7

The vegetation of the Olkusz Ore-bearing Region

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Introduction

The species richness and diversity of plant communities in an area are primarily connected with the diversity of its habitats. Habitat diversity depends on the variability of natural geological, hydrological and climatic conditions, but also on highly varying forms of human impact. Anthropogenic influences can modify topography, hydrology, and the chemical and physical properties of soil. As a consequence, new habitats are created which do not occur naturally. They become places for numerous native and alien species of plants, animals and other organisms to live. This can be seen in the commonly noted increase in the species richness of flora and phytocoenotic diversity, and in the development of semi-natural and synanthropic vegetation in particular. Often, however, the higher the richness of the flora and vegetation, the fewer the elements specific to the natural habitats of the area. In response to this, long lists of seriously endangered taxa and habitats are drawn up for different geographic areas, from small regions to whole continents, and human activity is regarded as a principal cause of this threat.

In the Olkusz Ore-bearing Region (OOR), deposits of ore-bearing dolomites containing zinc and lead ore bodies have been mined and processed for more than 800 years. Thick deposits of sand in the OOR have also been exploited, though for a much shorter time. This long-term economic activity has led to far-reaching changes in the landscape. New habitats have been forming, most of them highly contaminated with heavy metals originating from industrial waste and emissions. These new habitats are dumps of dolomite and by-products of zinc and lead production, large filled-in excavations, sinks, and deep pits at sand extraction sites. They have been partially reclaimed by planting trees and shrubs, and partially overgrown spontaneously. Apart from industrial activity, forest management also takes place in the OOR, including periodic timber

harvesting and planting of new generations of trees. Fires caused by people penetrating the forests occur quite often there. Farming has been developing for long ages over a large part of the OOR as well, but field cultivation has declined in recent decades. In places where it has already disappeared, secondary succession has begun towards forest communities via plant communities often dominated by species with broad ecological spectra. All these phenomena of anthropogenic or natural origin are reflected in the biodiversity of the OOR.

Botanical studies in the Olkusz Ore-bearing Region have a long history. They began in the 19th century and have continued, varying in intensity, to this day. Chapter 5 of this volume (Grodzińska and Godzik) gives an overview of studies in the OOR. From 2008 to 2011 a botanical study was carried out in the OOR, aimed at assessing the actual phytocoenotic richness of plant communities and determining whether long-term human activity, mainly exploitation and local processing of zinc and lead ores, has led to the formation of important new communities which increase the vegetation diversity of the region.

Studies on vegetation of the Olkusz Ore-bearing Region in 2008–2011

The area of the OOR studied in 2008–2011 covers 48 square kilometres (6 × 8 km). It extends from Międzygórze in the west to Stary Olkusz in the east and from Laski in the north to the Pustynia Starczynowska desert and Dolina Sztoły valley in the south (Fig. 1). Large areas, adding up to 2.5% of the OOR, are occupied by industrial infrastructure. There is still a working ore mine (*Pomorzany* II) at the northern edge of the OOR. In the centre are ore processing facilities, among them the biggest zinc mine in Poland, the Bolesław Mining and Metallurgical Plant (ZGH Bolesław). In the east are the closed *Olkusz* ore mine and the ZGH Bolesław ore flotation plant. Between the zinc smelter and the ore flotation plant is a flotation tailings heap (at ZGH Bolesław tailings ponds) covering more than 110 ha and rising more than 30 m. Next to the heap is an operating sand quarry.

For the whole OOR a map of the vegetation actually occurring in 2008–2011 was made. In the field, all homogeneous patches of vegetation covering more than 500 m^2 were marked on the map. An orthophotomap (1:5000) was used as the base. For each distinguished and mapped vegetation patch a list of the dominant species there was made in the field. Species known to be characteristic (i.e. specific to different vegetation types) were also included in the inventories. The lists usually comprised a dozen or so plant species. In editing the map the inventories were used to assign the patches to particular vegetation units.

In the mapping work, particular attention was paid to patches of plant communities related to calamine soil, found in places where heavy-metal-rich material left from zinc-lead ore mining and processing was dumped. Those communities were identified based on the presence of indicator species previously distinguished by Grodzińska and Szarek-Łukaszewska (2009). For forest communities the dominant tree species as well as tree stand age were taken into account. Age was determined by counting the whorls of branches of conifer species. Assuming the age of most trees to be the age of the tree stand, three age classes were distinguished: up to 20 years, from 21 to 40 years, and more than 40 years. Vascular plant nomenclature followed Mirek *et al*. (2002) and plant community nomenclature followed Matuszkiewicz (2002).

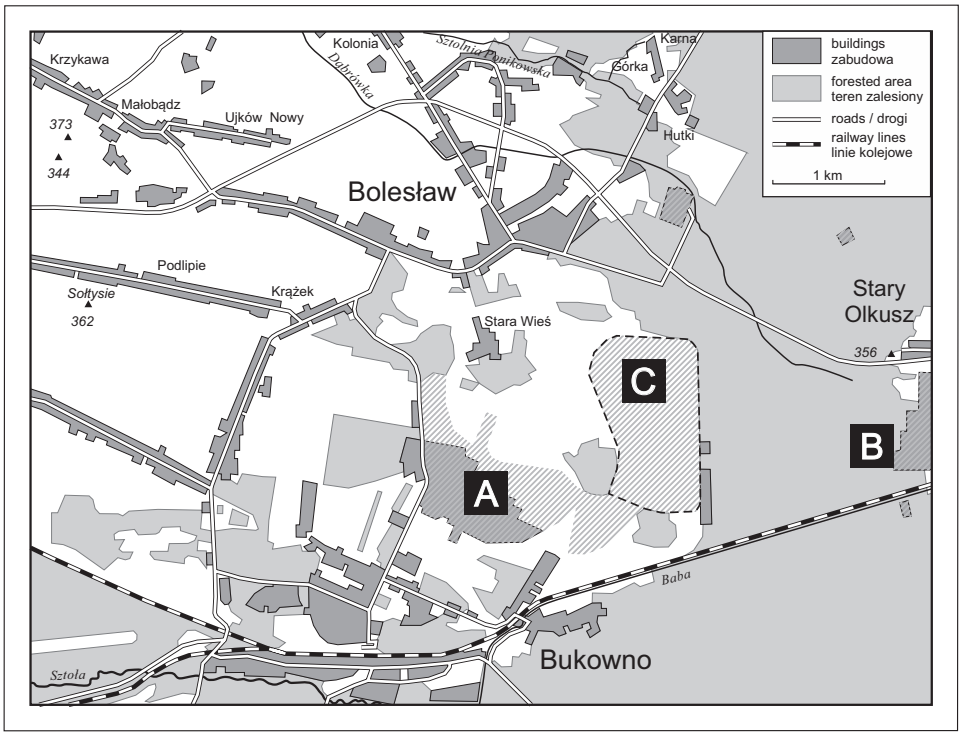


Fig. 1. The study area – the Olkusz Ore-bearing Region. A – ZGH Bolesław zinc smelter, B – flotation works, C – flotation tailings heap (P. Kapusta)

Ryc. 1. Teren badań – Olkuski Okręg Rudny. 8 – huta cynku ZGH Bolesław, 9 – zakład flotacji, 10 – hałda odpadów poflotacyjnych (P. Kapusta)

List of plant communities

In the 48 km^2 area more than 6000 homogeneous vegetation patches were distinguished and mapped and then assigned to 32 vegetation types. These were vegetation units described by phytosociologists and listed by Matuszkiewicz (2002) as well as communities without a syntaxonomic rank and related to specific local habitat conditions, distinguished by the authors of this publication.

The vegetation of the OOR can be divided into two main groups of plant communities: communities developing in habitats enriched by remnants of zinc-lead ore (calamine), and communities associated with other habitats. Within both groups, non-forest communities, forest communities and woodlands are distinguished. This division is shown below and corresponds to the terms given in the description of the OOR vegetation map (Fig. 2). Apart from these vegetation types, arable fields, sand pits, industrial and built-up areas, as well as areas completely devoid of vegetation, were indicated.

Plant communities associated with calamine soil

Non-forest communities

- Calamine grassland of the Armerion halleri alliance

- Grassland with dominant *Molinia caerulea* and grasslands with dominant *Molinia caerulea* and numerous species of the Armerion halleri alliance
- Grassland with dominant *Festuca ovina*
- Rush communities with *Phragmites australis*
- Fallows communities (uncultivated fields)

Forest communities and woodlands

- Forest communities similar to fresh pine forest
- Different types of woodland, including woodland with dominance of *Molinia caerulea* in the herb layer
- Woodland with a contribution of trees typical of wet habitats

Plant communities associated with non-calamine soil

Non-forest communities

- Psammophilous grassland
- *Nardus stricta* grassland and heathland
- Xerothermic grassland
- Fresh meadows and pastures
- *Molinia caerulea* meadows (meadows of intermittently wet habitats)
- Wet meadows
- Tall forb meadows
- Fens
- Rush communities
- Uncultivated fields (Fallows)
- Ruderal communities
- Scrub within arable fields

