted in an increase in population and the growth of agriculture. Natural, fertile and favourably placed habitats in river valleys were mainly used as meadows and pastures while higher terrace levels became arable land (PLIT, 2007).

As already mentioned, settlement within the River Little Vistula alluvial fan is very old. The settlement of Ustroń already existed in the 12<sup>th</sup> century and that of Skoczów in the 13<sup>th</sup> century. Other villages and settlements are much “younger”, since they were mostly established in the late 17<sup>th</sup> and early 18<sup>th</sup> centuries.

On the basis of the analysis of the **GENERAL-MAPPA DES...** sheets (1763–1764), it was found that in the mid-18<sup>th</sup> century, arable land together with dispersed rural settlements occupied 57.8% of the study area. These were located mainly in the north-western and central parts of the alluvial fan, and also around fish ponds and on the outskirts of forests. On the other hand, meadows and pastures accounted for around 10% of the fan area and were located mainly in river valleys and around the ditches which fed the ponds as well as on the bottoms of periodically drained reservoirs (Fig. 2). As already mentioned, the methods of breeding

carp used at the time required that the ponds be periodically drained. There were cases where almost all reservoirs in the area remained dry for a few years. On the **ÜBERSICHT DES...** (1839–1840) map, a situation was recorded where in comparison to the year 1762 the number of reservoirs decreased from 289 to 34, and their total area shrank from 17.2 km<sup>2</sup> to just 0.4 km<sup>2</sup>. Drained ponds were subsequently used as arable land, hay meadows and pastures for several years. The total area of arable land and dispersed development as well as meadows and pastures in the late 1830s and early 1840s amounted to approximately 84% of the alluvial fan area (Fig. 3, Table 1). The surface and layout of the modern agricultural landscape can be compared to the distribution and area of arable fields, meadows and pastures in the mid-18<sup>th</sup> century. Currently, such agricultural areas account for just over 67% of the fan area.

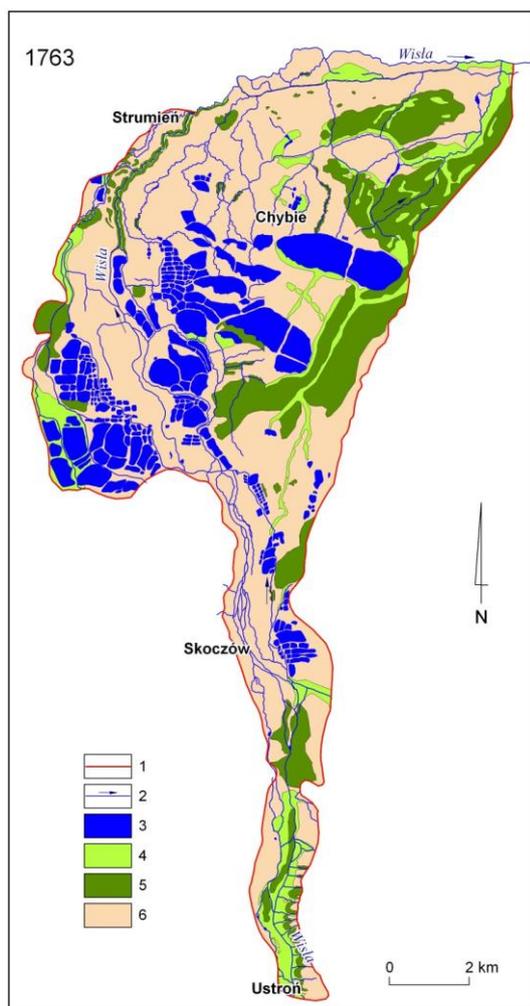


Fig. 2. Types of land use in the River Vistula alluvial fan area in the mid-18<sup>th</sup> century (according to General-Mappa des... 1763–1764)  
1 - border of the research area, 2 - river network, 3 - water reservoirs, 4 - meadows and pastures, 5 - forests and shelters, 6 - agricultural land and dispersed development

