Chapter 1

Plant Diversity in Agroecosystems and Agricultural Landscapes

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1. Introduction

Agricultural landscapes represent a cultural landscape group. Their origin, structure and ecological relations differ from natural landscapes considerably. By (Kizos and Koulouri 2005) they are defined as the visual result of land uses. They are nature systems developed with a great participation of the man, used by the man and maintained in the state of internal equilibrium. At present the role of rural areas does not mean only foodstuffs production. The sustainable rural areas development should involve maintaining the equilibrium between the productive, economic and social function of agricultural landscape and its ecological function, including maintaining the biodiversity. Those are the areas of numerous plant and animal organisms not connected directly with agricultural production, however, playing important environmental functions. The human activity performed in them should thus also consider the need of environmental protection [Millennium Ekosystem Assessment 2005, Fisher and Lindenmayer 2007].

The basic elements of the rural landscapes are the agroecosystems. Those are mainly grasslands and cultivated fields. Very important is their proportion in the agricultural landscape. The correct structure allows the agricultural production and maintain environmental values [Kovalev et al. 2004]. Biodiversity of agricultural fields is very small. Altieri [1999] citing Fowler and Mooney indicates that more than one billion hectares in the world are cultivated only about 70 species of plants. Therefore it is very important is the presence in the area of islands, corridors and other environmental elements.

1.1. The structure of agricultural landscapes and the biodiversity of plants

The biodiversity in agricultural landscape depends on its structure, including the share of natural components, land use structure and the intensity of farming. To evaluate the biodiversity in agricultural landscapes, there are applied various habitat and agricultural production parameters. For example Billeter et al. [2008] give:

- Land-use intensity parameters:
  - number of crops cultivated on a farm,
  - nitrogen input,
  - share of intensively fertilized arable area,
  - amount of livestock units per farm,
  - number of pesticide applications per field
- Landscape parameters:
  - area of semi-natural habitats,
  - number of semi-natural habitat types,
  - number of patches of woody and herbaceous semi-natural habitats,
  - average size of a semi-natural patch,
  - number of patches of woody and herbaceous semi-natural habitats per 100 ha,
  - semi-natural habitats edge density,
  - average Euclidean-nearest-neighbour distance between semi-natural landscape elements,
  - contagion index of woody and herbaceous semi-natural landscape elements,
  - proximity of woody and herbaceous semi-natural elements within a 5000 m radius.

In Poland [Jakubowski 2007] an attempt has been made to evaluate the biodiversity of agricultural landscape based on:

- the share of the landscape type with a varied little-mosaic use,
- the occurrence of protected habitats,
- the occurrence of rare field and meadow plant species,
- land relief enhancing the diversity of habitats,
- the occurrence of nature refuges connected with field or meadow habitats or species,
- the occurrence of large areas under extensive meadow or fen use,
- the occurrence of agrocenoses with numerous midfield woodlots and thickets, especially forming ecological corridors.

Agricultural landscapes are a significant component of the surface of the countries or regions. It can be shown that the diagram (Fig. 1). One of the conditions for its high biodiversity is multi-element structure and heterogeneity; the areas with low natural qualities, mostly due to strong anthropogenic impact on the environment and limited biodiversity: agricultural land. It also includes the areas of a high biodiversity, in general, however, small in size: forest islands and non-point woodlots, xerothermic grasses, fallow land and water ponds. Besides there is a network of ecological corridors, including: field boundaries, field margins, hedgerows, linear midfield woodlots, roads and shoulders. Those elements are supplemented with a settlement and transport network.