Forest communities and woodlands

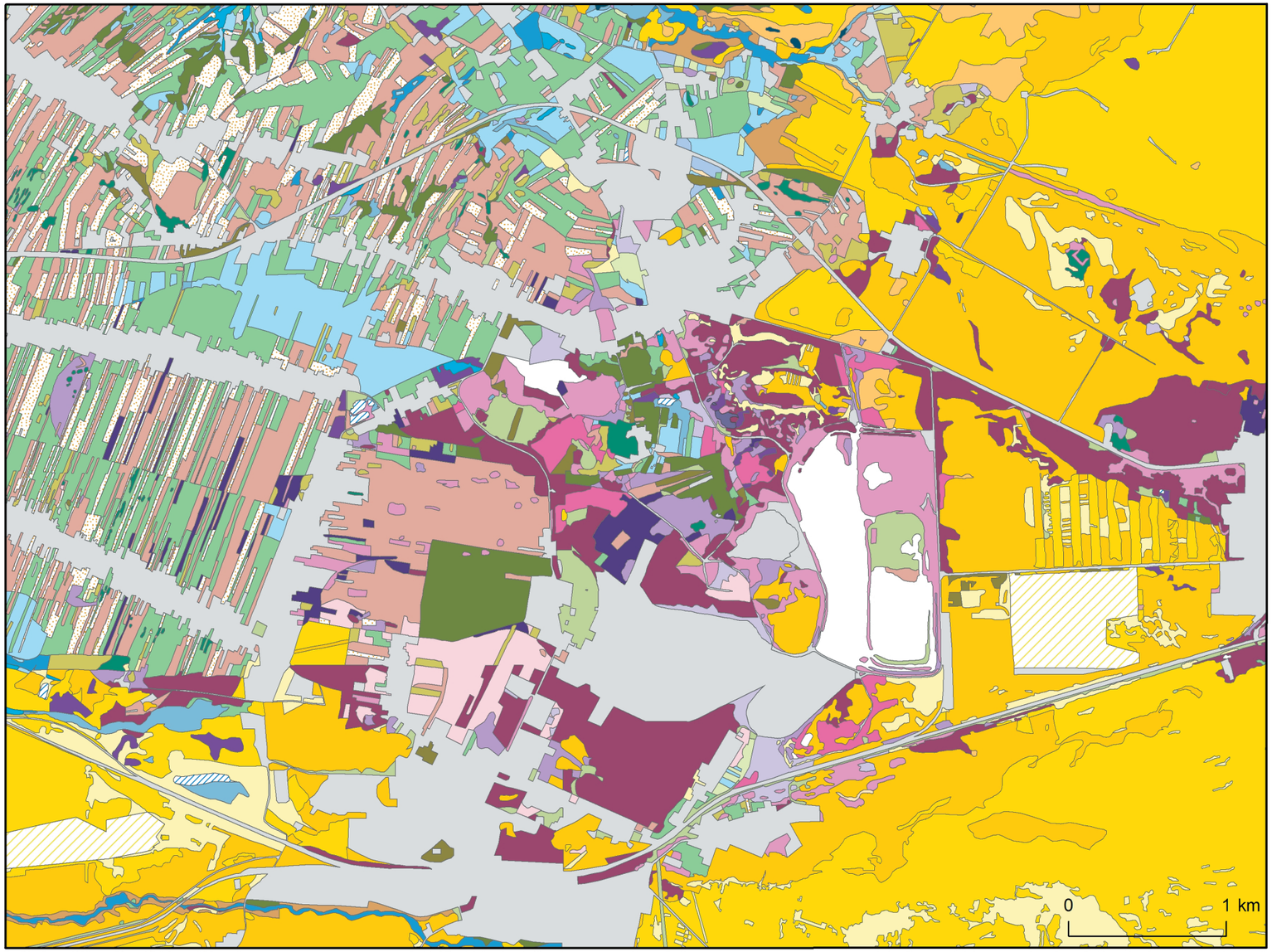
- Fresh pine forest
- Wet pine forest
- Bog pine forest
- Mixed pine forest
- Oak-lime-hornbeam forest and secondary forest communities in habitat of oak-lime-hornbeam forest
- Floodplain forest and secondary forest communities in habitat of floodplain forest
- Alder swamp (alder carr) and grey willow scrub
- Woodland in uncultivated fields (fallows)
- Woodland in ruderal habitats

Every distinguished vegetation patch was assigned to one of the vegetation types mentioned above and in this manner the vegetation map of the whole study area was completed (Fig. 2). It showed a very diversified mosaic in which three areas clearly stood out. The eastern and southern parts are dominated by forest communities which form extensive homogeneous complexes of pine forests or birch woods. In this solid complex of coniferous forests, fragments of other vegetation types occur only at some places east of Bolesław and Hutki town as well as south of the Olkusz-Katowice railway line. Most often these are species-poor grasslands covering sandy soils and patches of plant communities related to calamine soils which form belts along roads and the railway line. In the coniferous forests there is a relatively large island of oak-lime-hornbeam forest. An entirely different vegetation landscape has been formed in the northwestern part. There we note many small vegetation patches of regular shape resulting from earlier agricultural use. There are few currently cultivated fields; most have been abandoned over the last decade or so. In the central part of the map we see yet another vegetation scheme. The particular elements of the vegetation mosaic there are of different sizes and form a rather disorderly picture. This is the part of the Olkusz Ore-bearing Region most transformed by industrial activity, located between Bolesław and Bukowno.

Detailed description of the distinguished communities

Plant communities associated with calamine soil

The central part of the OOR, from Bolesław to Bukowno, as well as fragments of its eastern part (Stary Olkusz), were strictly



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- Grassland with dominant *Molinia caerulea*
- Grassland with dominant *Molinia caerulea* and numerous species of the Armerion halleri alliance
- Grassland with dominant *Festuca ovina*
- Rush communities with *Phragmites australis*
- Fallows communities (Uncultivated fields)

Forest communities and woodlands

- Forest communities similar to fresh pine forest
- Woodland with dominance of *Molinia caerulea* in the herb layer
- Different types of woodland
- Woodland with a contribution of trees typical of wet habitats

Plant communities associated with non-calamine soil

Non-forest communities

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- *Nardus stricta* grassland and heathland
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- Wet meadows
- Tall forb meadows
- Fens
- Rush communities
- Uncultivated fields (Fallows)
- Ruderal communities
- Scrub within arable fields

Forest communities and woodlands

- Fresh pine forest
- Wet pine forest
- Bog pine forest
- Mixed pine forest
- Oak-lime-hornbeam forest and secondary forest communities in habitat of oak-lime-hornbeam forest
- Floodplain forest and secondary forest communities in habitat of floodplain forest
- Alder swamp (alder carr) and grey willow scrub
- Woodland in uncultivated fields (fallows)
- Woodland in ruderal habitats
- Arable fields
- Sand pits
- Water reservoir
- Area without vegetation
- Built-up and industrial areas

Roślinność związana z podłożem galmanowym

Zbiorowiska nieleśne

- Murawy galmanowe ze związku Armerion halleri
- Murawy z panującą *Molinia caerulea*
- Murawy z panującą Molinia caerulea i licznymi gatunkami ze związku Armerion halleri
- Murawy z panującą *Festuca ovina*
- Szuwary z *Phragmites australis*
- Roślinność nieużytków porolnych

Zbiorowiska leśne i zadrzewienia

- Zbiorowiska leśne przypominające świeży bór sosnowy
- Zadrzewienia z dominującą *Molinia caerulea*
- Różnego typu zadrzewienia
- Zadrzewienia z udziałem drzew typowych dla siedlisk wilgotnych

Roślinność na siedliskach bez galmanu

Zbiorowiska nieleśne

- Murawy psammofilne
- Murawy bliźniczkowe i wrzosowiska
- Murawy kserotermiczne
- Łąki świeże i pastwiska
- Łąki zmiennowilgotne
- Łąki wilgotne
- Łąki ziołoroślowe
- Torfowiska niskie
- Szuwary
- Nieużytki porolne
- Zbiorowiska ruderalne
- Zarośla śródpolne

Zbiorowiska leśne i zadrzewienia

- Bór sosnowy świeży
- Bór sosnowy wilgotny
- Bór sosnowy bagienny
- Bór mieszany
- Las grądowy i leśne zbiorowiska zastępcze na siedlisku grądu
- Łęg i leśne zbiorowiska zastępcze na siedlisku łęgu
- Ols i łozowisko
- Zadrzewienia na ugorach
- Zadrzewienia na siedliskach ruderalnych
- Pola uprawne
- Piaskownie
- Zbiorniki wodne
- Teren pozbawiony roślinności
- Zabudowa i tereny przemysłowe

Fig. 2. The vegetation of the Olkusz Ore-bearing Region. Map authors: J. Holeksa, A. Błońska, A. Kompała-Bąba, G. Woźniak, M. Żywiec, P. Kurek

Ryc. 2. Roślinność Olkuskiego Okręgu Rudnego. Autorzy mapy: J. Holeksa, A. Błońska, A. Kompała-Bąba, G. Woźniak, M. Żywiec, P. Kurek

associated with zinc-lead ore extraction and processing, which went on mainly in the 19th and 20th centuries. These areas are currently covered by different plant community types (Fig. 2). On the calamine soils, which are common there, both grasslands and more or less compact woodlands and forests occur, forming an irregular mosaic of patches of different sizes. On the formerly barren surfaces of waste heaps and filled-in excavations as well as old arable fields contaminated by mining waste, grasslands have spontaneously developed, some more than 100 years old. Most woodlands were planted during reclamation of devastated areas. Afforestation has been carried out in different periods since the 1970s.

Non-forest communities

- Calamine grassland of the Armerion halleri alliance

Calamine grasslands are the plant communities most specific to the OOR and are unique for the region and the whole country (Grodzińska and Szarek-Łukaszewska 2009; Szarek-Łukaszewska and Grodzińska 2011). They are the easternmost localities of such grasslands in Europe (Ernst 1974; Matuszkiewicz 2002; Dierschke and Becker 2008; Szarek-Łukaszewska and Grodzińska 2011). Like most European calamine grasslands, they have patches of secondary origin in the OOR. The primary patches of these grasslands were associated with rocky outcrops rich in metals, which probably occurred in the OOR but are not to be found today.

