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XEROPHYTISATION OF MARSH FORESTS IN THE VICINITY OF AN OPEN PIT BROWN COAL MINE IN CENTRAL POLAND

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Abstract

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The article presents a portion of results obtained during monitoring of bog alder forest ecosystems *Ribeso nigri-Alnetum* S o l.-G ó rn. (1975)1987 (=*Carici elongatae-Alnetum typicum* K o c h 1926) which undergo transformations as a result of water drainage in the vicinity of the open pit brown coal mine Bełchatów taking place since 1975. The most common symptom of forest community degeneration in the drained habitats is xerophytisation, i.e. the replacement of hygrophilous plant species by mesophilous or even xerophilous species. Xerophytisation of hygrophilous communities results directly in their regression.

Key words: dynamics of forest communities, habitat drainage, forest xerophytisation, *Ribeso nigri-Alnetum*, Bełchatów Brown Coal Mine

Introduction

Anthropogenic transformations of the plant cover have been the subject of studies by numerous geobotanists and ecologists (Tüxen, 1966; Sukopp, 1969; Kornaś, 1972, 1981; Faliński, 1966, 1986, and others; Olaczek, 1972, 1974, 1982; Ellenberg, 1982; Holzner et al., 1983; Ozenda, 1986; Korpel, 1989; Bengtsson et al., 2000; Walker, Moral, 2003; and others). These studies strive to achieve a full explanation of the essence of plant cover synanthropisation which is defined as the process of replacement of native, autochthonous components by ubiquitous allochthonous elements. Instead of natural systems which are dependent on endo- and exogenous factors, secondary systems appear which are mainly dependent on the action of exogenous factors (Faliński, 1972). In the 1960s and 1970s, a theory of degeneration of plant communities has been formulated (Faliński, 1966, 1986 and others; Olaczek, 1972, 1974 and others). A system of notions has been proposed regarding quantitative transformations (degenerative phases) as well as qualitative transformations (degenerative forms). The new theory has facilitated the interpretation of observed changes which occur in forest communities under the influence of various anthropogenic factors, i.e. of anthropopressure (Olaczek, 1972). Faliński (1986) distinguished and characterised 6 basic ecological processes which take place in forest communities: fluctuation, primary succession, secondary succession, degeneration, regeneration and regression. In the present work they are jointly termed syndynamic processes. Transformations of the plant cover under the influence of anthropopressure are multidirectional and variable with regard to their dynamics. This regards both their causes, course and effects.

The issue of impact of drainage on the forest plant cover was studied i.e. by Babczyńska-Sendek et al., (1992), Kurowski (1993), Herbich (1994), Czerwiński (1995), Roy et al. (2000) and Sarkkola et al. (2005).

The study area is the Bełchatów Industrial Region (BOP) which occupies an area of 1020 km^2 in Central Poland. It includes the following elements:

- The largest open pit brown coal mine in Poland (Bełchatów) which currently occupies an area of ca. 19 km^2 and which reaches 200 m in depth. Coal has been mined here since 1980 (Photo 1).
- The Bełchatów electric power plant which started operation in 1982 and which has a generating capacity of 4320 MW (Photo 1).
- The outer dumping heap raised in the years 1977-1993 with an area of 15 km^2 and reaching a relative height of 195 m.
- Power plant ash dumping ground with an area of 4.2 km^2.
- Numerous accompanying plants and installations (Fig. 1).

Photo 1. Open pit brown coal mine and electric power plant in The Bełchatów Industrial Region (BOP).

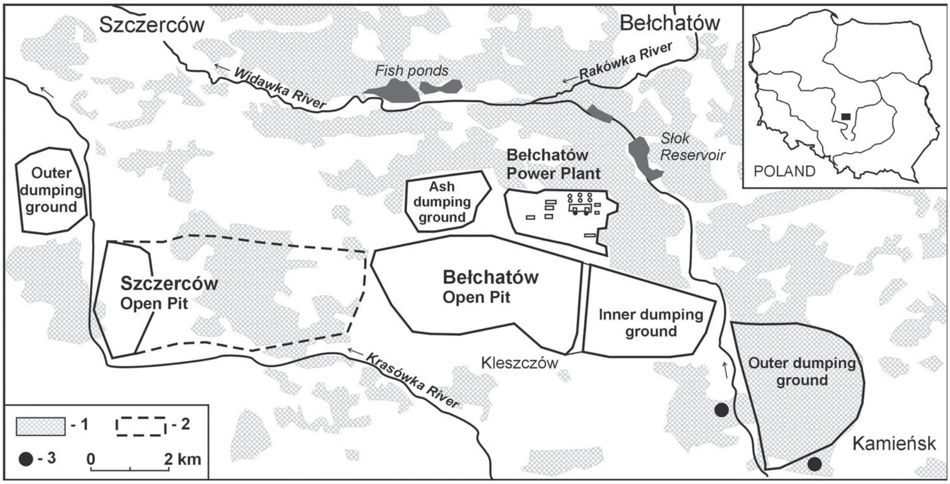

Fig. 1. The Bełchatów Industrial Region (BOP); 1 – forests, 2 – future area of the Szczerców Open Pit, 3 – study sites.