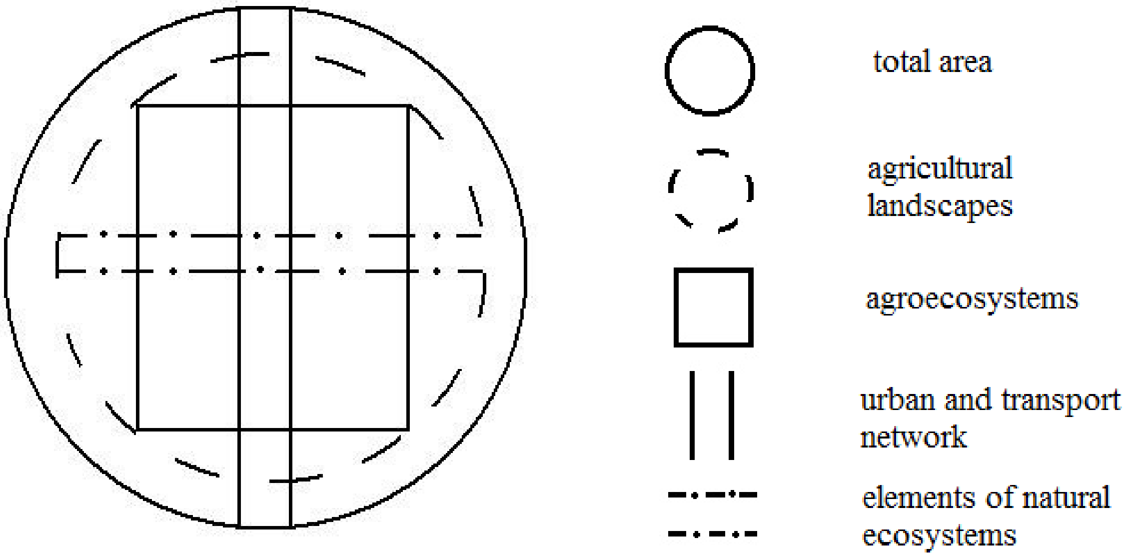

Figure 1. Diagram of the location and structure of agricultural landscape

Over the last decades the rural areas have undergone habitat homogenization and fragmentation [Jongman 2002]. In agricultural landscapes the structural diversity and heterogeneity are getting smaller and smaller. The development of agricultural production results in, one the one hand, a reduction in the number and diversity of natural elements of their structure and, on the other hand, the increase in the concentration and intensification of field crops, at the same time limiting the use of meadows and pastureland. In agricultural landscape there increases the number of large monoculture fields. Plant cultivation involves the application of technologies with high inputs of mineral fertilizers and plant protection agents. The plantation mechanization and large-size machines result in an elimination of midfield woodlots, water ponds and hollows. Striving for the consolidation of land and crops leads to the liquidation of wetlands, fallow land, and increasing the farm acreage is connected with giving up the field boundaries.

The key role in maintaining the biodiversity and biological equilibrium in agricultural landscapes is played by their elements with no direct effect on agricultural production. However, their indirect relationship through the impact on the biotope and the biocenosis of adjacent agricultural ecosystems is unquestionable and seen e.g., in the effect on the microclimate, soil properties and ecological relationships between organisms. Midfield and mid-meadow woodlots affect the biological and microclimatic conditions in the neighbouring arable fields. They limit the effects of water and wind erosion. Those areas act as a buffer, reduce non-point pollutions and the discharge of biogenes from the fields. They plan a crucial hydrological role. They create refuges for many species of fauna and flora non-specific for the neighbouring agricultural land. The organisms, by increasing the biodiversity in agricultural landscape, help maintaining its biological equilibrium. To maintain the richness of plant and animal species in the agricultural landscape, the following are of similar importance: the elements of natural landscapes, semi-natural land under use and fallow land, including: water ponds, swampy areas, wetland, peat bogs, dry turfs, field boundaries, slope, embankments, and others. Those, together with agricultural land, combined in the landscape join ecological corridors, thanks to which, numerous organisms can migrate between various ecosystems, which enhances the stability of their presence in the landscape. A high biodiversity occurs especially on the border of ecosystems. It is a result of varied habitat conditions in the zone of ecotone and the mutual penetration of organisms between the neighbouring habitats.

The development of agriculture with its economic and social function and, at the same time, the activity for the protection of the environment and landscape, are a springboard for the strategy of sustainable development of rural areas in many countries. The prevention of agricultural landscape degradation requires e.g. maintaining its multi-element, biologically-varied spatial structure, especially maintaining and revitalizing the landscape elements with a high plant biodiversity since the flora variation facilitates the development of zoocenosis.

