

The Upper Vistula Basin—A Geographical Overview

Joanna Pociask-Karteczka

Abstract The Upper Vistula Basin covers a large part of Southern Poland. This area is very diverse, as it comprises of various geographical regions formed during different geological periods what can be seen in its multifarious composition (Carpathian Mountains, Subcarpathian basins, Lesser Poland Uplands). Culturally, it combines a range of secular traditions formulated by different tribes, in particular by its original inhabitants. The majority of the first cities were founded as trade centers (13th–16th century), later transformed into tourist or industrial centers (19th–20th century). The subregions of the Upper Vistula Basin like Silesia, Cracow, Bielsko-Biała, Tarnów–Rzeszów, Tarnobrzeg–Stalowa Wola, continue to develop coal, chemical, steel, light and food industries. Nowadays, these cities are very well connected by a modern grid of motorways, expressways and railways enabling a faster development of the region. Agriculture has been a pillar of economy for the inhabitants of northern part of the Upper Vistula Basin where soils are rich, whereas in the Carpathians where the soils were poorer, only pastoral farming could be developed. In spite of the industrial activity in the region, the natural environment hasn't been modified much so far what makes it even more attractive for tourists who numerously visit wild and well preserved national parks of the regions, in particular the Tatra National Park. The Upper Vistula Basin is of a great importance in the hydrology of Poland, and its influence goes far beyond its watershed. It embraces the headwater area of the largest river in Poland, i.e. the River Vistula and its tributaries. The water resources (precipitation, river runoff) of the area are the richest in the whole country. The water cycle dynamics in the mountain area is very high due to steep relief, low permeability of the ground, and flood formation develops fast. It has been favoured by intensive surface and subsurface flow in the area with a dense agricultural land fragmentation and field road network.

Keywords Natural environment • Cultural and socio-economic factors • Water circulation • Southern Poland

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1 Location in Europe

The Upper Vistula Basin is located in southern part of Poland and is a part of the Vistula drainage basin. The River Vistula is the 17th largest river in Europe according to the length, and 11th one according to the catchment area. The Upper Vistula River (at Zawichost gauge) drains a total of 50,731.8 km² (Atlas Podziału Hydrograficznego Polski 2005). This area is about 25 % of the total Vistula drainage basin and is shared by Poland (91 %), Ukraine (5 %) and Slovakia (4 %, Table 1). The length of the water divide is 1,450 km and more than half of it overlaps the Main European Water Divide separating the Baltic Sea and the Black Sea basins (Fig. 1). The highest point within the watershed reaches the altitude of 2,438 m a.s.l. in the Tatra Mountains, whereas the lower one is 134 m a.s.l. The Upper Vistula Basin adjoins to the Oder River catchment in the west, the Danube River catchment in the south, and the Dniester River Basin in the east.

The length of the Upper Vistula River channel is 393.8 km and there is 653.7 km distance from downstream limit of the Upper Vistula to the river mouth at the Baltic Sea. The Upper Vistula River flows nearly latitudinally from the west to the east (Atlas Hydrograficzny Polski 1986a). The headwater area is located at the slopes of the Barania Mt. (1,220 m a.s.l.; Silesian Beskid, Carpathians). The Upper Vistula Basin includes several sub-basins. The main left-bank tributaries of the Upper Vistula River are: Przemsza, Dłubnia, Szreniawa, Nidzica, Nida, Czarna, Koprzywianka and the right-bank tributaries: Sola, Skawa, Raba, Dunajec, Wisłoka, San (Fig. 2).

The San River and the Dunajec River basins have a substantial share in the whole Upper Vistula Basin, i.e. 33.5 % (16,877.0 km²) and 13.5 % (6,796.3 km²) respectively. The watershed increase is significant at the Vistula confluence with Przemsza, Dunajec, and San (Fig. 3). There is a distinctly outlined river network and subbasins asymmetry. A number and length of the left-bank tributaries is lower than the right-ones, and the ratio of the left-bank basin to the right's one is 1:2.8 which is similar to the whole Vistula River basin (1:2.7, Chelmiecki 1991).

2 Geographical Diversity of the Upper Vistula Basin

The Upper Vistula Basin environment is geographically varied. The area covers three geographical regions: the Carpathian Mountains (45 % of the basin), the Subcarpathian basins (35 %), the Lesser Poland Uplands (25 %, Chelmiecki 1991).

Table 1 The Upper Vistula Basin area (Atlas Podziału Hydrograficznego Polski 2005)

Basin	Area (in km ²)			
	Total	Poland	Slovakia	Ukraine
Upper Vistula	50,731.8	46,308.1	1,952.4	2,451.2



Fig. 1 Location of the Upper Vistula Basin in Poland (Chelmicki 1991, modified)

Carpathians and Uplands include headwater areas of most of the tributaries of the Upper Vistula River, and the Subcarpathian basins constitute a transit area for the River Vistula and lower river courses of its tributaries (Fig. 4). The Carpathians are a very distinct region and a major landmark in the Upper Vistula Basin likewise across the whole country. They are characterized by complex geology and landforms ranging in altitude from 300–500 m in the marginal foothill zone in the north to 2,655 m a.s.l. (the Tatra Mountains) in the south. A considerable portion of the Carpathians shapes Beskid Mountains with an elevation 600–1,700 m a.s.l. stretching latitudinally (the belt of the Carpathian Foothills accompanies them to the north).