Patches of calamine grassland of different sizes are scattered in forests, woodlands and uncultivated fields, chiefly between Bolesław and Bukowno and also in the environs of Stary Olkusz. They occupy 125 ha, roughly 2.5% of the area of the OOR. Usually they are low-growing, and their cover varies from 10–15% to ca. 90%. Vascular plants are dominant in very dense grasslands, and lichens are an important component of less dense ones. Mosses do not play a significant role there. A common characteristic of all grasslands is the presence of clump grasses, mainly *Festuca ovina*. The high variation of soil properties (land form, humidity, chemistry), especially in soils built of stony mine waste, enables species with different life requirements to coexist. Growing together are species of warm and dry habitats (e.g. *Dianthus carthusianorum*, *Potentilla arenaria*, *Pimpinella saxifraga*, *Thymus pulegioides*, *Anthyllis vulneraria*), weakly and moderately wet habitats (*Lotus corniculatus*, *Ranunculus acris*, *Carex hirta*), poor habitats (*Campanula rotundifolia*, *Cardaminopsis arenosa*, *Gypsophila fastigiata*) and nutrient-rich habitats (*Trifolium pretense*, *Vicia cracca*).

Some of the species have developed high tolerance to high concentrations of heavy metals in the soil. They are called metallophytes, either obligatory or facultative (pseudometallophytes). The former are species that occur exclusively in metalliferous soils at least within a given region, and the latter grow in both metal-contaminated and uncontaminated soils within the same region (Baker *et al*. 2010). Obligatory metallophytes are absent from the OOR grasslands; the facultative ones in the OOR include *Cardaminopsis arenosa*, *Dianthus carthusianorum*, *Silene vulgaris*, *Viola tricolor*, *Biscutella laevigata* and *Cardaminopsis halleri* (e.g. Wierzbicka and Panufnik 1998; Wierzbicka and Pielichowska 2004; Wierzbicka and Słysz 2005; Słomka *et al*. 2010, 2011, 2012; Szarek-Łukaszewska and Grodzińska 2011).

Most of the vascular plants, mosses and lichens forming the calamine grasslands are common, and the vascular plants are common both locally (Nowak *et al*. 2011; Szarek-Łukaszewska and Grodzińska 2011) and nationally (Zając and Zając 2001) (Fig. 3). The only rare ones are *Biscutella laevigata*, *Gentianella germanica* and *Erysimum odoratum*

Fig. 3. Calamine grassland of the Armerion halleri alliance with *Biscutella laevigata* (photo G. Szarek-Łukaszewska)

Ryc. 3. Murawa galmanowa ze związku Armerion halleri z pleszczotką górską (*Biscutella laevigata*) (fot. G. Szarek-Łukaszewska)

(Grześ 2007; Grodzińska and Szarek-Łukaszewska 2009; Szarek-Łukaszewska and Grodzińska 2011). *Biscutella laevigata* is known only from two localities in Poland – mountainous terrain in the West Tatras and lowland terrain in the Olkusz Ore-bearing Region (Wóycicki 1913; Grodzińska and Szarek-Łukaszewska 2009; Szarek-Łukaszewska and Grodzińska 2011). The grassland mosses are species usually associated with anthropogenic habitats. Some of them are noted very often in metalliferous soils (*Brachythecium albicans*, *Ceratodon purpureus*, *Pohlia nutans*). The lichens include species common (*Cladonia pyxidata*, *Verrucaria muralis*, *V. nigrescens*) and rare in the studied region (*Cladonia rei*, *Amadina punctata*), and others rare for the whole Silesia-Cracow Upland (*Bacidina chloroticula*) or Poland (*Agonimia vouaxii*, *Vezdaea leprosa*) (Bielczyk *et al*. 2009).

The calamine grasslands in the OOR belong syntaxonomically to the Armerietum halleri association (Armerion halleri alliance, Violetalia calaminariae order, Violetea calaminariae class) (Grodzińska and Szarek-Łukaszewska 2009; Szarek-Łukaszewska and Grodzińska 2011). These communities are species-poorer than such grasslands in Western Europe (Ernst 1974; Dierschke and Becker 2008; Baker *et al*. 2010). They lack a characteristic species of the Western European grasslands, *Minuartia verna* subsp. *hercynica*; the *Silene vulgaris* and *Armeria maritima* ecotypes typical of metalliferous habitats grow there instead. *Biscutella laevigata* is considered a locally characteristic species of the OOR (Grodzińska and Szarek-Łukaszewska 2009). The calamine grasslands in the OOR differ from the Western European ones in having constant and often abundant occurrence of such species as *Rumex thyrsiflorus*, *Cardaminopsis arenosa*, *Gypsophila fastigiata*, *Potentilla arenaria* and *Anthyllis vulneraria*, and the lichens *Vezdaea stipitata* and *Diploschistes muscorum*.

The calamine grasslands form islands of colourful low vegetation on the post-mining landscape of the OOR. There are single pine trees and their seedlings. The grasslands increase the biodiversity of the region since they host species typical of metalliferous soils. These communities should be protected by law and active measures should be applied (cutting of propagating trees) to ensure their existence. The two oldest calamine grasslands of the OOR in the vicinity of Bolesław are under protection in the Natura 2000 system.

- Grassland with dominant *Molinia caerulea* and grassland with dominant *Molinia caerulea* and numerous species of the Armerion halleri alliance

Grasslands with dominant *Molinia caerulea* occur mainly near the ZGH Bolesław mine

and occupy 41 ha, ca. 0.9% of the OOR. The communities mainly cover reclaimed areas. Reclamation has been based on covering waste heaps or degraded land with a layer of usually rich soil brought in from outside the area. On this substrate, grasslands with *Molinia caerulea* (Szarek-Łukaszewska and Grodzińska 2011) have developed spontaneously. They are characterised by the constant presence and high abundance of this grass. Despite the dominance of *Molinia caerulea*, a high, tufty plant, these communities are not species-poor. Usually the grass does not form a compact continuous layer. Species of wetter and more fertile habitats proliferate around those tufts (e.g. *Plantago lanceolata*, *Lotus corniculatus*, *Ranunculus acris*), and among them, in places with a thinner soil layer, grow species of drier habitats (e.g. *Festuca ovina*, *Silene vulgaris*, *Galium album*, *Thymus pulegioides*, *Campanula rotundifolia*). Species characteristic of calamine grasslands of the Armerion halleri alliance occur more rarely (*Armeria maritima*, *Biscutella laevigata*). Noteworthy is the presence of *Cardaminopsis halleri*, considered a zinc and cadmium hyperaccumulator, in some *Molinia* grasslands. It is able to accumulate more than 10,000 mg/kg Zn and more than 100 mg/kg Cd in its shoots. The few mosses and lichens in grasslands with *Molinia caerulea* include the mosses *Ceratodon purpureus* and *Bryum pallescens* and the lichens *Cladonia symphycarpia*, *C. monomorpha*, *C. rei* and *Vezdaea leprosa*.

- Grassland with dominant *Festuca ovina*

Sandy poor soils enriched with different amounts of waste from ore extraction and processing are dominated by species-poor grassland with *Festuca ovina* (Szarek-Łukaszewska and Grodzińska 2011) (Fig. 4). Patches of

Fig. 4. Grassland with dominant *Festuca ovina* on calamine soil (photo P. Kapusta)

Ryc. 4. Murawa z panującą kostrzewą owczą (*Festuca ovina*) na podłożu galmanowym (fot. P. Kapusta)

these grasslands are not very frequent in the OOR. They occur near the ZGH Bolesław mine in the central and southern parts of the mining area, and occupy ca. 47 ha (1% of the OOR). These grasslands are dominated by *Festuca ovina*. The constant elements are *Cardaminopsis arenosa*, *Viola tricolor* and *Rumex thyrsiflorus*. The grassland is dense. Only in less densely overgrown fragments there are lichens among the *Festuca ovina* tufts: many *Cladonia* species (*C. pyxidata*, *C. monomorpha*, *C. rei*, *C. subulata*) and also *Vezdaea leprosa* and *Stigmidium* sp. Less often noted are mosses (*Bryum pallescens*, *Ceratodon purpureus*, *Plagiomnium cuspidatum*). These grasslands resemble calamine grassland of the Armerion halleri alliance in having *Festuca ovina*, *Cardaminopsis arenosa* and *Rumex thyrsiflorus*. They differ in lacking thermophilous species of the Festuco-Brometea class; there are many lichens instead.

- Rush communities with *Phragmites australis*

There is a rather small patch covering ca. 1 ha in a locally wet place in the central mining area. It is surrounded by different types of woodlands. *Phragmites australis* is a dominant species there. Other important species are *Eupatorium cannabinum*, *Valeriana officinalis* and *Molinia caerulea*. Among these high-growing perennials are *Galium uliginosum*, *Sanguisorba officinalis*, *Linum catharticum*, *Epipactis palustris* and mosses.