Midfield woodlots and other woodland system elements in agricultural landscape support the production and ecological functions of agroecosystems [Benton et al. 2003]. Those are the elements which are non-homogenous in terms of origin, form, structure and nomenclature. In literature one can find various names: woodlots, shelterbelts, hedgerows, and also midfield clumps, water-edge hedgerows and avenues. Midfield woodlots occur as patches and linear forms. Woodlots, especially the linear ones, are also considered corridors found in the matrix of agricultural landscapes. They are mostly made up by woody vegetation with a share of herbaceous vegetation, and the total biodiversity is enhanced by abundant fauna. Linear woodlots, including hedgerows are a key ecological element in the countries of Western Europe; e.g. France, England [Baudry et al. 2000]. They are also present in Central and Eastern Europe [Ryszkowski et al. 2003, Lazarev 2006] as well as in North America [Brandle et al. 2004] and on other continents [Onyewotu et al. 2004, Tsitsilas et al. 2006].

An indirect effect of woodlots on the plant biodiversity in agricultural landscape involves the development of abiotic habitat conditions, which is seen e.g. from braking the wind speed, restricting the wind and water soil erosion, limiting water evaporation from soil, increasing air humidity, slowing-down the snow melting rate, decreasing daily and annual air temperature amplitudes, limiting the occurrence of ground frosts, restricting the mobility of harmful agrochemical compounds, which creates conditions favourable to the vegetation of many plant species, including crops which occur in agroecosystems.

Biotic elements of midfield woodlots, on the other hand, remain in a close ecologic relationship with agrophytocenosis. On that ecological island there are found, permanently or seasonally, pests and pathogens of crops as well as weeds which can migrate to arable fields. However, the species richness of those places is mostly made up by organisms favourable to crops; entomopathogenic fungi, predator beetles and flies, ladybirds feeding on aphids. The insects representing the family *Apidae* are of special importance since they pollinate many plants, including crops. Most herbaceous plants which occur in woodlots, are not, however, expansive weeds posing a threat to agroecosystems in nature. A complex character of the structure of midfield woodlots and their functions are seen from the environmental and agroecological research results reported by many authors from various research centres in the world and presented as a review by Mize et al. [2008]. Woodlot lanes are most frequently established with the use of 2-5 species of woody plants. Their biodiversity and effect on the landscape change with growth. At the initial stage a high share is accounted for by weeds, mono- and dicotyledonous plants. Their seeds are found in the soil seed bank and transferred with the wind and by animals. Later the trees and thicket vegetation start to dominate; their competition for light and water increases. Light-loving species give up. The vegetation of woodlot patches is also exposed to a strong human pressure resulting from the agrotechnical practises for crops, e.g. tillage, mineral fertilization and pesticide application and so it is, in general, less stable than in woodlands.

In Canada [Boutin et al. 2003] point to the diversity of the vegetation in hedgerows depending on their origin: natural woody, planted woody and herbaceous. Hedgerows made up of natural and planted woody plants demonstrated a greater diversity and richness of plant species. In natural hedgerows there were identified 31 woody species in the layer of trees > 5 m, 63 species of those plants in the layer shrubs < 5 m as well as 94 species of herbaceous plants. Planted hedgerows were mostly composed of ecotone vegetation, typical for the edges of arable fields.

Walker et al. [2006] point to a high biodiversity of plants and a complex nature of green lanes, composed of the external part with woody species and herbaceous plants, the inside verge and the central track. It was the inside verge which was richest in plant species. The area was most covered with *Urtica dioica, Rubus fruticosus, Arrhenatherum elatius*, while the central track - mostly with *Agrostis stolonifera, Ranunculus repens, Dactylis glomerata, Trifolium repens, Lolium perenne, Holcus lanatus, Plantago major*. Plant communities in respective parts of green lanes were developed due to habitat conditions, including light, moisture, reaction, nitrogen content, as well as the elements of agrotechnical practises in the adjacent arable fields.

In Poland, in Lower Silesia (south-western Poland), the biodiversity of plants of midfield woodlots depended on their type: midfield clumps, water-edge hedgerows and avenues. In total in 183 woodlots there were found 77 woody plant species; most occurred in midfield clumps, and least – in avenues. The greater the area of woody species in midfield woodlots or the greater their length, the greater their abundance [Orłowski and Nowak 2005].