The BOP area includes also a second coal deposit (Szczerców) with an area of ca. 16 km^2 which is separated from the main deposit by a salt diapir and is scheduled for mining starting in 2008 (Kozłowski, 1987; Kurowski, 1993; Materials of the Bełchatów Brown Coal Mine, 2002).

The study subjects are floristic and phytosociological transformations of hygrophilous forests that undergo drainage. The main goal of the study is elucidation of the course of transformations of the bog alder forest *Ribeso nigri-Alnetum* (*RnA*) = *Carici elongatae-Alnetum typicum* K o c h 1926 in conditions of permanent habitat drainage. The achievement of this goal must be preceded by the description of syndynamic processes that take place in the investigated forest phytocoenoses.

Hypotheses, methods and materials

The following working hypotheses have been adopted in the present study:

- Artificial drainage of habitats is the most important anthropogenic factor which causes various responses and syndynamic processes in forest communities in the vicinity of the open pit mine.
- Because the causal factor – drainage – is persistent, various responses of forest phytocoenoses which had developed on hydrogenic and semihydrogenic soils lead to degenerative changes, regression, and subsequently to changes linked with succession.
- The impact of drainage on forest ecosystems is multifactorial and the syndynamic processes it causes are usually irreversible and contribute to synanthropisation of the plant cover.

The studies have been performed on established permanent observation plots: phytosociological, dendrometric and ecological ones.

The phytoecological monitoring method was applied (Kurowski, 1993), including i.e. comparisons of the following data:

- series of phytosociological relevés (400 m^2 each) performed by the Braun-Blanquet method in time intervals of several years starting in 1977 (20 relevé plots in the RnA community),
- basic characteristics of tree stand structure in 8 plots (0.25 ha each) based on investigations performed in 1981, 1986, 1991 and 2001; data were prepared according to the statistical dendrometric method of Paczoski (1928).

The comparison of results obtained at respective time points made it possible to evaluate changes in basic phytosociological and dendrometric parameters. The following average percentage cover index values were assumed in place of respective Braun-Blanquet cover degrees: 1% for +, 5% for 1, 17.5% for 2, 37.5% for 3, 62.5% for 4 and 87.5% for 5.

The X^2 statistical test was used to estimate the significance of changes in the number of trees on the study plots. The interdependence between the change in tree number and wood resources (large timber volume) and the distance from the mine was analysed using the Spearman rank correlation coefficient.

Furthermore, investigation of population numbers and density as well as production level and biomass status of selected herb layer species have been performed in the years 1982, 1986, 1991 and 2001. They concerned, however, a different association (the bog pine forest *Vaccinio uliginosi-Pinetum*).

Vascular plants names was mentioned from the nomenclature for Mirek et al. (2002). Soils classification nomenclature was used for Polish Society of Soil Science (1989).

Results and discussion

Causes of transformations and responses of forest phytocoenoses to habitat drainage

The main causes of transformations in forest ecosystems of the BOP are:
- drainage of the brown coal deposit,
- deforestation; large-area felling (areas of the open pit, the power plant, the dumping grounds etc.); linear (glade) felling (roads, power lines, canals etc.),
- dust pollution (power plant, conveyers, ash and slag dumping areas, wheeled transport, spoil heaps),
- gaseous pollution (power plant, transport etc.),
- peat exploitation,
- construction of canals replacing natural river sections and leading away the drained water.

The positively most important complex reason is the ground drainage within the brown coal deposits: Bełchatów (starting in autumn of 1975) and Szczerców (starting in 2000), which caused above all the disappearance of surface waters and groundwater, drying out of habitats and decrease in air humidity. Currently, the system of vertical drainage in the area of Bełchatów open pit includes ca. 300 wells; for the Szczerców open pit, also 300 wells have been planned as the final level. The depth of constructed wells reaches up to 350 m. Their average daily output is ca. 777 000 m^3 of water, leading to a significant impoverishment of the natural environment – by over 280 million m^3 of water yearly. A portion of these resources is utilised by the power plant, the remaining part is directed to the rivers Widawka and Krasówka (Odra catchment basin). Groundwater level in the centre of the drained area has been decrease by 200–250 m. The drainage of the brown coal deposit has led to the appearance and expansion of a depression crater. Currently its surface encompasses ca.