- Fallow communities (uncultivated fields)

Fallow communities occur mainly near the ZGH Bolesław smelter. Small areas of them are found north of Bolesław. Cereals and root crops were cultivated in the brown soil there up to the early 1980s (Szarek-Łukaszewska and Grodzińska 2011) (Fig. 5). Cultivation was abandoned due to high soil contamination with heavy metals coming mainly from emissions of zinc and lead smelters, which reached the highest levels in Poland at that time. Then various kinds of waste left from ore processing were stored there in places. Species-rich grassland communities have grown in the fallows that formed as a consequence of this and were left uncontrolled. They are distinguished by the constant presence of *Crepis biennis*, *Melandrium album*, *Valeriana officinalis* and many grassland species (*Leontodon hispidus*, *Achillea millefolium*, *Rumex thyrsiflorus*, *Daucus carota*, *Lotus corniculatus*, *Avenula pubescens*). Weeds and remnants of old crops grow in those communities as well (*Cirsium arvense*, *Conyza canadensis*, *Fallopia convolvulus*, *Veronica arvensis*, *Galeopsis bifida*). *Festuca ovina* also occurs but is less significant; sometimes this grass forms bigger or smaller patches of dense turf. In uncultivated fields *Pinus sylvetris* appears quite often, proliferating there from neighbouring woodlands and forests.

Forest communities and woodlands

- Forest communities similar to fresh pine forest

Forest communities similar to fresh pine forest occupy ca. 15% of the OOR (717 ha). In its northeastern and eastern parts they extend from Laski through Stary Olkusz and the eastern edge of the ZGH Bolesław tailings ponds, and further south they reach Bukowno, surrounding the town from the south and west. These forest communities adjoin typical fresh pine forests (Leucobryo-Pinetum association) and various types of woodland and grassland (Fig. 6). These are tree stands built mainly of pine (*Pinus sylvestris*) and birch (*Betula pendula*) of different ages ranging from young (up to 20 years) to over 40 years old, but mostly young (Figs 7 and 8). Canopy cover is therefore diverse, most often 60–90%. The shrub layer is poorly developed (cover 5–10%). The herb layer cover usually reaches 50–80%. *Festuca ovina* is a constant

Fig. 5. Grassland covering fallows on calamine soil (photo G. Szarek-Łukaszewska)
Ryc. 5. Murawa na nieużytkach porolnych na podłożu galmanowym (fot. G. Szarek-Łukaszewska)

species in the herb layer. In its tufts are species typical of grassland (e.g. *Cardaminopsis arenosa*, *Rumex thyrsiflorus*, *Galium album*, *Dianthus carthusianorum*, *Armeria maritima*, *Thymus pulegioides*, *T. serpyllum*, *Carex caryophyllea*, *Leontodon hispidus*) and forest species characteristic of coniferous forests (*Orthilia secunda*, *Moneses uniflora*, *Vaccinium myrtillus*). Noteworthy is the presence of orchids (*Epipactis helleborine*, *E. atrorubens*). Mosses are represented by *Brachythecium salebrosum*, *B. velutinum*, *Sciuro-hypnum edipodium* and *Campylium calcareum*; *Pleurozium schreberi* occurs where canopy cover is greater. The lichens include *Cladonia* (*Cladonia contorta*, *C. furfuracea*, *C. fimbriata*), *Scoliciosporum chlorococcum* and *Peltigera rufescens*.

- Different types of woodland, including woodland with dominance of *Molinia caerulea* in the herb layer

In the mosaic of communities in the central part of the OOR, woodlands occupy the largest area, ca. 6.5% of the OOR (310 ha). They have developed in areas degraded by mining and then afforested under reclamation schemes. Various tree and shrub species were used to reclaim this terrain, usually *Betula pendula* and *Pinus sylvestris*, less frequently *Larix decidua* and *Robinia pseudoacacia*, and only sporadically *Hippophaë rhamnoides* and *Eleagnus commutata* (Fig. 9). These plantations are seldom more than 20 years old (Fig. 8), reflecting their recent introduction in post-mining areas.

Fig. 6. Fresh pine forest (Leucobryo-Pinetum) on calamine soil (photo M. Jędrzejczyk-Korycińska)
Ryc. 6. Bór sosnowy świeży (Leucobryo-Pinetum) na podłożu galmanowym (fot. M. Jędrzejczyk-Korycińska)

The woodlands form patches of different sizes, ages and species compositions. Interestingly, in less dense plantations, both younger and decades-old ones, the core herb layer species are those of warm and dry habitats, among them species that are frequent or even characteristic of calamine grasslands (e.g. *Thymus pulegioides*, *Galium album*, *Pimpinella saxifraga*, *Festuca ovina*, *Anthyllis vulneraria*, *Biscutella laevigata*, *Armeria maritima*, *Helianthemum nummularium*). They are quite often accompanied by typical forest species characteristic of coniferous forests (*Orthilia secunda*, *Moneses uniflora*, *Vaccinium myrtillus*). In some patches (probably places where rich soil was brought in during recultivation) *Molinia caerulea* is frequent. Bare sites are occupied by lichens, most often *Verrucaria muralis*, *Vezdaea stipitata*, *Bacidina phacodes*, *Bacidia bagglietoana* and *Sarcosagium campestre*.

- Woodland with a share of trees typical of wet habitats

In a small area between Bolesław and the tailings ponds are wet habitats where a tree layer has developed (ca. 21 ha, 0.4% of the OOR). It is built of *Alnus glutinosa*, *Fraxinus excelsior*, *Populus tremula*, *Betula pendula* and *Robinia pseudoacacia*. The trees form young tree stands several metres high and currently not very dense. Tufty grasses, mostly *Deschampsia caespitosa*, *Calamagrostis epigejos* and *Molinia caerulea*, dominate in the herb layer, accompanied by *Lysimachia vulgaris*,

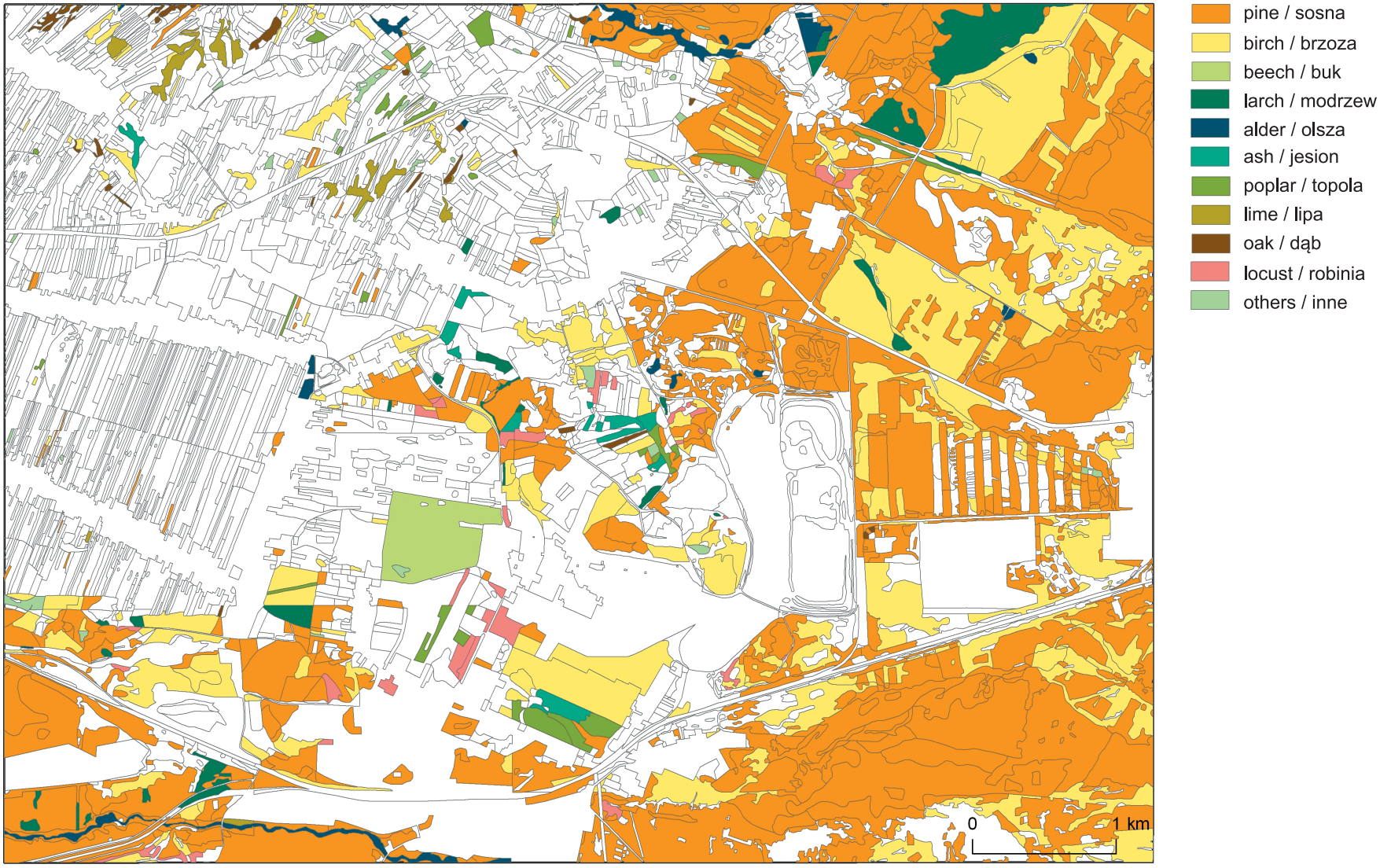

Fig. 7. The dominant tree species in the Olkusz Ore-bearing Region
Ryc. 7. Dominujące gatunki drzew w Olkuskim Okręgu Rudnym

Fig. 8. Age of the tree stands in the Olkusz Ore-bearing Region
Ryc. 8. Wiek drzewostanów w Olkuskim Okręgu Rudnym

Eupatorium cannabinum, and more rarely *Filipendula ulmaria*, *Valeriana sambucifolia* and *Solidago canadensis*.