The Carpathians were formed during the Alpine orogeny. The mountains take the form of a fold and thrust belt with numerous thin-skinned nappes. The flysch (interbedded sandstones, shale and mudstone) prevails in geology of the region. A small portion of the southern part of the Upper Vistula basin—the Tatra Mountains—is composed of crystalline (granite) and metamorphic rocks.

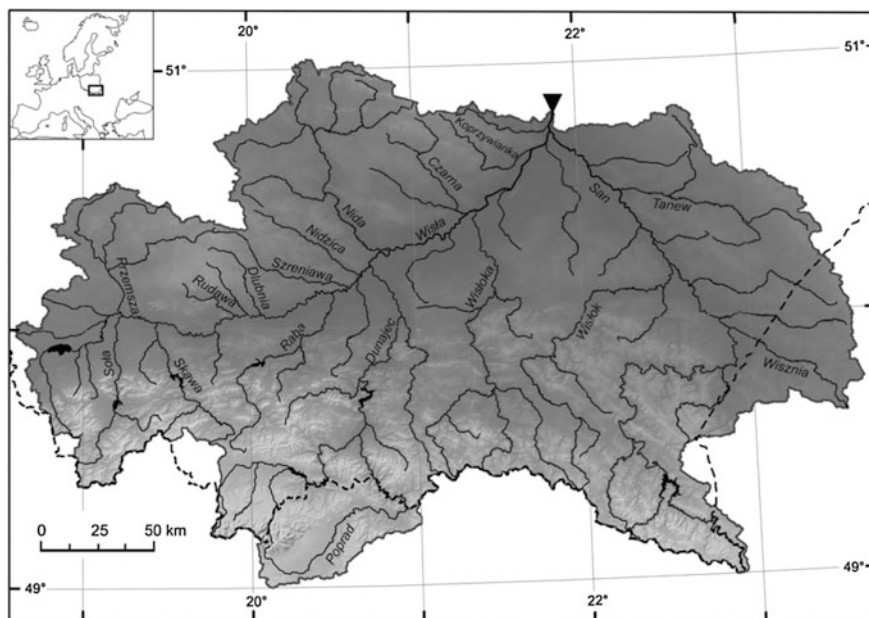


Fig. 2 The river network in the Upper Vistula Basin

There are several climatic-vegetation belts in the Carpathians (Hess 1965):

- temperate warm (foothill belt: 300–600 m a.s.l., multi-species deciduous forest),
- temperate cool (the lower sub-alpine forest belt: 600–1,100 m a.s.l.; Carpathian beech forest, herb layer),
- cool (the upper sub-alpine forest belt: 1,100–1,550 m a.s.l., spruce, shrub poorly developed, mosses),
- rather cold (dwarf mountain pine belt: 1,550–1,850 m a.s.l., *Pinetum mughi carpaticum*, numerous herbs),
- temperate cold (alpine belt: 1,850–2,200 m a.s.l., high mountain grasslands),
- cold (subnival belt: above 2,200 m a.s.l., fells, bare rock and almost no vegetation, lichens).

There are high, medium and low mountains within the drainage basin of the Upper Vistula River (Starkel 1991). High mountains are represented by the Mount Babia, build of flysch and the Tatra Mountains bordered to the north by a series of sedimentary nappes consisting of limestones, sandstones and flysch. The crestline of the Tatra with the altitude exceeding two thousand metres a.s.l. extends for 57 km forming the frontier between Poland and Slovakia, while the part of the Tatra belonging to Polish territory (150 km²) is much smaller than to Slovakia. The vertical relief between the northern foothills and the main crest is 1800 m, providing for a range of altitudinal geoecological belts from the beech forests on the foothills, across the timberline at about 1,700 m a.s.l., further to alpine meadows

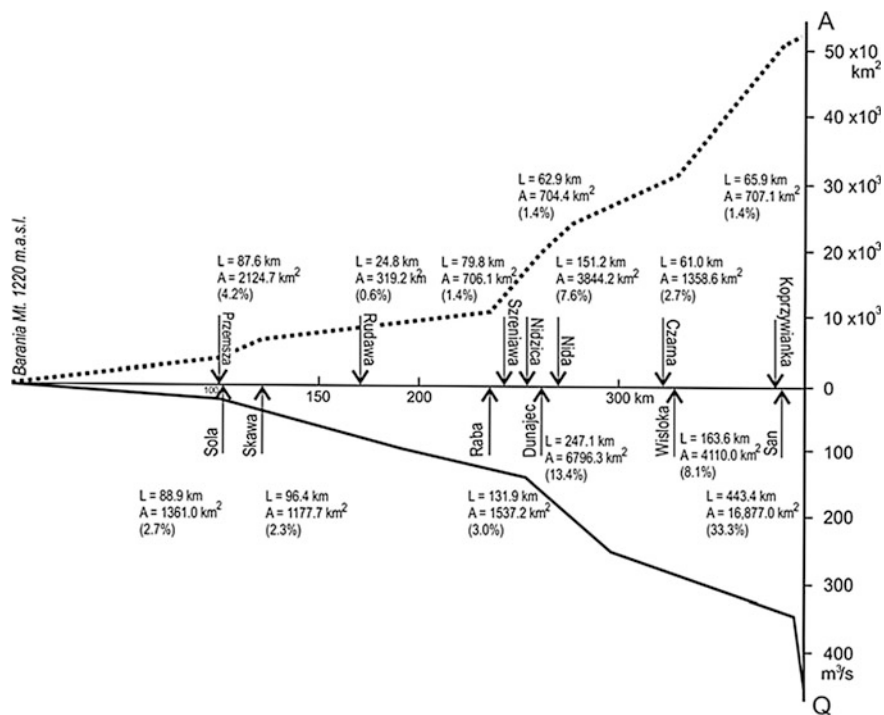


Fig. 3 Increase of watershed (A) and the Vistula discharge (Q) in the Upper Vistula Basin (L—length of rivers, A—area of watershed, (%)—a share of watershed in the Upper Vistula Basin (Atlas Hydrograficzny Polski 1986a, b; Atlas Podziału Hydrograficznego Polski 2005)