1 000 km^2. As the drainage construction work continues, consecutive forest complexes are engulfed by the depression crater, while its centre moves towards the west, i.e. in accordance with the direction of drainage and coal exploitation. It is estimated that hydrological disturbances will take place in a total area of up to 1400 km^2 (Kozłowski, 1987; Kurowski, 1993; Materials of the Bełchatów Brown Coal Mine, 2002).

In the initial years of drainage, early responses and transformations of hygrophilous forest phytocoenoses were observed. They precede the occurrence of syndynamic processes. They include i.e.:

a. Limitation of undergrowth productivity:
   - decrease in the numbers and density of hydrophytes and hygrophytes,
   - decrease in the production rate and drop in plant biomass status,

b. Withdrawal of hemerophobous species:
   - successive disappearance of hydrophilous and hygrophilous species (*Hottonia palustris*, *Calla palustris*, *Scirpus sylvaticus*, *Carex acutiformis* etc.),
   - inhibition of growth of peat mosses, liverworts, fungi and lichens,

c. Appearance of hemerophilous species:
   - appearance of ubiquitous nitrophilous mesophytes (*Urtica dioica*, *Galium aparine*, *Lamium maculatum*, species of the genus *Rubus* sp. pl. etc.),
   - appearance of neophytes, e.g. *Padus serotina*, *Acer negundo*, *Impatiens parviflora*.

d. Inhibition of tree stand increment:
   - increased separation of deadwood,
   - limited tree growth and tree stand increment.

Transformations of hygrophilous forest communities

Investigation of transformations of forest communities in drained habitats within the Bełchatów Industrial Region have led to the description of the following four basic syndynamic processes: fluctuation, degeneration, regression and secondary succession. Their course and dynamics have been studied in several communities of hygrophilous forests. They have been more thoroughly characterised in the case of the bog alder forest *Ribeso nigri-Alnetum* (Photo 2A, Fig. 2).

Fluctuation is a common phenomenon in all types of forest communities in BOP, irrespective of the degree of their anthropogenic transformation. In communities of hygrophilous forests, fluctuation includes various transformations of adaptive character under the influence of the sudden change in abiotic and biotic conditions. An increased sowing of trees and shrubs as well as development of mesophytes which fill the gaps left by disappearing hydrophytes and hygrophytes have all been observed. The rescue function of fluctuation is quickly overshadowed by the occurring deep degenerative transformations and subsequent irreversible regressive transformations which embrace all habitat areas of deciduous and coniferous wet forests within the depression crater.

Degeneration of forest phytocoenoses is a widespread phenomenon in forests of the BOP. It occurs practically in all types of forest communities and especially in hygrophil-

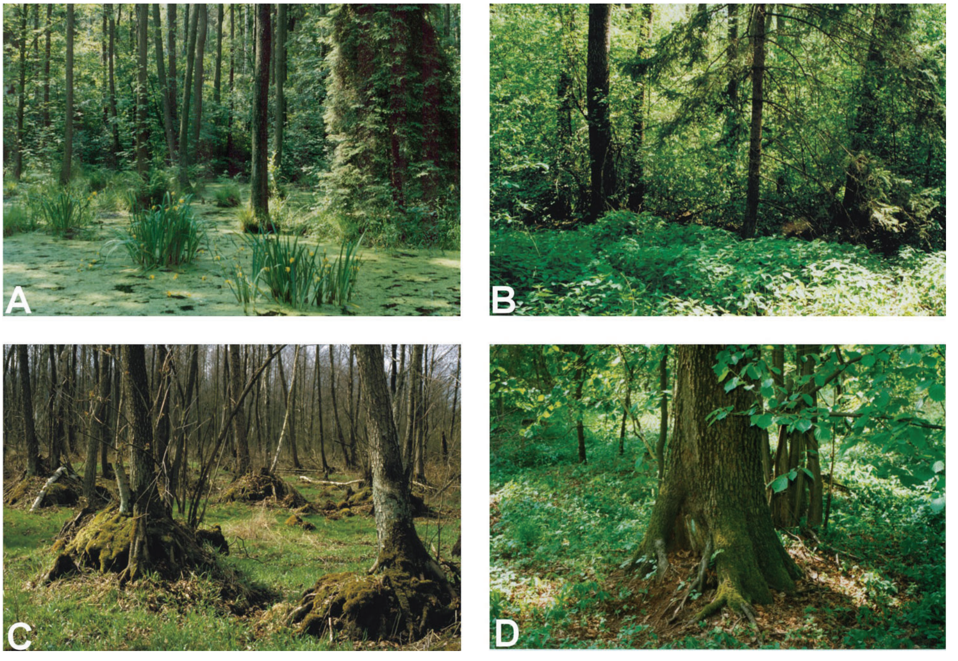

Photo 2. Stages of transformation of phytocoenosis *Ribeso nigri-Alnetum.*
A – *Ribeso nigri-Alnetum* – natural phytocoenosis; B – rump community *Alnus-Urtica*; C – regression of phytocoenosis *Ribeso nigri-Alnetum* – stage of disintegration of tufts; D – fragmentarily developed oak-hornbeam forest community (?*Tilio-Carpinetum*), which is developing in advanced stage of creative secondary succession.