Plant communities associated with non-calamine soil

Non-forest communities

Various plant communities associated with habitats differing on soil fertility and soil humidity have developed on soil without calamine: grassland formed on sandy soils (psammophilous, Koelerio-Corynephoretea class), heathland, *Nardus stricta* grassland of the Nardo-Callunetea class associated with acid soils, and xerothermic grassland of the Festuco-Brometea class occurring on fertile and calcium carbonate-rich soils. Pasture and meadow communities of the Molinio-Arrhenatheretea class are important elements of the OOR vegetation. High richness has been recorded in pastures with *Cynosurus cristatus* (Cynosurion alliance, Arrhenatheretalia order) and *Arrhenatherum elatius* meadows in fresh habitats (Arrhenatherion elatioris alliance, Arrhenatheretalia order), *Molinia caerulea* meadows (meadows of intermittently wet habitats) with *Iris sibirica* (Molinion caeruleae alliance, Molinietalia order), wet meadows with *Caltha* sp. (Calthion palustris alliance, Molinietalia order) and tall forb meadows with *Filipendula ulmaria* (Filipendulion ulmariae alliance, Molinietalia order). In bog habitats, rush communities of the Phragmitetea class with *Phragmites australis* (Phragmition alliance) and tall-growing sedges (Magnocaricion alliance) occur. Fens of the Scheuchzerio-Caricetea nigrae class develop in permanently waterlogged sites. Agricultural wasteland communities have formed in places previously cultivated. Former balks and older fallows have scrub with dominant *Prunus spinosa* (Pruno-Rubion fruticosae alliance, Rhamno-Prunetea class). Nitrophilous vegetation of the Artemisietea, Bidentetea tripartite and Galio-Urticenea classes and the Plantaginetalia maioris order and Molinio-Arrhenatheretea class has appeared in areas near transport routes, waste heaps and buildings.

- Psammophilous grassland

The poor sandy soils in which psammophilous grasslands develop are located predominantly in the eastern and southern parts of the OOR, east of Bolesław and Bukowno and west of Bukowno. They increase the diversity of extensive areas of coniferous and birch forests, forming small islands of non-forest vegetation, and in some places they occupy sizeable areas covering even dozens of hectares. Such a case is the Pustynia Starczynowska desert, where despite many years of effort the staff of the Olkusz Forest District have not yet succeeded in creating compact vegetation cover over a large area. A second aggregation of psammophilous grasslands is east of Hutki town and the main pithead of the *Pomorzany* mine. There is a large area of sparsely vegetated sand west of Bukowno, extending on either side of the railway line to Katowice. Altogether the psammophilous grasslands occupy 166 ha, 3.4% of the whole area.

Two types of psammophilous grassland have been recognised in the OOR. Very low herb cover is typical of psammophilous grassland developing on the poorest sandy soils. Grasses with narrow blades dominate there, the most frequent of them being *Corynephorus canescens*, *Festuca ovina* and *Koeleria glauca*. These plants are accompanied by other species, among which *Scleranthus perennis*, *Jasione montana*, *Hieracium pilosella*, *Trifolium arvense*, *Thymus serpyllum*, *Herniaria glabra* and *Rumex acetosella* are the most frequent ones in the environs of Bukowno and Bolesław. At more fertile sites, floristically richer, more compact

Fig. 9. *Betula pendula* woodland on calamine soil (photo G. Szarek-Łukaszewska)

Ryc. 9. Zadrzewienia brzozowe z *Betula pendula* na podłożu galmanowym (fot. G. Szarek-Łukaszewska)

grasslands have formed with a share of colourfully flowering species such as *Dianthus deltoides* and *Armeria maritima*, and even the meadow plants *Leucanthemum vulgare*, *Lotus corniculatus* and *Leontodon hispidus*, as well as species of xerothermic grassland and thermophilous margins, such as *Carex caryophyllea*, *Phleum phleoides*, *Anthyllis vulneraria* and *Coronilla varia*.

The occurrence of psammophilous grassland depends on a couple of factors. These communities are often met on slopes with shifting loose sand which is unfavourable for plant growth. They also form as a result of frequent fires which destroy litter and plants on dry sandy soil. This is an opportunity for plant succession to begin, the first stage of which is psammophilous grassland. These communities occur at many sand quarries. A factor in their maintenance is the use of sandy terrain by off-road vehicle enthusiasts. While destroying compact plant cover it creates conditions for the growth of plant pioneers typical of psammophilous grassland.

These communities are common in Poland but they are gradually disappearing, as areas with poor soils are less intensively used and are becoming afforested. In the OOR these grasslands are among the interesting elements of vegetation and are not endangered because there are many sand quarries and sites used by off-road vehicles.

- *Nardus stricta* grassland and heathland

Plant communities in which *Calluna vulgaris* or *Nardus stricta* dominate develop

most often on sandy soils that are more fertile than those with psammophilous grassland. Accompanying those two dominant species are *Hypericum maculatum*, *Hieracium pilosella*, *Solidago virgaurea* and *Hypochoeris radicata*. Heathlands and *Nardus stricta* grasslands occupy a tiny area of only 2.2 ha, less than 0.1% of the total area. Small patches are scattered along the railway line from Bukowno to Olkusz. This type of grassland does not play a significant role in the vegetation cover of the OOR.

- Xerothermic grassland

Plant communities resembling xerothermic grassland, that is, thermophilous communities characteristic of steppe, have formed on fertile calcareous substrate where rendzina soils develop, on sunny and south-facing slopes, as well as at limestone quarries. The dominant grass species there are accompanied by a diverse group of plants with large, colourful flowers or inflorescenses. The grasslands owe their grassy character mainly to *Brachypodium pinnatum*. The colourfully flowering species include *Geranium sanguineum*, *Anthericum ramosum*, *Euphorbia cyparissias*, *Filipendula vulgaris*, *Helianthemum nummularium*, *Centaurea scabiosa*, *Prunella grandiflora*, *Dianthus carthusianorum*, *Sanguisorba minor*, *Carex caryophyllea*, *Seseli annuum* and *Thesium linophyllon*. *Peucedanum oreoselinum* occurs more abundantly on woodland margins near meadows or scrub. Xerothermic grasslands cover 40 ha. The biggest patch, over 8 ha, is in Ujków Stary, and the second-biggest is south of Podlipie on the gentle southern slopes of a hill located in Sołtysie (part of Podlipie village). Xerothermic grassland is among the rarest and most endangered types of vegetation in Poland and for that reason merits special protection wherever it occurs.

- Fresh meadows and pastures

Fresh meadow communities classified as the Arrhenatherion elatioris alliance develop on moderately wet fertile soils (Fig. 10). Only a few of these meadows are repeatedly mown every year; most are used and mown once a year or are not mown any longer. In their floristic composition many fresh meadow species have been recorded, including *Arrhenatherum elatius*, *Campanula patula*, *Crepis biennis*, *Knautia arvensis*, *Pastinaca sativa*, *Rumex thyrsiflorus* and *Tragopogon pratensis*. Other species such as *Leontodon hispidus*, *Lotus corniculatus*, *Vicia cracca*, *Leucanthemum vulgare*, *Trifolium montanum*, *Plantago lanceolata* and *Molinia caerulea* are also frequent. At drier sites a species typical of xerothermic grassland, *Brachypodium pinnatum*, can be found. *Colchicum autumnale* flowers in autumn in some meadows. The fresh meadows cover 355 ha and account for over 7% of the total area. Most of them are in the northwestern agricultural part, in the vicinity of Podlipie, Małobądz, Krzykawa and Kolonia, where they occupy as much as 25% of the area.

- *Molinia caerulea* meadows (meadows of intermittently wet habitats)

These meadows occur in wet habitats, especially during springtime. These are very species-rich meadows. Due to limitation of mowing over recent years it has become Poland's rarest vegetation type and is threatened with disappearance. Species such as *Selinum carvifolia*, *Sanguisorba officinalis*, *Gladiolus imbricatus*, *Iris sibirica*, *Succisa pratensis*, *Serratula tinctoria*, *Silaum silaus*, *Galium boreale*, *Carex tomentosa*, *Betonica officinalis*, *Alchemilla glabra* and *Molinia caerulea* form its floristic composition. At wetter sites the sedges *Carex davalliana*, *Carex panicea* and *Carex nigra* occur as well. The protected orchids *Dactylorhiza incarnata* and *D. majalis* are also found there.

Fig. 10. Fresh meadow of the Arrhenatheretalia order (photo M. Jędrzejczyk-Korycińska and T. Nowak)
Ryc. 10. Łąka świeża z rzędu Arrhenatheretalia (fot. M. Jędrzejczyk-Korycińska i T. Nowak)

Molinia caerulea meadows occur in depressions and river valleys and occupy a small area of ca. 11 ha in the OOR. They are found southwest of Hutki town and a large patch is located in Bolesław.

- Wet meadows

The environs of Bolesław and Bukowno have several types of wet meadow. These are associations belonging to the Calthion palustris alliance: Angelico-Cirsietum oleracei, Cirsietum rivularis and Scirpetum silvatici. The biggest areas are occupied by phytocoenoses with *Cirsium rivulare* (Fig. 11). The wet meadow phytocoenoses include *Cirsium palustre*, *Equisetum palustre*, *Valeriana officinalis*, *Caltha palustris* and *Galium uliginosum*, as well as species typical of rush communities, such as *Galium palustre* and *Equisetum fluviatilis*. *Polygonum bistorta* appears in some places, and *Deschampsia caespitosa* occurs very abundantly in some patches.