and the uppermost periglacial belt of rock faces, frost-shattered debris and occasional small permanent snow beds. The relief forms of the Tatra Mountains result from the glaciations of the last Ice Age, therefore the Tatra Mountains—apart from the Alps—comprise the only high mountain landscape of Central Europe with the alpine attributes. These affected most of all mountain valleys and gave them their specific relief character. Glacial erosion produced substantial valley widening and over-deepening whereas in the upper parts, series of cirque basins and knife-edged arêtes were formed. Rock walls up to 1,000 m in height give the area high mountain character (Fig. 5). The Tatra Mountains have no glaciers, and the uppermost mountain subnival belt occurs (Kotarba 1998). The relief forms of today have been shaped by the action of running water and slope processes.

Whereas medium mountains in the Carpathians consist of both compact mountain's groups of Beskid, as well as more isolated ridges as Bieszczady where denivelation ranges between 400–800 m and elevation 800–1,300 m a.s.l. Low mountains are usually situated on the border of medium mountains, where

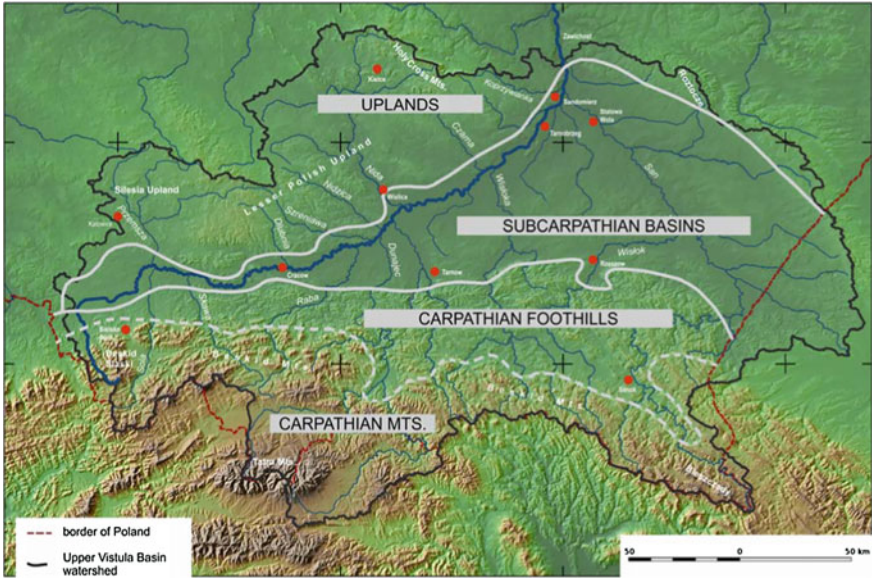


Fig. 4 Geographical regions in the Upper Vistula Basin



Fig. 5 A typical landscape in the Tatra Mountains (Photo K. Wojnarowski)

denivelation reaches 200–400 m (some Beskid ranges and the Holy Cross Mountains).

The Beskid Mountains are represented by discontinuous series of forested or partly forested mountain ranges (300–1,200 m a.s.l.) spreading from the east to the west. Along the northern edges of the Beskid Mountains, the Carpathian Foothills extend with an average elevation around 300–500 m a.s.l. They form a hilly area of gentle slopes with a thick cover of loess-like silty deposits particularly prone to the processes of runoff and wash in arable land (Fig. 6).

The Subcarpathian basin with lowland landscape is the lowest region in elevation (200–300 m a.s.l.). It consists of the Oswiecim Plain to the west and the Sandomierz Basin to the east. They both divide the Upper Vistula Basin into two parts: southern—mountainous and northern—upland. The left-bank side of the Upper Vistula basin is comprised of following uplands: Silesian, Lesser Poland and Roztocze. A hilly landscape with Jurassic limestone (karst phenomena), Cretaceous marls covered by loess deposits, is typical for this area (Fig. 7). Sporadic and isolated patches of forests occur locally. The only northern marginal zone of the upland zone differs considerably due to the Holy Cross Mountains—the oldest Caledonian orogeny mountains in Europe elevated up to 612 m a.s.l. The mountains are built of Palaeozoic and Mesozoic metamorphic formations (quartzitic sandstone, mudstone, slate). The oldest evidence of *Dinosauromorpha*, four-legged animals living during the Early Triassic was found there recently. The fossil



Fig. 6 The Beskid Mountains—a direction of plowing accelerate surface flow and soil erosion (Photo K. Ostafin)



Fig. 7 A typical landscape of uplands in the Upper Vistula Basin (Photo M. Kumon)

footprints are dated to approximately 250 million years ago. Footprints of early bipedal dinosaurs known as *Sphingopus*, from 246 million years ago, have also been found there (Niedźwiedzki and Remin 2008).