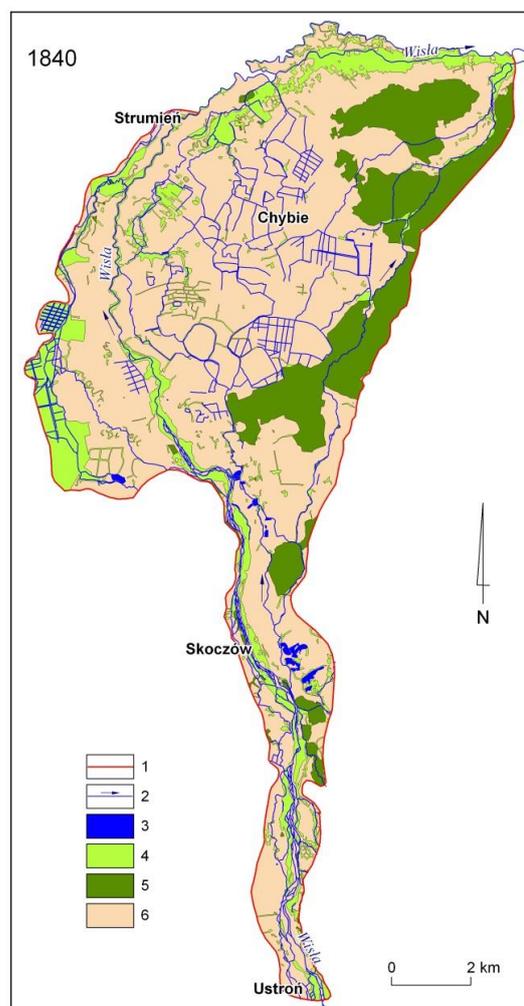


Fig. 3. Types of land use in the River Vistula alluvial fan area in the mid-19<sup>th</sup> century (according to Übersicht der Militar ... 1839-1840)  
1 - border of the research area, 2 - river network, 3 - water reservoirs, 4 - meadows and pastures, 5 - forests and shelters, 6 - agricultural land and dispersed development

Table 1. Changes in land use in the River Vistula alluvial fan area in the years 1763–2015

Type of use	1763–1764		1839–1840		2015	
	[km <sup>2</sup> ]	[%]	[km <sup>2</sup> ]	[%]	[km <sup>2</sup> ]	[%]
Agricultural land and dispersed development	65.94	57.80	79.15	69.40	64.85	56.90
Meadows and pastures	11.40	10.00	16.76	14.70	10.36	9.10
Forests and shelters	19.44	17.10	17.64	15.50	17.41	15.30
Water reservoirs	17.20	15.10	0.43	0.40	21.36	18.70
Total	113.98	100.00	113.98	100.00	113.98	100.00
Rivers, trenches and windmills [km]	225.10		345.20		432.30	

#### 4.2. Water landscapes

The area of the River Little Vistula alluvial fan was not used for intensive farming until the late Middle Ages owing to high groundwater levels, wet areas and swamps dominated there. Their adaptation for agricultural purposes required costly and complicated hydraulic engineering procedures such as the construction of a network of drainage ditches and levees around river and stream channels. The groundwater present at low depths and flooding during high water stages often destroyed agricultural crops. The geographical environmental conditions described were unfavourable for the development of agriculture, but on the other hand were very favourable for the development of the fish farming industry. The development of the latter dates back to the late 16<sup>th</sup> and early 17<sup>th</sup> centuries. At that time, huge pond complexes were constructed between Ochaby Wielkie and Zaborze and also in the vicinity of Podlesie, Mnich and Zabłocie. These reservoirs were supplied with water by a network of ditches and mill races whose length in the mid-18th century was around 225 km and reached over 432 km at this time (Table 1). The fish ponds present within the alluvial fan shape the environment of this area not only within the areas submerged under water, but also by raising groundwater levels well beyond pond boundaries. Water reservoirs have contributed significantly to increasing the variety of species on arable lands as well as in the meadows and pastures within the alluvial fan. Their emergence is associated with the succession of new species of plants and animals which were previously absent in these areas mentioned. In the landscape of the area described, a “mosaic” can clearly be seen, which is related to the presence of numerous water bodies. After a detailed analysis of historical maps and a