The wet meadows cover slightly more than 100 ha, ca. 2% of the total area. There is a large complex of wet meadows in the valley of the stream flowing between Bolesław and Podlipie. Smaller fragments are scattered along the *Ponikowska* adit and the Kanał Dąbrówka channel near Kolonia and Laski.

- Tall forb meadows

Because *Molinia caerulea* meadows (meadows of intermittently wet habitats) are not mown any longer, in some places there are species-poorer communities with dominant *Filipendula ulmaria* (and occasionally *Lysimachia*

vulgaris and *Valeriana officinalis*). As a result of ongoing succession processes, species such as *Aegopodium podagraria*, *Carex acutiformis*, *Chaerophyllum aromaticum*, *Bromus inermis*, *Calamagrostis epigejos* and *Solidago canadensis* are spreading intensively there. Tall forb meadows occupy only 5 ha, mainly in the environs of Laski, Kolonia and Hutki in the northern part of the studied area.

- Fens

Peatland communities of the Scheuchzerio-Caricetea nigrae class are extremely valuable. Plants typical of fens occur there, including *Carex nigra*, *Comarum palustre*, *Eriophorum angustifolium* and *Valeriana simplicifolia*, along with species associated with calciphilous peatlands of the Caricion davallianae alliance (*Carex davalliana*, *Epipactis palustris*, *Eriophorum latifolium*, *Parnassia palustris*). Plants of wet meadows (e.g. *Caltha palustris*, *Cirsium oleraceum*, *C. palustris*, *C. rivulare*, *Dactylorhiza incarnata*, *D. majalis*, *Filipendula ulmaria*, *Lotus uliginosus*, *Lysimachia vulgaris*, *Molinia caerulea*, *Sanguisorba officinalis*) also play an important role. Fens form on waterlogged terrain where decomposition of organic matter is limited and it accumulates as peat. Peatlands occupy 5.5 ha in the OOR (0.1% of the total area), most often in areas of wet meadow of the Molinietalia order. Several fen patches, the biggest one covering 1.4 ha, were noted in the valley of a small stream north of Krzykawa. Another fen occupying more than a hectare is in Krążek.

Fig. 11. Wet meadow of the Calthion alliance with *Cirsium rivulare* (photo M. Jędrzejczyk-Korycińska and T. Nowak)

Ryc. 11. Wilgotna łąka ze związku Calthion z ostrożniem łąkowym (*Cirsium rivulare*) (fot. M. Jędrzejczyk-Korycińska i T. Nowak)

• Rush communities

The rush communities in the study area are of marginal importance. They appear mainly in watercourse valleys, depressions, or near natural and artificial reservoirs (Fig. 12). The communities do not occupy large areas – altogether 24.5 ha (0.5% of the OOR). The biggest complexes of rush communities occur around the *Ponikowska* adit in the vicinity of Kolonia town north of Bolesław and in the western part of Bukowno, called Cyzowizna. The rush community with *Phragmites australis* (reed rush) occurs most often. Much less frequent are rush communities with *Typha angustifolia* (reed-mace rush) and sedge rushes with *Carex gracilis* and *C. acutiformis*. Apart from the dominant species there are other plants typical of wet meadows (e.g. *Angelica sylvestris*, *Deschampsia caespitosa*, *Filipendula ulmaria*, *Lysimachia vulgaris*, *Lythrum salicaria*, *Scirpus sylvaticus*).

• Uncultivated fields (fallows)

Agriculture has played a large role in the development of OOR vegetation. Agricultural landscape dominates west of Bukowno and Bolesław. Extensive fields cultivated until recently form a continuous strip from Skotnica in the south to Małobądz, Krzykawa and Krzykawka in the north. Fallows cover a much larger area than cultivated fields, reflecting the disappearance of agriculture. Fallows currently occupy 410 ha as against only 180 ha of cultivated fields.

The floristic composition of phytocoenoses formed in previously cultivated fields greatly depends on the time elapsed since cessation of cultivation (Fig. 13). Segetal weeds of the

Fig. 12. Rush community with *Phragmites australis* (photo M. Jędrzejczyk-Korycińska)
Ryc. 12. Szuwary z trzciną pospolitą (*Phragmites australis*) (fot. M. Jędrzejczyk-Korycińska)

Fig. 13. Fallows (photo M. Jędrzejczyk-Korycińska and T. Nowak)
Ryc. 13. Nieużytki porolne (fot. M. Jędrzejczyk-Korycińska i T. Nowak)

Stellarietea mediae class (e.g. *Papaver rhoeas*, *Centaurea cyanus*, *Agrostemma githago*, *Myosotis arvensis*, *Matricaria maritima* subsp. *inodora*, *Veronica persica*, *Apera spica-venti*, *Polygonum persicaria*, *Melandrium album*, *Conyza canadensis*, *Galinsoga ciliata*) play an important role in younger fallows. These species are remnants of previously cultivated cereal and root crops. Of course the occurrence of particular species depends on which crops were cultivated previously there.

Communities representing the Agropyretea intermedio-repentis class form in older fallows. They are built mainly of rhizomic and stolonate plants, often dominated by *Elymus repens*, *Bromus inermis*, *Carex hirta* or *Calamagrostis epigejos*. These species spread rapidly and form large patches which encroach on adjoining fields. Also present in older fallows are ruderal species (e.g. *Artemisia vulgaris*, *Cirsium arvense*, *Eupatorium cannabinum*) and meadow species (*Arrhenatherum elatius*, *Festuca pratensis*, *Rumex acetosa*, *Avenula pubescens*, *Leontodon hispidus*, *Dactylis glomerata*, *Phleum pratense*, *Crepis biennis*, *Pastinaca sativa*). At drier sites, *Agrostis capillaris* and *Armeria maritima* and occasionally even species of xerothermic grassland (*Ononis arvensis*, *Centaurea scabiosa*) occur. *Rubus caesius* is dominant in some patches, and *Pteridium aquilinum* penetrates others. *Solidago canadensis* has occupied the oldest fallows and often has formed large, almost monotypic aggregations.

- Ruderal communities

Ruderal vegetation does not play a significant role in the OOR. Patches of it are found chiefly in industrial areas near buildings and fences, along roads, and on lawns and railway land, where it does not occupy large areas.

A bigger patch has developed on freshly brought soil at the top of tailings heaps. Communities of the Onopordion acanthii alliance (Echio-Melilotetum, Artemisio-Tanacetetum, Dauco-Picridetum) develop on dry and not very fertile soils. Phytocoenoses of Poo-Tussilaginetum form at open sites with freshly dug, often clayey soil. In sandy habitats there are patches with *Berteroa incana*. Exceptionally rare there are nitrophilous communities, which include *Urtica dioica*, *Aegopodium podagraria*, *Arctium tomentosum* and *Chaerophyllum aromaticum*. On trodden sites (roadsides, lawns) there are patches with *Lolium perenne* and *Plantago maior*. Patches with *Puccinellia distans*, *Lolium perenne*, *Atriplex prostrata*, *A. patula*, *Trifolium repens*, *Lactuca serriola* and *Bidens frondosa* occupy small areas. Ruderal vegetation covers ca. 80 ha, 1.6% of the total area. Patches of it occur over the whole area, the largest in the central part of the OOR between Bukowno and Bolesław, where reclamation work conducive to its growth takes place.

- Scrub within arable fields

On the agricultural landscape, especially in old balks, scrub of the Rhamno-Prunetea class develops. The most common is scrub with *Prunus spinosa* and *Crataegus monogyna*. Sometimes *Rhamnus cathartica*, *Rosa canina*, *Sambucus nigra* and *Cornus sanguinea* are part of its composition. On south-facing slopes of hills, more thermophilous scrub with *Rhamnus cathartica* and *Cornus sanguinea* occurs, and in places with *Ligustrum vulgare*. Scrub with *Corylus avellana* and *Euonymus verrucosa* occurs there as well. The herb layer in all types of scrub is poorly developed due to the high shrub cover and shading. Most often the herb layer has species penetrating from adjacent phytocoenoses: plants of xerothermic grassland and of meadows, and synanthropic species. In the balks, scrub of *Lycium barbarum*, *Sambucus ebulus* and plantations of *Hippophaë rhamnoides* occur only sporadically. Nitrophilous scrub with *Sambucus nigra* develops along roads or near buildings. Nitrophilous species (*Aegopodium podagraria*, *Chaerophyllum aromaticum*, *Urtica dioica*) appear in its herb layer. Scrub within arable fields occupies only 19 ha but due to abandonment of fields it is forming quite large aggregations of shrubs and low trees in places. This is the case in, for example, the abandoned fields of the former village of Stara Wieś.

Forest communities and woodland

Forests are dominant in the eastern and southern parts of the Olkusz Ore-bearing Region. The dominant community associated with the poor sandy soils there is fresh pine forest. Three other types of pine forest – wet, bog and mixed, growing in similar soils – occupy much smaller areas. Forests growing on nutrient-rich soils – oak-lime-hornbeam forests, floodplain forests and alder swamps (alder carrs) – are much less common. In the environs of Bolesław and Bukowno are fertile habitats where such forests develop. The present distribution of forest vegetation has been shaped largely by agriculture encroaching on these habitats, changing oak-lime-hornbeam forests to cultivated fields and changing wet floodplain forests and alder swamps to mown meadows.

- Fresh pine forest

Fresh pine forest develops on poor sandy soils of moderate humidity. Its tree stand is formed mainly of pine, accompanied in places by *Betula pendula*. Under the tree stand is a very species-poor herb layer, usually consisting of two grasses (*Deschampsia flexuosa*, *Festuca ovina*), three dwarf shrubs (*Vaccinium myrtillus*, *V. vitis-idaea*, *Calluna vulgaris*) and a few species including two wintergreens (*Orthilia*

secunda, *Pyrola chlorantha*), *Chimophila umbellata* and *Melampyrum pratense* (Fig. 14). *Lycopodium complanatum* is extremely rare in pine forests, met in only a few stands.