3 Tradition and Culture

The Upper Vistula Basin is endowed with a rich tradition and culture which is a combination of secular traditions and customs. They have roots in history, but continue to develop, incorporating old tradition with modern sensibilities. An exceptional role in the cultural landscape in the Upper Vistula Basin was played by the Carpathians. This area acted as a cultural and artistic transmitting zone from the south of Europe—the Danube basin to the north and north-east (Węclawowicz 1995). New patterns were carried by tribes penetrating in particular mountain valleys: the Polish and German speaking settlers, Italian, Greek, Jewish and Armenian merchants and Wallachian shepherds. A coexistence of these various cultures influenced the features of localities. The trace of the past can still be seen in tiny medieval towns with stone churches and brick houses, villages composed of wooden cottages of primitive log construction, Latin wooden Roman Catholic village churches in the west of the Carpathians and Orthodox ones in the east. At the close of the 19th century the Carpathian ethno-cultural mixture was incorporated into the Austrian part of Poland called Galicia. The marvel of the Carpathians

cultural landscape lies in the artistic merit of historical monuments as well as in a specific *genius loci*: the surroundings with hills, river valleys, forest and old architecture. So the Carpathian cultural heritage consists of the whole historical structure of monuments, sites, routes, local dialects, even customs.

The folk culture of the Carpathians has been formed by considerable influence of pastoral tribes from Transylvania and the Balkans shepherds (Maj 1995). It is revealed in certain types of folk crafts, local music, wood carving, painting on glass, regional costumes and certain rituals. Local people keep their tradition. Carpathians folk costumes are colorfully decorated and they are often seen during holidays and festivals. Women wear open-work embroidered shirts, flowered skirts, and necklaces of coral beads. White lace aprons complete the outfits. Men wear blue vests tied with a sash; on their heads there are hats trimmed with decoration. The flowered skirts of Polish traditional costumes are topped with vests and blouses.

The Upper Vistula Basin was populated mostly by Roman Catholics. A considerable influence of the Orthodox Church was observed in the Carpathians eastward of the River Dunajec. In the 16th century Lemko tribes accepted the Greek Catholic rite (known as the Ukrainian-Byzantine rite), and the followers of the Orthodox rite formed a considerable religion minority. They were compulsorily resettled to the other regions of Poland or to the former Soviet Union shortly after the World War II. A considerable concentration of the worship centers in the Carpathians is exceptional in Poland and in the world. Tradition of pilgrimage to Carpathian worship centers reaches back up to the old times. By the 16th century about 100 centers has been formed most of them with crowned images of the Virgin Mary (Jackowski 1995). The most important ones are in Kalwaria Zebrzydowska, Kalwaria Paławska, Tuchow, Ludzmierz. Since Cracow—Lagiewniki has been established as an international center of the Divine Mercy worship, the sanctuary increased the significance. Recently Wadowice has received international recognition as the birthplace of the Pope John Paul II, especially after he became canonised.

Over the centuries (up to 1939) judaism was an important religion in the Upper Vistula Basin. The Jews have been living in Poland since the king Casimir the Great (14th century) allowed them to settle in Poland in great numbers. The king was favorably disposed toward the Jews. This religion developed especially at the end of 18th century when mystic movement called Chassidism expanded. A lot of pilgrimage centers developed in the Carpathians like Lezajsk, Bobowa, Dynow, Stary Sacz, Rymanow. Some of them had become the residence places of charismatic Chassidic leaders.

Cracow is the most important historical and cultural center in the Upper Vistula Basin situated by the River Vistula. This is the second largest and one of the oldest cities in Poland. It is also a leading center of Polish academic, cultural, and artistic life, and one of the most important economic hubs. The former capital of Polish kingdom (until 1596) with its numerous historical, cultural and religious monuments, offers attractions to a few million tourists a year (2012—8 million, 2014—9.9 million).

The cultural qualities are represented by monuments of sacral architecture (churches, monastery complexes, small wooden Roman and Greek Catholic

churches, chapels and by-road statues) and the relicts of residential architecture of old urban systems. Fortified castles, cathedrals and museums are still present in the Upper Vistula Basin as a part of its architectural and cultural heritage. The 16th century castles topping white-rocks of Jurassic limestone in the Lesser Poland Uplands are very spectacular. The places of national martyrdom and numerous cemeteries including those from the World Wars I and II are closely associated with the history of the Carpathians—the place of three big military operations in the 20th century: in 1914–1915, in 1939 and in 1944–1945 (Przyboś 1995; Groch and Kurek 1995). The battle at Gorlice in 1914, which ended in a defeat of Russian army as well as the Dukla Pass combat in 1944 (not a very successful operation of the Soviet troop either) which was one of the bloodiest and most relentless battles in the history of the Second World War are especially worth of mentioning.

4 Population and Economy—Land Use and Functional Variety

Until the middle of the 6th century, the Upper Vistula Basin was very sparsely populated—the Slavonic settlers from the north reached the edge of the Carpathians. The mountains with elevation above 350 m a.s.l. were not populated at all (Przyboś 1995). At the end of the 9th century Wislica was founded. It was the most ancient settlement in Polish territory at that time, located at the Krakow Upland very close to the important trade route running from Cracow to Sandomierz. It was probably the capital of the Vistulans, a Slavonic tribe. Inhabitants of ten sub-settlements around Wislica worked for the needs of the city in the 12th century. The city was presumably burnt down by Tatars during the invasion of 1241 and it was never again inhabited by settlers. A gypsum baptismal font found during excavations works is thought to had served as a font for collective baptism in the 9th century. If so, it would be the place of the earliest baptism on the Polish lands. The Wallachian colonization wave characterized by the dominating animal husbandry and shepherding type of economy arrived from the east at the end of the 14th century.