visit to the area, it was found that individual types of land use exhibited considerable variety in terms of their spatial distribution and area. This phenomenon, where different habitats, ecosystems and communities form inter-leaving patches, is often referred to as a “spotted pattern”. The exchange of biological information (at the species and individual levels) as well as of matter and energy plays an important role in shaping mosaic landscapes. The emergence of large complexes of fish ponds and a dense network of ditches and canals within the alluvial fan resulted in these areas being colonised by limnic and hydrophilic communities. This process resulted in a marked increase in biodiversity within the water bodies themselves and in their vicinity. The interspersed lake, river and wetland communities as well as agricultural crops, meadow, pasture and forest communities have created an extensive network of ecotones.

In the middle of the 18<sup>th</sup> century, 289 ponds and other water bodies were identified in the study area, with a total area of 17.2 km<sup>2</sup>. Huge pond complexes were situated in the central and south-western sections of the River Vistula alluvial fan, mainly in the vicinity of Ochaby, Zaborze and Podlesie. A large fish pond complex was also constructed in the Skoczów area. The fish ponds were connected by a network of ditches and canals more than 225 km long, via which the reservoirs were fed with water (Fig. 4).

In the 1840s, a map (*ÜBERSICHT DES...*, 1839–1840) recorded a comprehensive draining of most existing ponds. In comparison to the years 1763–1764, the number of reservoirs decreased from 289 to 34, and their total area shrank from 17.2 km<sup>2</sup> to just 0.4 km<sup>2</sup>, i.e. more than 40 times less. At the same time, the length of the network of ditches and canals feeding the ponds increased to 345 km (Fig. 4, 5, Table 1).



Fig. 4. A complex of several dozen ponds in the area of the Drogomyśl and Ochaby Wielkie settlements, 1763–1764 (according to General Mappa des ..., 1763–1764, original scale ca. 1:28,800)



Fig. 5. A complex of several dozen ponds in the area of the Drogomyśl and Ochaby Wielkie settlements, 1763–1764 (according to Ubersicht der Militar... 1839-1840, original scale 1:28,800)

Nowadays, water bodies in the area described are still used mainly as fish ponds. Their number in comparison to mid-19<sup>th</sup> century figures has increased from 34 to 172. However, as a result of the construction in the 1950s of the reservoir impounded by a dam in Goczałkowice whose waters “flooded” part of the alluvial fan within the Oświęcim Basin, the surface area of standing water increased to 21.4 km<sup>2</sup>, which accounts for almost 19% of the entire area analysed (Fig. 6).