ous forests. As a result of progressive coal deposit drainage, groundwater disappears and habitats become drastically dehydrated. Since the causal factor persists and broadens its range, various and numerous responses of hygrophilous forest phytocoenoses lead directly to degenerative changes. A common feature of forest phytocoenosis degeneration in drained habitats is the replacement of hygrophilous plant species by mesophilous and in extreme cases even by xerophilous ones. I suggest to name this form of degeneration "xerophytisation" – this term includes both floristic and habitat changes. It leads to a transformation of the hygrophilous forest into a mesophilous one.

In phytocoenoses of bog alder forest *Ribeso nigri-Alnetum* (Photo 2A) located at a distance of ca. 5 km from the centre of the depression crater, 2–3 years after starting drainage the disappearance of following hydrophilous and hygrophilous species is observed: *Hottonia palustris*, *Calla palustris*, *Caltha palustris*, *Scirpus sylvaticus*, species from genus *Sphagnum*, *Thelypteris palustris*, *Carex acutiformis*, *Iris pseudoacorus*, *Myosotis palustris* etc. At the same time, appearance of (mostly nitrophilous) mesophytes was observed: *Rubus idaeus*, *Rubus plicatus*, *Galium aparine*, *Lamium maculatum* etc. After 5 years, degeneration is happening in all bog alder forest biochores located up to 6 km from the depression