With the laps of time the colonization pushed to the south—mainly along the Carpathian river valleys. Most of cities in the Upper Vistula Basin were founded in the 13th through 16th centuries as trade centers, those cities developed in the 19th and 20th centuries becoming industrial or tourist centers. Agriculture was the main activity of inhabitants north to the Vistula River (uplands). Rich soils (chernozem) and gentle slopes inclination had been favourable land attributes for cultivation of wheat, sugar beet, and tobacco. This portion of the basin is predominantly comprised of cultivated crops with pockets of forest and very little hay lands (flat bottom of river valleys). The predominant role of agriculture in the economy of this part of the Upper Vistula Basin remains till nowadays (Fig. 8).

In the Carpathians there were favourable conditions for pastoral farming and wood industry. Poor soils and steep relief allowed to cultivate primarily rye and

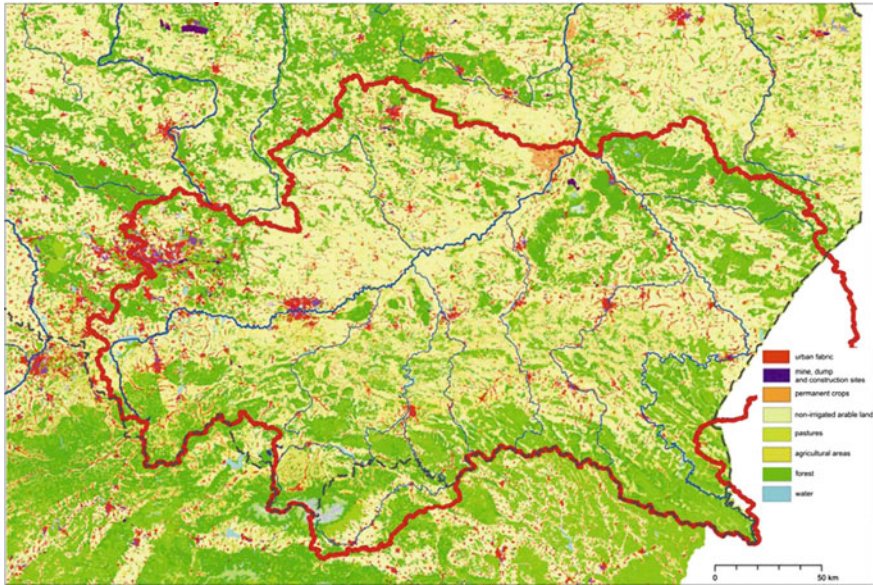


Fig. 8 Land use in the Upper Vistula Basin (CORINE 2006)

potatoes. Small size and plot fragmentation of farms reflected a high-density population in rural areas and a historic process of triple partitions of Poland by Austrian, Russian and Prussian empires (1772, 1793, 1795). Most of the Upper Vistula Basin was under Austrian annexation and the inheritance-related division of fields in high-density population rural areas was possible. The region was separated from the rest of Poland and deprived of the opportunities for progress. Farms were very small, by area, in comparison with farms in the Prussian partition of Polish lands.

Salt had been exploited for more than seven ages in the salt mine established in the 13th century (Wieliczka) and exported to all over Europe via the Vistula River waterway, which had been one of the main trading arteries in Poland for hundreds of years. Except for salt, among the goods shipped *via* this route between the 10th and 13th centuries there were: timber, grain, and building stone.

There were other natural resources in the Upper Vistula Basin in the past. Oil and natural gas industry (vicinity of Sanok) was a traditional branch in the Carpathians. Thanks to native sulfur deposits (vicinity of Tarnobrzeg), Poland was one of the world's largest producers of sulfur. The Silesia is the most industrial region in the Upper Vistula Basin. The coal mine activity and many branches of industry concentrate there. Brine pumped from mines is discharged to the River Vistula and cause a significant pollution of its water. The population density in this region exceeds 500 person per 1 km² (Fig. 9). At present, apart from Silesia, there are a few strongly industrialized regions in the Upper Vistula Basin with the following centers: Cracow, Bielsko-Biala, Tarnow–Rzeszow, Tarnobrzeg–Stalowa

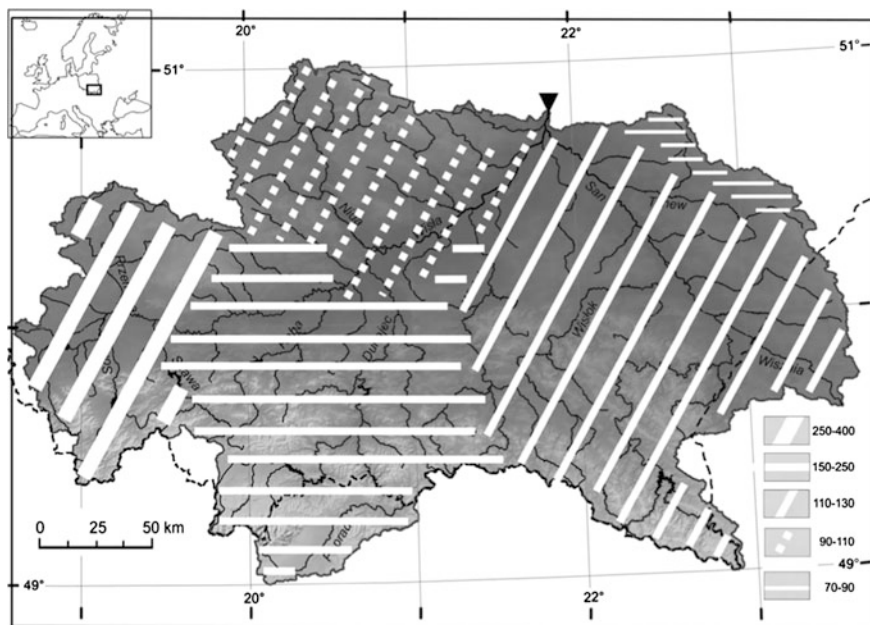


Fig. 9 Population density (person per km²) in communes in the Upper Vistula Basin (Raport z wyników 2011, 2012)

Wola with the industries like: electromechanical, food, light, chemical and steel. A discovery of abundant mineral water mainly in the Carpathians enabled developing of spas, health and revitalizing resorts for therapeutic healing, as well as production of bottled water.