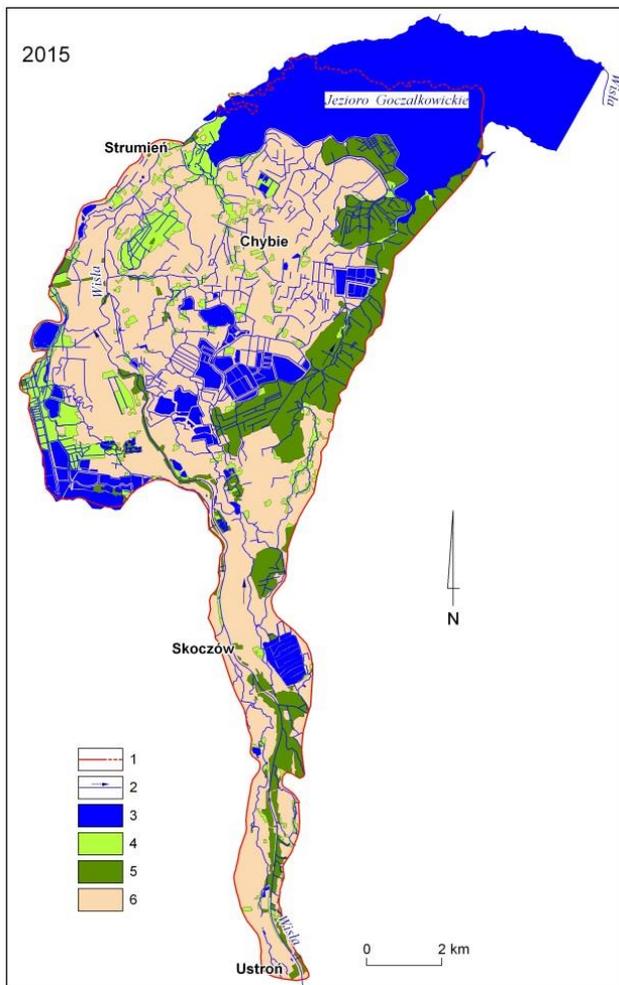


Fig. 6. Modern types of land use in the River Little Vistula alluvial fan area

1 - border of the research area, 2 - river network, 3 - water reservoirs, 4 - meadows and pastures, 5 - forests and shelters, 6 - agricultural land and dispersed development

#### 4.3. Forest landscapes

After the ice sheet had disappeared from Central Europe, the great plant “journey” began, with the neighbouring River Odra valley, which was open to the south, serving as the main conduit. During the Boreal period, deciduous trees entered the River Vistula valley: birches, limes, oaks and elms, as well as shrubs such as hazel. During the optimum climate period, beeches, yew trees and

firs emerged within the River Vistula alluvial fan, followed by hornbeams and ashes (MICHALIK, 1991).

The variety of the vegetation in the alluvial fan area is limited, but the terraced structure of the fan has influenced the spatial distribution of the plant communities. Alder carrs and tree clusters, once widespread on the often flooded low-lying terraces of the River Vistula, are now present only sporadically. These are mostly young stands. Deciduous and mixed forests grow in drier areas, usually on higher terrace levels. In swamped endorheic depressions, marshy coniferous forests are present among fresh ones.

The area and distribution of forests and tree stands within the River Vistula alluvial fan have not changed significantly since the mid-18<sup>th</sup> century. These mainly covered the southern and north-eastern parts of the area analysed. Tree felling on a large scale since the end of the 16<sup>th</sup> and the beginning of the 17<sup>th</sup> centuries has resulted in deforestation of the fan. In the 1860s, they occupied slightly more than 17% of the area studied, and from the 1840s until the present day, forests accounted for around 15% of this area.

#### 5. Final remarks

The landscape within the River Little Vistula alluvial fan has always been conditioned by the manner of its use. For centuries, the fish pond industry has dominated there, and until the middle of the 20<sup>th</sup> century, hydro-energy was used for driving the wheels of sawmills and fulleries. The main reason for this direction of development within the valley was the unfavourable physiographic conditions, primarily damp and heavy soils, which were difficult to cultivate. The threat of flooding was also an important factor limiting the development of agriculture and settlement. Until the end of the 19<sup>th</sup> century, settlement locations were dictated by the extent to which the valley was flooded during high water stages, as numerous such episodes have destroyed hydraulic engineering structures, dykes, mills and fulleries. Violent floods have hindered, or even prevented, the development of the affected areas.

Analyses of archival topographic maps have demonstrated that from the mid-18<sup>th</sup> century, the share of arable land and dispersed development remained at around 57–58% of the alluvial fan area. Only during periods of comprehensive draining of ponds, as in the years 1839–1840, has the arable land area increased to 70% (Table 1). Other types of land use within the alluvial fan (meadows and pastures as well as forests and tree stands) have remained at largely unchanged levels over the

last 250–260 years. The large fish pond complexes which were present within the alluvial fan from the 16<sup>th</sup> or 17<sup>th</sup> centuries dominated the landscape of the study area, although they accounted for “only” 15 to 19% of the total area. Owing to the dense network of ditches, canals and mill races, they have shaped the environment of the area not only within the areas submerged under water, but also by raising groundwater levels well beyond pond boundaries. Due to their number and uneven distribution, they result in a “mosaic” landscape within the alluvial fan, which is clearly dominated by the “water element”. The interspersed lake, river and wetland communities as well as agricultural crops, meadow, pasture and forest communities have created an extensive network of ecotones.

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