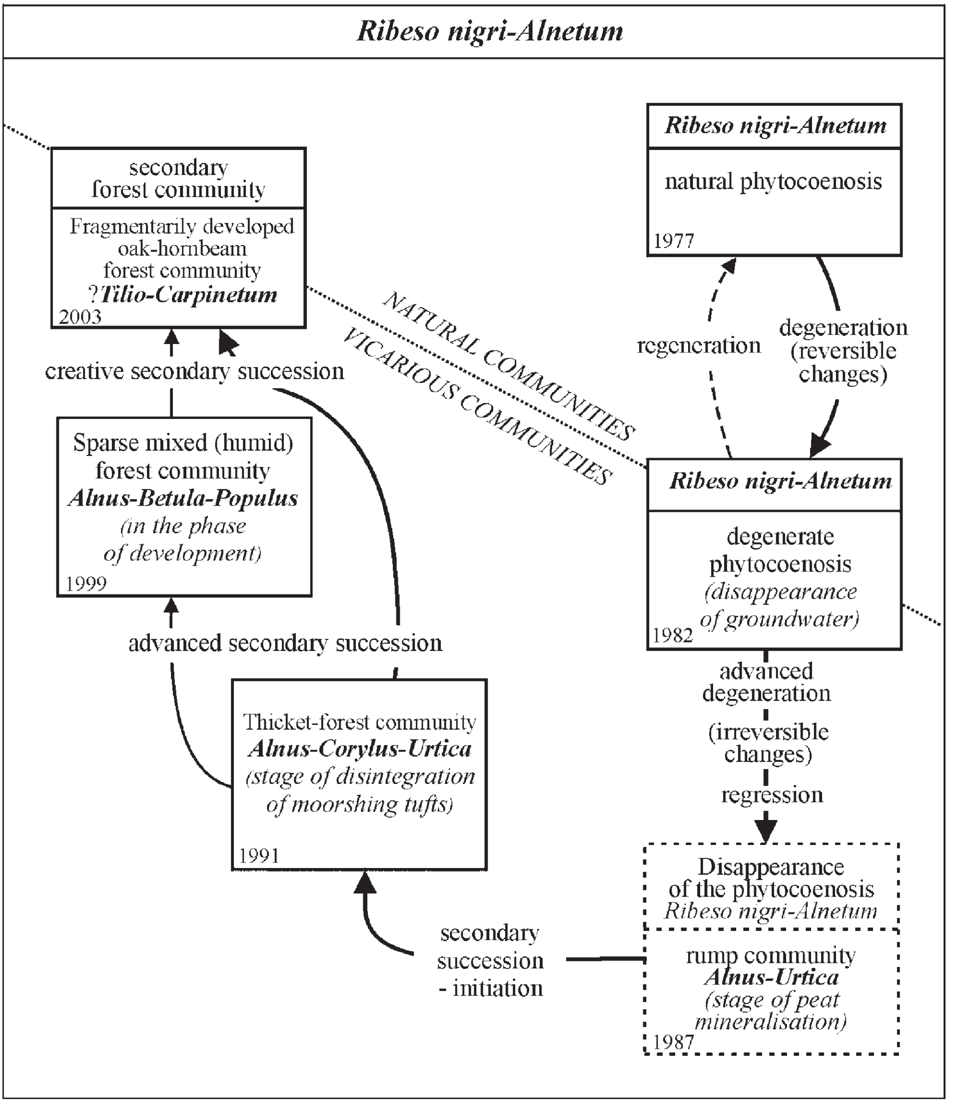

Fig. 2. Pattern of transformations of *Ribeso nigri-Alnetum* phytocoenoses caused by habitat drainage in the BOP during the years 1977–2003 (forest range Łękińsko and Pytowice; 4-6 km from the centre of the depression crater in 1977).

centre. The regression of stenohydric species commences around this time. Degeneration of *Rn-A* phytocoenoses increases in intensity; after ca. 5 years of permanent drainage, oak-hornbeam forest species appear which enter these habitats from the neighbouring ecosystems of fertile species-rich deciduous forest *Tilio cordatae-Carpinetum betuli*. The progressive exchange of species leads to the deterioration of characteristics of a natural bog alder forest community. Other degeneration forms (apart from xerophytisation) that may be observed here include fruticetisation (Olaczek, 1974) which is also called rubietisation in its more specific facet (Ratyńska, Szwed, 1995), as well as ruderalisation (Rambouskova, 1984; Czerwiński, 1995; Łaska, 2001; Kurowski, 2004) which is also called geranietisation (Brzeg, Krotoska, 1984). Some responses of phytocoenoses correspond to the characteristics of other degenerative forms, i.e. floristic impoverishment described by Czerwiński (1995) which leads to the creation of rump communities.

Similar degenerative changes in patches of *Rn-A* located at a distance of over 10 km from the centre of depression crater appeared usually after ca. 10 years from the start of drainage, while in phytocoenoses of this association located over 16 km from the depression no changes have been detected either in the flora or in forest structure. As the centre of the depression crater shifts, especially after the commencement of drainage of the second brown coal deposit (Szczerców) in 2000, consecutive patches of the bog alder forest undergo degeneration.

Regression. The regression process has affected in the first line (ca. 10 years after the commencement of drainage) the *Ribeso nigri-Alnetum* phytocoenoses which occupied bog alder forest biochores located up to ca. 6 km from the centre of the depression crater. After subsequent 5 years, regression has occurred in bog alder forests located up to 16 km from the depression centre. Currently, this distance also designates the limit of regression in the bog alder forests of Bełchatów. The initial phase of the regression process is characterised by the disappearance of hydrophilous and hygrophilous species. Their place is taken by the species which commonly occur in riverside willow-poplar forests, especially by *Urtica dioica*, *Galium aparine*, *Lamium maculatum*, less often by *Deschampsia cespitosa* and *Poa trivialis*. The first three listed species undergo a spectacular expansion in many plots during the second phase of regression. Bog alder forests in advanced phases of regression are similar to riverside ash-poplar forest communities *Fraxino-Alnetum* and *Poo trivialis-Alnetum* (Olaczek, 1972; Jakubowska-Gabara, 1985; Czerwiński, 1995). At the same time, the layer structure of the community changes. Due to plentiful falling out of *Alnus glutinosa* and other trees, a significant decrease in compactness of the canopy layer takes place, while *Frangula alnus*, *Padus avium* and *Corylus avellana* find place for intensified development in the appearing gaps. This phenomenon contributes conspicuously to the increase in compactness of the shrub layer. The result is a rump community *Alnus-Urtica* with a less diverse, conspicuously impoverished flora and with a distinct physiognomy and structure with regard to the natural community (Table 1, Fig. 2, Photo 2B). At the same time, obvious soil degradation takes place: black earth and peat turn to moorsh, while the characteristic large tufts are destroyed (Photo 2C).

Secondary succession. Within the post-hydrogenic *Ribeso nigri-Alnetum* biochores where regression has taken place, the secondary succession process starts. Its initiation, rate of development and direction is dependent on the current floristic composition of the dissociating structures of previously occurring phytocoenoses as well as on types of com-

T a b l e 1. Variation of cover index for typical species at respective stages of transformation of bog-alder forest *Ribeso nigri-Alnetum* phytocoenoses in forest complexes located 4–6 km from the centre of the depression crater (based on phytosociological documentation from 5 permanent observation plots).