Fresh pine forest occupies 730 ha, 15.2% of the OOR. It develops chiefly on poor sands of the Pustynia Starczynowska desert and adjacent areas north of it, as well as east of Hutki town. The pine forest tree stand most often is young, and rarely older than 40 years (Fig. 8). The biggest fragments of the oldest pine stands are in the southern part, north of the Pustynia Starczynowska desert, on both sides of the Sztoła river valley, and in the eastern part between Hutki and the Pomorzany District of Olkusz. Some single trees are over 100 years old but most are up to 60 years old. The young age of the pine trees is due in part to forest management but the more important factor is the frequent fires which destroy tree stands.

- Wet pine forest

Patches of wet pine forest occupy wetter but still poor sandy soils. This is a type of coniferous forest in which pine is the dominant tree, accompanied by *Betula pendula* and in places *B. pubescens*. *Frangula alnus* is a frequent species in the shrub layer. *Molinia caerulea* occurs abundantly in the herb layer, accompanied by other grasses: *Deschampsia flexuosa* and very rarely *Festuca ovina*, which is otherwise common in fresh pine forest. Two *Vaccinium* species grow there (*V. myrtillus*, *V. vitis-idaea*), and at a few sites also *V. uliginosum*. *Calluna vulgaris* and *Orthilia secunda* are frequent. Due to higher moisture the soil is slightly more fertile than in fresh pine forest, enabling species such as *Lysimachia vulgaris*, *Equisetum sylvaticum* and *Maianthemum bifolium* to grow there.

Fig. 14. Fresh pine forest (Leucobryo-Pinetum) on sandy soil (photo M. Jędrzejczyk-Korycińska and T. Nowak)
Ryc. 14. Bór sosnowy świeży Leucobryo-Pinetum na podłożu piaszczystym (fot. M. Jędrzejczyk-Korycińska i T. Nowak)

The biggest patches of wet pine forest are north of Hutki town, where they occupy small hollows scattered within fresh pine forest. Wet pine forest covers only 38 ha, less than 1% of the study area and 20 times less than the cover of fresh pine forest.

- Bog pine forest

Bog pine forest was found at only one site, southwest of Karna hamlet, where it occupies a small hollow only 30 ars in area. Under the pine tree stand a dense carpet of peat moss has developed, on which clumps of two dwarf shrubs characteristic of this coniferous forest are distinguished (*Vaccinium uliginosum*, *Ledum palustre*) as well as *Eriophorum vaginatum*, typical of peat bogs. Several species typical of marsh habitats also occur: *Galium palustre*, *Peucedanum palustre* and *Carex nigra*.

- Mixed pine forest

In some forest fragments where the tree stand is dominated by pine there are, besides the plants common in pine forests, species typical of forests developing in more fertile habitats. They grow at sites where the soil fertility is intermediate between the poor soils of pine forests and the nutrient-rich soils of deciduous forests. In places it is difficult to distinguish patches that developed naturally in such moderate conditions from those growing on soil that was initially fertile but then was degraded due to felling of deciduous trees and pine many years ago.

Pine dominates the tree stand of mixed pine forest. *Quercus robur* appears in small numbers. The shrub layer is richer than in the pine forests, in that *Frangula alnus*, *Sorbus aucuparia* and the North American *Padus serotina* were recorded. Frequent in the herb layer are *Vaccinium* species (*V. myrtillus*, *V. vitis-idaea*) and other plants of coniferous forest (*Trientalis europaea*, *Chimaphila umbellata*, *Orthilia secunda*). The presence of species such as *Maianthemum bifolium*, *Luzula pilosa*, *Mycelis muralis*, *Oxalis acetosella*, and *Athyrium filix femina*, and especially plants typical of deciduous forest (*Polygonatum verticillatum*, *Melica nutans*, *Carex pilosa*, *Anemone nemorosa*) reflects higher habitat fertility.

Mixed pine forests cover 27 ha in the north and south of the study area: north of the highway between Kolonia and Hutki and in the valley of the Sztoła river. In the first of these localities they are located between pine forests and wet meadows, and in the latter between pine forests and floodplain forests. In both cases they occupy sites intermediate between poor habitats of pine forest and nutrient-rich habitats of floodplain forest or wet meadows; the latter have occupied habitats of felled floodplain forests.

- Oak-lime-hornbeam forest and secondary forest communities in habitat of oak-lime-hornbeam forest

Deciduous forests associated with fertile and moderately wet habitats covered most of the land around Bolesław in the past. They were felled ages ago and replaced by agricultural fields. Now only small fragments of oak-lime-hornbeam forest are left, only a few hectares in area, located in the northern part of the region west of Hutki and between Kolonia, Laski and Krzykawka. There are more such forests, covering over 100 ha, which formed after planting of pine in habitat of oak-lime-hornbeam forest. The biggest fragment of such oak-lime-hornbeam-like forest, covering several tens of hectares, is located within the city limits of Olkusz around a quarry where dolomite was once excavated. A fairly large woodland which is becoming more and more similar to oak-lime-hornbeam forest has developed in the town of Bukowno-Tłukienka.

In the best-preserved oak-lime-hornbeam forests the tree stand is formed mainly by

Carpinus betulus, *Quercus robur* and *Tilia cordata*, accompanied in low numbers by *Fagus sylvatica*, *Betula pendula* and *Populus tremula*, and also by planted *Pinus sylvestris* in some places. *Padus avium*, *Corylus avellana*, *Sorbus aucuparia* and *Frangula alnus* grow in the shrub layer. *Lilium martagon*, *Convallaria majalis*, *Anemone nemorosa*, *Viola reichenbachiana*, *Hepatica nobilis* and *Paris quadrifolia* occur in the species-rich herb layer.

In secondary communities in habitat of oak-lime-hornbeam forest the dominant tree usually is *Pinus sylvestris*, which was planted there. Other planted species typically grow together with pine, such as *Robinia pseudoacacia* or oaks – the native *Quercus robur* and the North American *Quercus rubra*. Trees that have spontaneously grown in the pine stands also occur: *Betula pendula*, *Populus tremula*, *Fagus sylvatica*, *Tilia cordata*, *Alnus glutinosa*, *Fraxinus excelsior*, *Acer platanoides*, *Acer pseudoplatanus* and *Ulmus glabra*. Usually these forests have a well-developed shrub layer with young trees and shrubs: *Sambucus nigra*, *Euonymus europaea*, *Viburnum opulus*, *Padus avium*, *P. serotina* and *Rhamnus cathartica*. In the herb layer of secondary forests there are several species that mark oak-lime-hornbeam forest habitat: *Melica nutans*, *Polygonatum odoratum*, *Convallaria majalis* and *Dryopteris filix-mas*. Besides these plants typical of oak-lime-hornbeam forest there are many species that grow only temporarily in forests under economic pressure or in habitats where a forest is in its initial stage of succession. They use spaces not yet occupied by typical forest species. Among them are nitrophilous species that use the rich nutrient resources of the soil, such as *Urtica dioica*, *Eupatorium cannabinum*, *Chaerophyllum aromaticum* and *Chelidonium majus*. There are also common meadow species: *Ranunculus acris*, *Veronica chamaedrys*, *Agrostis capillaris*, *Achillea millefolium*, *Dactylis glomerata* and *Arrhenatherum elatius*. Finally, there is also a large group of species associated with impermanent habitats that are often disturbed in various ways, such as the annuals *Cardaminopsis arenosa* and *Galeopsis bifida* and the pioneers *Tussilago farfara* and *Equisetum arvense*.

- Floodplain forest and secondary forest communities in habitat of floodplain forest

The fertile, wet habitats in the river and stream valleys are suitable for the development of alluvial forests. On the agricultural landscape they were converted to wet meadows to serve as one of the most important sources of pasture for animals. In the environs of Bolesław and Bukowno there are a few sites where floodplain forests could develop. The biggest river of this area, the Sztoła, flows through a narrow, deep valley cut in sandy soil where there is not much room for floodplain forest. The biggest areas of floodplain forest, together covering more than 20 ha, are in the north along the *Ponikowska* adit in a section several hundred metres long between Hutki and Laski. Alder floodplain forest has persisted there, with a sturdy tree stand composed of *Alnus glutinosa* and *Fraxinus excelsior* and a shrub layer built mainly of *Padus avium*. In the herb layer of this forest are a number of species typical of floodplain forest: *Carex paniculata* forming large clumps, *C. gracilis* occurring abundantly, and also *Phragmites australis*, *Caltha palustris*, *Cirsium palustre*, *Valeriana simplicifolia*, *Geum rivale* and *Peucedanum palustre*.

- Alder swamp (alder carr) and grey willow scrub

Bog alder forest (alder swamp, alder carr) occupies only 1 ha. Patches of it develop in a few small hollows north of the valley of the *Ponikowska* adit west of Górka hamlet. The tree stand of alder swamp is built of *Alnus glutinosa* and *Betula pubescens*. In the shrub layer of this forest are the willows *Salix aurita*

and *Salix cinerea* as well as *Frangula alnus*. The herb layer contains species typical of alder carr (*Comarum palustre*, *Menyanthes trifoliata*, *Lysimachia thyrsiflora*, *Solanum dulcamara*) as well as *Phragmites australis*, *Peucedanum palustre* and *Typha latifolia*.