There is one city, Cracow, with population over half million (761,873 thousand) and a few medium-size cities (100–300 thousand: Katowice, Kielce, Rzeszów, Bielsko-Biała, Tarnów). A basic function of those cities is the industry (especially in the west) as well as services, education, and culture. Together, they constitute a grid of well connected cities linked by numerous latitudinal and meridional lines of communication (Zborowski 1995). Some of the routes are very old, they used to connect Germany with Russia, the Baltic Sea with the Black Sea and Hungary since the Middle Ages (Birek and Janiec 1995). The construction of main Vienna route and several other roads had taken place in the 18th century. The industrial and technological revolution induced new demands for transportation in the 19th century and it resulted in construction of a railway network. Most of railway lines constructed during that time by Austrian government (subcarpathian and transversal lines) are still operating.

The network of public roads has been improving in recent years. Motorways and expressways linking Warsaw, Silesia, Cracow and Ukraine are a part of national roads network. Government's investments on road construction increases, as it is necessary due to rapid development of the country and the inflow of European

Union funds for infrastructure projects. Moreover, Poland as a country located at the “cross-roads” of Europe needs a large and increasingly modern network of transport infrastructure.

In spite of long lasting human activity there are areas in the Upper Vistula Basin where natural environment has not been significantly modified, even in the upland part of the basin. Large parts of the Carpathians are covered with forests, and their share exceeds 70 % in some areas (e.g. south-eastern part of the region). The mountains are known for rich and unique fauna and flora with numerous endemic species and communities. The most intact, undisturbed, wild natural areas have been protected as national parks. There are nine national parks in the Upper Vistula Basin and this constitutes 40 % of total number of national parks in Poland. Three of these nine parks preserve mountainous environment, where wilderness areas prevail. A mountain climate (low air temperature and ample snow cover) encourage winter sports there, so numerous ski resorts are located in the south-western part of the mountains. Tourism is a very important branch of economy in the Carpathians which are the principal touristic region in the country. The touristic traffic is considerably diversified there. The highest concentration of traffic is observed in the Tatra Mountains and their vicinity. The Tatra National Park was established in 1950. Number of visits has reached 3 million per annum, which is considered to be beyond the park’s long-term carrying capacity. The following types of recreational use are characteristic of the park: organized group sight-seeing, hiking, ski-tourism, downhill skiing, mountaineering, and caving. Sheep grazing remains an important activity in the Park. First, it had been eliminated, but later in 1981 was reintroduced in order to preserve local culture and maintain biodiversity. The Polish and Slovak Tatra Mountains range was included into the Biosphere Reserves (UNESCO Man and the Biosphere Programme).

All regions in the Upper Vistula Basin have experienced strong political and economic changes after more than 40 years of communism and especially after having joined the European Union on 1 May 2004. Some of these changes are significant for water cycle. Natural reforestation of abandoned agricultural land is a widespread present phenomenon in the Upper Vistula Basin. The increase of the surface of designated protected areas, extended forest cover due to natural succession. Such changes favour slower water circulation and water storage in the basin. Nowadays one may observe a remarkable increase in the awareness of the value of water as a good which should be limited in use.

5 Hydrological Significance of the Upper Vistula Basin in the Hydrology of Poland

The Upper Vistula Basin plays a very important role in the hydrology of Poland. Due to significant water resources the Carpathians secure water for a number of regions far beyond their boundaries being an important water tower for the rest of

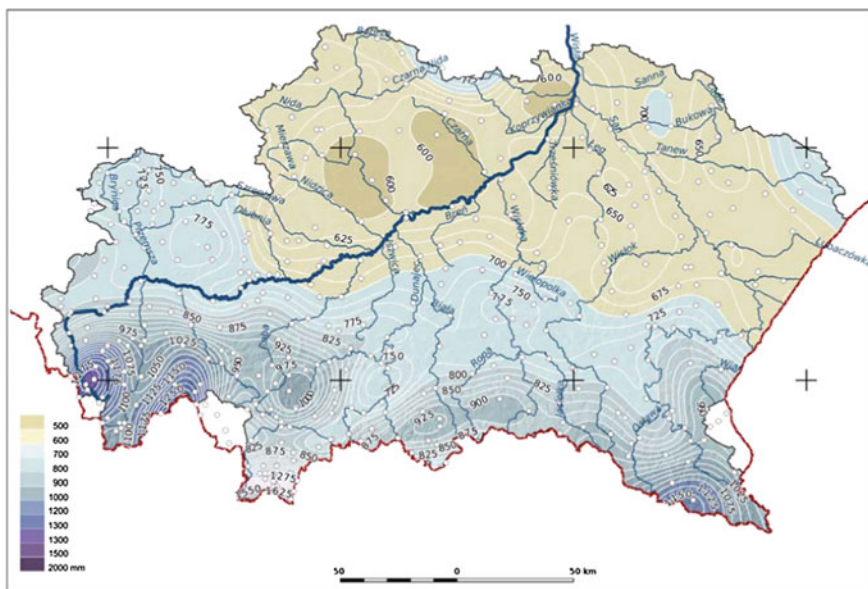


Fig. 10 Mean annual precipitation in the Upper Vistula Basin (1952–1981, after Cebulska et al. 2013, modified)

the country. The spatial distribution of precipitation in the Upper Vistula Basin is uneven. The smallest annual precipitation (550–650 mm) occurs in the Sandomierska Basin, and the highest one—reaching 1,700 mm occurs in the Tatra Mountains. This is the highest precipitation in Poland (Fig. 10). Considering horizontal precipitation (which is not measured) in the Tatra Mountains, there might be even 70 % more of water available in the water cycle. Precipitation on the northern slopes of the Tatra Mountains is approximately 200 mm higher than on southern slopes due to the rainfall shadow (Pociask-Karteczka 2014).