Type of community	*Ribeso nigri-Alnetum*		*Alnus-Urtica*	*Alnus-Corylus- Urtica*	*? Tilio- Carpinetum*
	natural	degenerate			
Date	1977	1982	1987	1991	2003
Dominant syndynamic process	degeneration		regression	secondary succession	creative secondary succession
Name of species	average percentage cover index (calculated per single plot)				
Trees and shrubs					
Alnus glutinosa, a	67.5	42.5	37.5	37.5	33.5
Padus avium, b, c	11.5	12.5	12.5	12.5	10
Frangula alnus, b, c	10	12.5	16.5	16.5	12.5
Corylus avellana, b, c	<1	2.2	4	15.5	15.5
Quercus robur, b, c	<1	1.2	2.0	2.4	4.9
Sambucus racem., b, c	<1	2.4	2.4	3.2	3.2
Populus tremula, b, c	-	-	<1	1.2	4.9
Carpinus betulus, b, c	-	-	-	1.6	2.4
Acer platanoides, b, c	-	-	<1	1.8	3.4
Acer pseudoplat., b, c	-	-	-	1.8	3.4
Rubus idaeus, b, c	1.2	1.2	4.5	5.5	2.6
Rubus plicatus, b, c	1.5	1.5	4.5	9.5	5.7
Rubus caesius, b, c	-	-	<1	1.2	-
Herb layer					
Hottonia palustris	1	-	-	-	-
Oenenthe aquatica	<1	-	-	-	-
Calla palustris	1.4	-	-	-	-
Cardamine amara	<1	-	-	-	-
Caltha palustris	1	<1	-	-	-
Scirpus sylvaticus	1.8	1	-	-	-
Thelypteris palustris	13.2	5.7	2.4	-	-
Sphagnum palustre et al.	4.5	2	<1	-	-
Carex acutiformis	12	8.7	1.2	<1	-
Iris pseudoacorus	11.2	8	2.2	1.4	-
Carex elongata	12	5.7	2.4	2.2	-
Urtica dioica	12.5	10	39.5	34.6	11.7
Galium aparine	5.7	5.7	14.2	14.2	6.7
Lamium maculatum	1.2	2.6	9.7	8.9	2.4
Aegopodium podagraria	1.2	2.4	3.4	8.7	8.7
Anemone nemorosa	<1	2.4	3.2	11.7	15.7
Paris quadrifolia	2	1.2	1.2	2.4	4.5
Festuca gigantea	1	1.2	4.5	4.5	4.7
Milium effusum	<1	1.2	1.2	2.4	4.5
Asarum europaeum	-	1	3.5	3.5	3.5
Hepatica nobilis	-	1	1	2.4	4.9
Galeobdolon luteum	-	-	-	2	8
Calamagrostis epigejos	-	-	-	<1	<1
Festuca ovina	-	-	-	-	<1
Sum of average percentage cover indexes for herb layer species	84.5	60.5	90.3	100.3	76.7

munities which were adjacent to bog alder forests. In the *RnA* bog alder forest complexes, secondary succession begins after at least partial disintegration of the tree stand and after withdrawal of the rush and bog forest flora. This stage is characterised by the disintegration of tufts which undergo moorshing. It takes place ca. 15 years after the commencement of drainage. Some shrub species, especially *Corylus avellana* and *Frangula alnus*, manifest significant expansion – in many study plots they become fully dominant in the shrub layer. Species with a lesser share include *Sambucus racemosa*, *Sambucus nigra*, *Salix cinerea*, *Salix caprea* and others. A common phenomenon is a mass occurrence of bramble species, especially of *Rubus idaeus* and *Rubus plicatus*. The result is an initial thicket-forest community *Alnus-Corylus-Urtica* with appearing oak-hornbeam forest species: both herbaceous (*Anemone nemorosa*, *Aegopodium podagraria* and others) and arborescent ones (*Carpinus betulus, Acer platanoides*, *Acer pseudoplatanus* etc.). This phytosociological unit is similar to the vicarious community *Alnus-Rubus* distinguished by Czerwiński (1995) which shows dynamic similarities to the oak-hornbeam forest. The successional tendencies of the bog-alder forest – in the direction of the oak-hornbeam forest – have been described earlier by Pawłowski and Zarzycki (1972) and Herbich (1994).