Grey willow scrub occurs in only one depression a few thousand square metres in size north of the valley of the *Ponikowska* adit near Cegielnia hamlet. This is a scrub community with no tree layer; instead there is an abundantly developed shrub layer composed of *Salix pentandra*, *S. aurita* and *S. cinerea*. The herb layer resembles that met in alder carr.

- Woodland in uncultivated fields (fallows)

Quite a large part of the agricultural fields abandoned in the past is now overgrown by trees up to 10 or 15 years old, some much younger. Seedlings of light-seeded trees, mainly *Betula pendula*, *Populus tremula*, *Salix caprea* and *Pinus sylvestris*, appear after some time in fallows, especially near forests or scrub. Pine and larch trees have been planted in some fallows. Such woodlands occupy nearly 60 ha at present and their area is increasing from year to year. Under the trees the same species occur as in young fallows, and as time passes and the tree canopy closes the first forest herbs appear. In such conditions the occurrence of *Vaccinium myrtillus*, *Pteridium aquilinum* and two wintergreens (*Pirola minor*, *Orthilia secunda*) has been noted.

- Woodland in ruderal habitats

Trees have already grown in parts of ruderal habitats despite the significant changes such sites undergo. Most often *Betula pendula* develops spontaneously in such conditions. Ruderal habitats are recultivated as well, with many tree species being planted there: *Betula pendula*, *Pinus sylvetris*, *Quercus robur*, *Larix decidua*, *Alnus glutinosa*, *Robinia pseudoacacia* and *Acer negundo*. The herb layer plants in these plantations are the same as in ruderal communities without a tree layer.

The natural assets of the Olkusz Ore-bearing Region

We used the botanical study and the vegetation map to make an evaluation of the natural assets of the OOR and to distinguish the most valuable areas (Fig. 15).

The grassland vegetation developing in calamine habitats is assigned the highest value because it is unique for Poland and for Europe. Very rare taxa are present in its species composition. The highest value was also assigned to the vegetation of thermophilous grasslands associated with a few dolomite hills, and to the plant communities developing in wet, waterlogged and boggy habitats. The latter are tall forb meadows, wet meadows, *Molinia caerulea* meadows, fens and rushes, as well as patches of bog pine forest, floodplain forest, alder swamp and grey willow scrub. All of those are among the rarest plant communities in the vegetation of Poland. In their species composition are taxa endangered on the national scale.

Areas classified as most valuable occupy 9% of the OOR. The grasslands are located mainly in the central part between Bukowno and Bolesław, where the landscape generally is deformed by past mining activity. The patches of plant communities of wet, waterlogged and boggy habitats occur north and west of Bolesław; they are associated with the valley of the *Ponikowska* adit in hollows among fields. There are far fewer wet habitats in the south. They occur along the Sztoła river and in the valley of Sztolnia stream.

We assigned moderate value to the fresh pine forests, wet pine forests and mixed pine forests in the OOR with tree stands at least

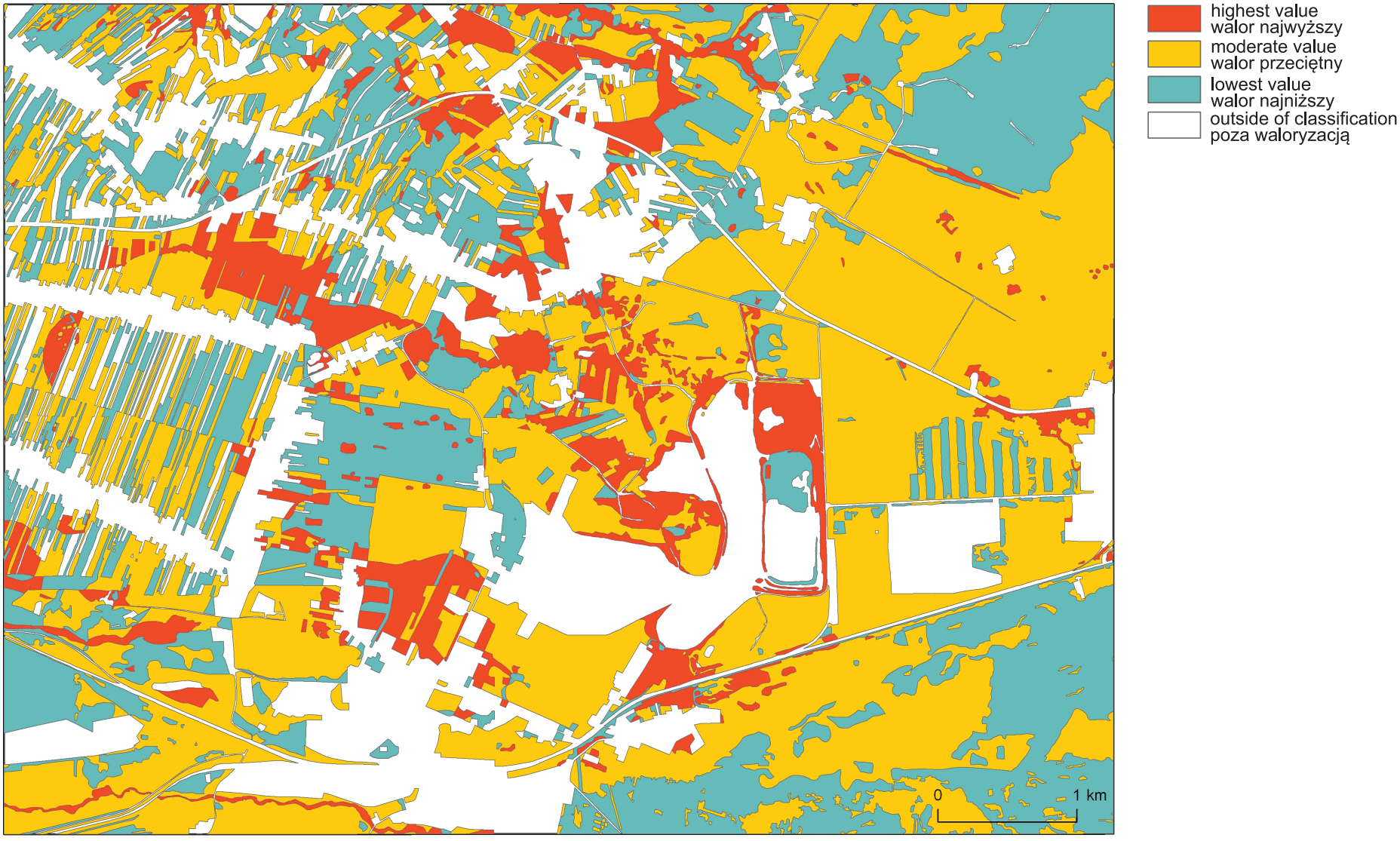

Fig. 15. Valorisation of the vegetation of the Olkusz Ore-bearing Region

Ryc. 15. Waloryzacja przyrodnicza roślinności Olkuskiego Okręgu Rudnego

40 years old. Also of moderate value, as communities that maintain the richness of the local flora, are oak-lime-hornbeam forests, psammophilous grasslands, heathlands, pastures and fresh meadows. Vegetation patches on calamine soil where tree stands have been planted, with the result that some rare species have disappeared, also fall into this category. Vegetation of moderate value covers the largest area of the OOR, 41%. It is scattered through the whole area but mostly east of Bolesław and Bukowno.

The lowest value was assigned to pine forest communities with tree stands younger than 40 years, cultivated fields, the vegetation of fallows and ruderal vegetation, as they do not contain valuable elements of the flora. They occupy 24% of the OOR, on its periphery in the northeastern and southeastern parts. The largest areas in this category are covered by coniferous forest vegetation with young pine and birch tree stands. In the western part the types in this category are mainly cultivated fields and fallows.

Outside of this classification are sand quarries, built-up and industrial terrain, as well as areas temporarily devoid of vegetation due to the type of land use. Altogether they occupy 25% of the OOR.

Conclusions

The diverse vegetation of the Olkusz Ore-bearing Region includes valuable communities such as those of calamine grasslands not found elsewhere in Poland, and also more frequent communities of lower value. The former are at least partially of natural origin, and the latter are associated mainly with different forms of human activity.

Zinc-lead ore mining and processing, sand and rock quarrying, agriculture and forestry are all taking place today in the OOR, a relatively small area of Poland. Centuries of mining have drastically altered the area's vegetation. Mining has expanded the areas of metalliferous (calamine) habitats which previously existed naturally in the OOR. Unique calamine grassland communities have formed spontaneously, without human intervention, on post-mining waste containing residue of ore.

Mining work has lowered the water table in the OOR and areas far from it. This has led to the disappearance of waterlogged and wet habitats of high value. They used to cover much larger areas than at present. Mining has also altered the use of arable land. Field cultivation has been limited, and meadow mowing and fertilising has ceased in many areas. The result is a mosaic of small vegetation patches of field crops, younger and older fallows, and sodded meadows with botanically valuable species, often protected ones, as well as invasive alien or expansive native species.

Forestry and afforestation done in the course of reclaiming mining and smelting waste heaps and also outcrops left from ore or sand excavation have contributed to unification of the vegetation in nearly half the OOR. Fresh pine forests and woodlands resembling them dominate those places.

Ruderal vegetation has expanded with the increase of construction of industrial infrastructure, roads and housing estates.

The values of the Olkusz Ore-bearing Region are manifold – natural, cultural and scientific. Our study characterised the natural values of its vegetation. Culturally the area contains a record of centuries of zinc-lead mining and the accompanying civilisation. Scientifically the area is a field laboratory for many kinds of research, especially the calamine grasslands and the remaining patches of wet meadows. These values should be taken into account in planning land use in the OOR.

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