A mean annual discharge of the Upper Vistula River amounts 449 m³/s (at Zawichost, 1951–1980; Punzet 1991), this is approximately 40 % of the discharge at the river mouth to the Baltic Sea in spite of the draining just 25 % of the watershed (Fig. 1). The Vistula river regime of the middle and lower courses is influenced by the Upper Vistula. There are two flood seasons during the year: one due to the snowmelt (March–April), and another one due to summer rain (July or August, Fig. 11). However, the eastern part of the area is mostly affected by continental type of the climate and the summer flood season is rather not marked or slightly marked. The meteorological conditions in the Upper Vistula Basin in Poland are influenced by polar maritime (west) or continental (east) air masses and for this reason the area's climate is transitional—between oceanic and continental (Niedźwiedz and Obrębska-Starkłowa 1991).

The discharge of the River Vistula increases according to the left- and right-bank tributaries confluence. The Carpathian tributaries are predominant in the Vistula

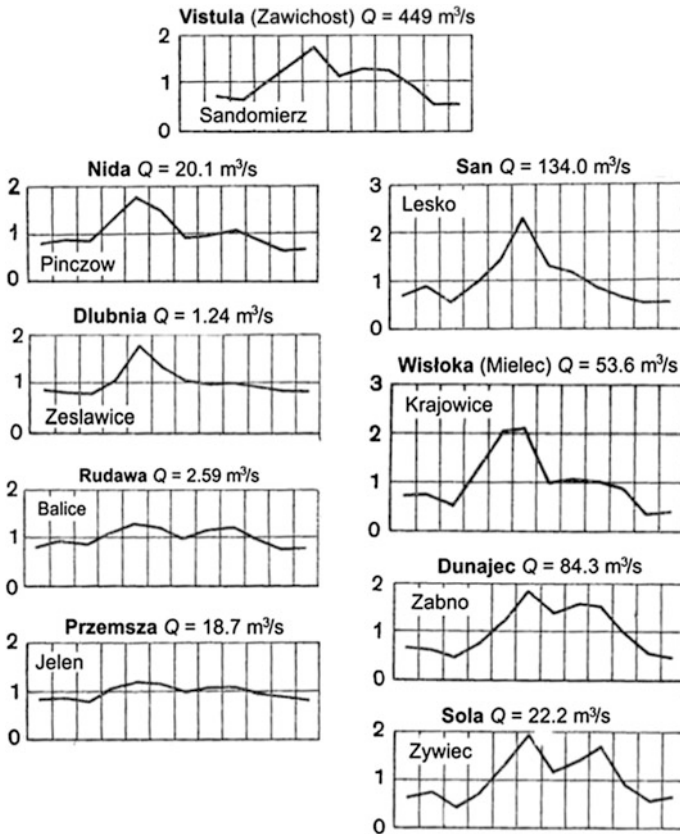


Fig. 11 The monthly Pardé coefficients in the Upper Vistula Basin and the mean annual river discharge (Q) in 1951–1980 (Punzet 1991)

discharge supply (Fig. 3). The river network density in the southern part of the Basin is smaller due to higher permeability of soils and geological formations (limestone, marls). The total mean annual discharge (1951–1980) of some significant Carpathian rivers: Sola, Dunajec, Wisłoka, and San (the right-bank Vistula River tributaries) reaches 294.1 m³/s, i.e. almost 7 times more than the total discharge of upland left-bank Vistula River tributaries: Przemsza, Rudawa, Dłubnia, and Nida (44.0 m³/s; Punzet 1991).

Steep relief of the Carpathians, relatively small permeability of soil, high density of valleys and field roads favour a very dynamic and rapid hydrological cycle and outflow from the catchments. A runoff coefficient (a runoff/precipitation) in the Carpathians exceeds 60 % and it is the highest in the whole country. An average annual specific runoff is also very high and reaches 50 dcm³/s/km² (Lajczak 1996, Fig. 12). A considerable contribution of groundwater in the river runoff is a