In the second stage of succession, the ubiquitous riverside forest species, mainly nitrophilous mesophytes (*Urtica dioica*, *Galium aparine*, *Lamium maculatum* etc.), which have hitherto dominated in the herb layer, are successively supplanted by oak-hornbeam forest species: herb, shrub and tree species. Ca. 20 years after the commencement of drainage, some bog-alder forests witness the appearance of a short-lived vicarious anthropogenic community *Alnus-Betula-Populus* which is a humid mixed forest with a sparse young tree stand including species from the receding bog alder forest (*Alnus glutinosa*, *Padus avium*, *Betula pendula*) and new arrivals: *Populus tremula*, *Quercus robur*, *Carpinus betulus*, *Sorbus aucuparia*, *Acer platanoides*, *Acer pseudoplatanus*, *Fraxinus excelsior*, *Pinus sylvestris* and others. Currently, after nearly 30 years of continuous drainage, the third stage of creative secondary succession leads to the appearance of more and more compact secondary forest communities which are usually similar to a fragmentarily developed mesophilous oak-hornbeam forest *Tilio-Carpinetum*, albeit without its complete flora and typical layer structure. The herb layer contains i.e. *Anemone nemorosa*, *Aegopodium podagraria*, *Hepatica nobilis*, *Paris quadrifolia*, *Asarum europaeum, Milium effusum* and *Festuca gigantea* (Table 1, Fig. 2, Photo 2D).

Conclusion

- Artificial drainage of habitats is the most important causal factor of degeneration, regression, secondary succession and other syndynamic processes occurring in forest phytocoenoses in the vicinity of the open pit mine.
- The most important responses and early changes of phytocoenoses in hydrogenic and semihydrogenic habitats are related to the floristic composition, spatial structure and the function of forest ecosystems.

- The most common symptom of degeneration of forest phytocoenoses in drained habitats is the replacement of hygrophilous plant species by mesophilous and even by xerophilous ones. I name this form of degeneration "xerophytisation"   this term includes both changes in floristic composition and in habitat. Xerophytisation of hygrophilous communities results directly in their regression. The following degenerative forms of forest phytocoenoses (presented in the order of frequency of occurrence) have been found in marshy and wet habitats: xerophytisation, floristic impoverishment, ruderalisation, fruticetisation and cespitisation.
- All types of hygrophilous forest communities which develop in hydrogenic and semihydrogenic habitats undergo regression within the area of influence of the depression crater. This group includes *Ribeso nigri-Alnetum*, *Salicetum pentandrae-cinereae*, *Fraxino-Alnetum*, *Carici remotae-Fraxinetum*, *Tilio-Carpinetum stachyetosum*, *Vaccinio uliginosi-Pinetum*, *Molinio-Pinetum* and *Sphagnetum magellanici pinetosum*. The time point of occurrence and the rate of regression show a strong correlation with the distance between the individual bog forest and wet forest complexes and the depression centre.
- Secondary succession occurring in sites which have previously witnessed regression of the natural community leads to the creation of secondary vicarious communities. Their development is often preceded by brushwood and thicket stages with domination of pioneering arborescent species. Secondary communities are short-lived and dynamically unbalanced. Their flora is impoverished with regard to the natural communities and its floristic composition is variable. These communities are only fragmentarily formed after nearly 30 years, although they are floristically and to some extent also physiognomically and structurally similar to specific natural communities. The hygrophilous forest *Ribeso nigri-Alnetum* undergoes transformation to the mesophilous oak-hornbeam forest *Tilio-Carpinetum*.
- The most important results of the investigated transformations of forest ecosystems include:
  - synanthropisation of the plant cover, including especially:
    - impoverishment of the natural floristic diversity,
    - reduction of genetic resources of the local flora,
    - deterioration of the natural phytocoenotic diversity; appearance of dynamically unbalanced vicarious forest communities,
  - reduction of the potential of forest habitats, including especially:
    - degradation of hydrogenic and semihydrogenic soils,
    - change of forest habitat types,
    - reduction of tree stand resources,
    - impoverishment of the natural habitat diversity and others.

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References

Babczyńska-Sendek, B., Kimsa, T., Wika, S., 1992: Vegetation of the Kraków-Częstochowa Upland in circumstances of anthropopressure (in Polish). Prądnik. Prace Muz. Szafera. *5*: 47–63.

Bengtsson, J., Nilsson, S.G., Franc, A., Menozzi, P., 2000:. Biodiversity, disturbances, ecosystem function and management of European forests. For. Ecol. Manage., *132*: 39–50.

Brzeg, A., Krotoska, T., 1984: Community *Pinus-Geranium robertianum* – degeneration form of oak-hornbeam forest (in Polish). Bad. Fizj. nad Polską Zach. *35*. ser. B: 43–66.

Czerwiński, A., 1995: Geobotany in environment protection of Podlasie and Mazury forests (in Polish). Politechnika Białostocka, 345 pp.

Ellenberg, H., 1982: Vegetation Mitteleuropas mit den Alpen in Őkologischer Sicht. E. Ulmer, Stuttgart, 990 pp.

Faliński, J.B., 1966: Une definition de la déformation de phytocénose. Un systéme des phases de dégénération des groupements végétaux. Discussion phytosociologique. Ekologia Polska, B, XII, *1*: 31–42.

Faliński, J.B., 1972: Synanthropisation of the plant cover – an attempt to define the nature of the process and of the main fields of investigations. Phytocoenosis, *1,* 3: 157–170.

Faliński, J.B., 1986: Vegetation dynamics in temperate lowland primeval forests. Ecological studies in Białowieża Forest. Geobotany 8. Dr. W. Junk Publ. Dortrecht, 537 pp.

Herbich, J., 1994: Spatial and dynamical diversity of the vegetation in valleys in a young-glacial landscape exemplified by the Kashubian Lakeland (in Polish). Monogr. Bot., *76*: 1–175.

Holzner, W., Werger, M.J., Ikusima, L., (eds), 1983: Man's impact on vegetation. Geobotany, 5. Dr W. Junk Publ., The Hague, London, 365 pp.

Jakubowska-Gabara, J., 1985: Forest communities in the Rawa Upland and their anthropogenic changes (in Polish). Monogr. Bot., *65*: 1–148.

Kornaś, J. 1972: Human and his impact to plant cover of Poland – synanthropic flora (in Polish). In: Szafer, W., Zarzycki, K. (eds), Plant cover of Poland. T. I. PWN. Warszawa, p. 95–128.

Kornaś, J., 1981 Impact of human to flora: mechanics and consequence (in Polish). Wiad. Bot., *3*: 165–182.

Korpel, S., 1989: Primeval forestry in Slovak (in Slovak). Veda, Bratislava, 328 pp.

Kozłowski, Z., 1987: Development of open mining in Bełchatów Region. In: National Conference "Natural environment protection in Bełchatów Industial Region" (in Polish). Bełchatów. p. 117–130.

Kurowski, J.K., 1993: The dynamics of the forest phytocoenosis in the opencast mine Bełchatów region (in Polish). Univ. Lodz. Press, Łódź, 173 pp.

Kurowski, J.K, 2004: Dégénération et régénération des phytocénoses forestières en Pologne Centrale. Natura Mosana. *57*, 3: 57–76.

Łaska, G., 2001: The disturbance and vegetation dynamics: a review and an alternative framework. Plant Ecology *157*: 77–99.

Materials of the Bełchatów Brown Coal Mine, 2002. Bełchatów.

Mirek Z., Piękoś-Mirek H., Zając M., Zając M., 2002: Flowering plants and Pteridophytes of Poland a checklist. W. Szafer Institute of Botany. Polish Academy of Science. Kraków, 442 pp.

Olaczek, R., 1972: Forms of anthropogenic degeneration of forest plant communities in agricultural landscape of lowland Poland (in Polish). Univ. Lodz. Press, Łódź, 170 pp.

Olaczek, R., 1974: Directions of forest phytocoenoses degeneration and methods of their research (in Polish). Phytocoenosis *3*, 3/4: 179–190.

Olaczek, R., 1982: Synantropization of phytocoenoses. Memorabilia Zoologica, *37*: 93–112.

Ozenda, P., 1986: La cartographie ecologique et ses applications. Masson, Paris, 160 pp.

Paczoski, J., 1928: Biological structure of forest (in Polish). Sylwan *46*, 3:1–29; 5: 1–38.

Pawłowski, B., Zarzycki, K., 1972: Dynamics of plant communities (in Polish). In: Szafer, W., Zarzycki, K. (eds), Plant cover of Poland. T. I. PWN, Warszawa. p. 481–501.

Rambouskova, H., 1984: Some notes on forest ruderalisation. Preslia *56*: 117–123.

Ratyńska, H., Szwed W., 1995: Degeneration of oak-hornbeam forest in Agroecological Landscape Park (in Polish). Parki Nar. i Rez. Przyr., *13*: 99–113.

Roy, V., Ruel, J-C., Plamondon, A.P., 2000: Establishment, growth, survival of natural regeneration after clearcutting and drainage on forested wetlands. For. Ecol. Manage., *129*: 253–267.

Sukopp, H., 1969: Der Einfluss des Menschen auf die Vegetation. Vegetatio, *17*: 360–371.

Sarkkola, S., Hökkä, H., Lacho, R., Päivänen, J., Penttila, T., 2005: Stand structural dynamics on drained peatlands dominated by Scots pine. For. Ecol. Manage., *206*: 135–152.

Tüxen, R., 1966: Antropogene Vegetation. Bericht über das Internationale Sympozium in Stolzenau a. Weser 1961 der Intern. Vereinigung für Vegetationskunde. W. Junk, Den Haag, 398 pp.

Walker, L.R., Moral, R., 2003: Primary succession and ecosystem rehabilitation. Cambridge University Press, Cambridge, 442 pp.

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