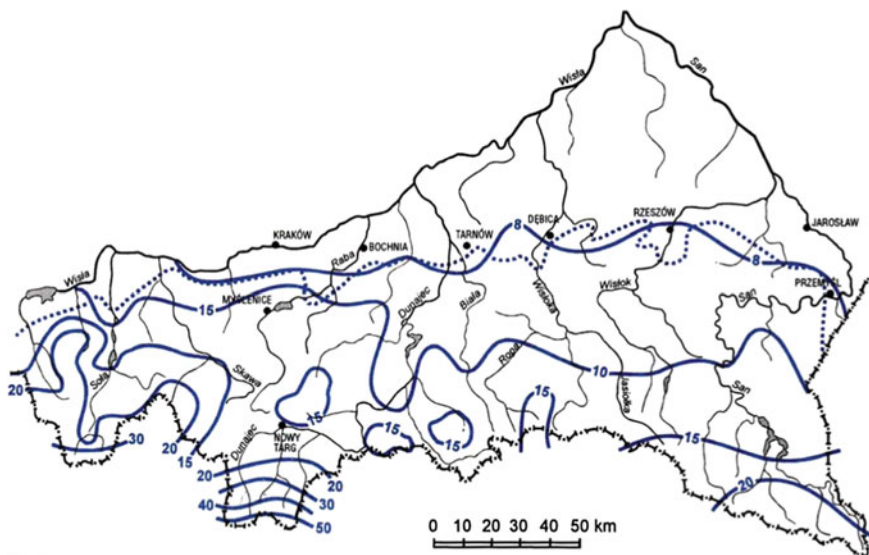


Fig. 12 The average annual specific runoff in the Carpathians (Dynowska 1995)

distinguishing feature of upland rivers. It is related to the rich groundwater aquifer in limestone and marls.

Flood potential of the Carpathian rivers and good water quality contributed to creation of water storage reservoirs. Most of reservoirs were built to retain water during high rainfall events and to prevent or reduce downstream flooding. Over the course of time, reservoirs have acquired some new functions. Finally at present, most of reservoirs are multi-purpose, but yet flood control and hydroelectricity use prevail (Table 2). In some reservoirs water must be stored in order to meet water demand of other regions. Hence significant water withdrawals occur, e.g., from the Sola River to Silesia Region and from the Raba River to Cracow. Water from the reservoir on the Raba River meets approximately 70 % of Cracow water demand.

In the Upper Vistula Basin, one can distinguish three types of landscape with different water cycles: (i) mountainous, (ii) upland and foothills and (iii) lowland (Starkel 1991). The characteristics of the mountain landscape are: quite steep slopes (inclination between 20 and 40° prevails), debris covers, significant denivelation and overall general high altitude above sea level. Hence the mountain area favors a fast surface and subsurface flow, that may lead to formation of floods. High mountains raise above the upper timberline, where highest precipitation occurs. Regionally significant water storage occurs in high mountain postglacial lakes. In medium mountains (Beskid) and foothill region, flysch sediments—a sequence of rhythmically interbedded sandstone and shale/mudstone—do not constitute rich groundwater aquifer, while mantle cover with significant share of clay fraction limits infiltration and considerable slope favours surface flow. Agrarian landscape structure is also an important factor determining the water circulation in the Beskid

Table 2 The largest water storage reservoirs in the Upper Vistula Basin

Name of reservoir	River	Total volume ($\times 10^6 \text{ m}^3$)	Area (km^2)	Use
Solina	San	472	22	Flood control, hydroelectricity
Czorsztynski	Dunajec	234.5	11	Flood control, hydroelectricity
Roznowski	Dunajec	193	16	Flood control, hydroelectricity, touristic
Swinna Poreba ^a	Skawa	161	10.35	Flood control, hydroelectricity, touristic
Goczalkowicki	Vistula	166.8	32	Water demand, flood control, touristic
Dobczycki	Raba	127	10.7	Water demand, flood control, hydroelectricity
Zywiecki	Sola	94.6	10	Flood control, water demand, hydroelectricity, touristic
Klimkowka	Ropa (Wisłoka)	43.5	3.1	Water demand, flood control, hydroelectricity, touristic
Miedzybrodzki	Sola	26.6	3.8	Flood control, water demand, hydroelectricity, touristic

^aunder construction

and Subcarpathian foothills. Land fragmentation, reflected in so-called field patchwork or chessboard pattern, generates favourable conditions for a fast intensive water surface flow, especially in snowmelt season and summer rain period. It also intensifies soil erosion (Woch and Borek 2015). Small river basins with arable land fragmentation are prone to the flash floods which are triggered primarily by intense rainfall.

Uplands are areas of smaller denivelations (50–100 m) and smaller slopes inclination. Carbonate rocks are most extensive there and they are among the most productive aquifers known in the Upper Vistula Basin. Hence there are numerous springs with a high discharge rate, especially karst springs in the Lesser Poland Upland. Loess cover on the widespread plateaus is sensitive to linear erosion. Lowland landscape is typical for the Subcarpathian basins. Post-glacial and fluvial-glacial deposits cover the Miocene loams. This is a transit region for the River Vistula and lower courses of its tributaries.

6 Final Remarks

The Upper Vistula Basin occupies approximately 15 % of Poland. Northern part of the Basin played a very important role in the Middle Ages being the center of the Polish statehood with Wislica and then with Cracow which was the capital of the country from the mid-11th century until 1596. During several centuries of historical development, the region gained a unique ethno-cultural identity.

The regional diversity of natural environment of the Upper Vistula Basin (north—uplands, south—mountains, central part—lowland) caused different economic activity in particular portions of the region. Agriculture and industry prevail in the western, northern and central part of the area. Land cover of the southern, mountainous part remains least affected, with significant share of forest.

The Upper Vistula Basin is of utmost importance in the hydrology of Poland. It embraces the headwater area of the largest river in Poland, i.e. the River Vistula and its tributaries. The water resources (highest precipitation, river runoff) of the area—the water tower of a large part of Poland—are the richest in the whole country. The dynamics of the hydrological cycle in the mountain area is very high due to steep relief and low ground permeability. Flood formation, favoured by intensive surface and subsurface flow at the area with a dense agricultural land fragmentation and field road network, proceeds fast. Hence, the Upper Vistula Basin plays an important role in flood generation in the country.

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