Nevertheless, precious environmental islands to maintain the biodiversity in the landscape and agroecosystems include field boundaries, combining physical and functionally-different ecosystems of agricultural landscape. The smaller the arable fields and farms and the more extensive the farming, the greater the number of field boundaries. Le Coeur et al. [2002] quoting the results reported by many authors [Helenius, Hooper, McAdam et al., Pointereau and Bazile] demonstrates that along with the agricultural production intensification in the second half of the 20th century, those semi-natural landscape elements disappear. The scale of field boundaries loss is high; e.g. in the UK 5000 km annually, in Northern Ireland - 14%

of the field boundaries network between 1976 and 1982, in Finland 500 000 km, 740 000 km in France. The authors show, at the same time, a strong relationship between the diversity and the structure of vegetation which occurs in field boundaries and the effect of the interaction of many habitat and economic factors, e.g. the landscape structure, field management method, farm type as well as the nature of the field boundary itself.

Field boundaries, despite their small size, show a great richness of its organisms; mostly herbaceous plants, and sometimes also trees and shrubs. The flora is accompanied by abundant fauna. The species richness of field boundaries depends e.g. on their age and width. Czarnecka [2011], investigating along 4 field boundaries of a total length of 1000 m, identified 67 plant species. Symonides [2010] citing studies by many authors indicate that in Poland in the field boundaries and in the immediate vicinity may occur up to several hundred species of plants. Sometimes there is an expansion of those plants (weeds) into arable fields. The agroecological importance of field boundaries, however, mostly comes from the occurrence of pollinating insects and organisms entomophagous towards crop pests.

Field boundaries are often a part of field margins. Those are linear elements of agricultural landscape showing a complex structure and high biodiversity; e.g. aqueous, ruderal, woody vegetation. Depending on the margin structure and on the distance from the arable field, crops, herbaceous plants, shrubs, trees, and aqueous plants dominate. The flora of the area adjacent to fields is developed by agricultural activities; e.g. fertilization, herbicides application. The vegetation of field margins also affects agricultural vegetation, both directly and indirectly [Marshall and Moone 2002].

Other agricultural landscape elements showing high ecological qualities are midfield ponds, combining the biotopes of greater, open surface waters. They play a retention function and affect water relations in agroecosystems, which is crucial for the development of crops and other companion crops, especially when exposed to seasonal precipitation deficits. Midfield ponds are an essential component of biodiversity, including flora diversity in agricultural landscapes and agroecosystems. They serve as a habitat for many plant species representing various plant communities. The richness and the frequency of occurrence of the phytocenoses within water ponds, with an example of Wełtyń Plain (in Poland), are presented in the Table 1. by Gamrat [2009].

The diversity of plant species which occur in those habitats depends on their form of water ponds, changes which occur there; devastation, overgrowing, shallowing. The richness of plant species, their structure and biodiversity are much affected by agricultural and non-agricultural human activity, being an important cause of the eutrophization of those habitats. Within the water ponds one can find the vegetation of aquatic, marshland, meadow, shrubby and ruderal habitats [Pieńkowski et al. 2004, Gamrat 2006]. In open ponds, marshland and aquatic vegetation dominates. In overgrowing ponds, the species richness is greater, however, the vegetation of wet stands gives up. While in the post-water-ponds hollows there dominates ruderal vegetation, including nitrophilic vegetation, typical for agricultural landscape.

Phytocenosis, the most frequent of communities
Oenantho-Rorippetum, Phalaridetum arundinaceae community with: *Calamagrostis canescens, Deschampsia caespitosa, Elymus repens, Epilobium hirsutum, Galium aparine, Lemna minor, Phragmites australis, Rubus caesius, Typha latifolia, Urtica dioica*
Phytocenosis, moderately frequent communities
Calamagrostietum epigeji, Caricetum acutiformis, Epilobio-Juncetum effusi, Rumicerum maritimi, Salicetum pentandro-cinereae, Scirpetum sylvatici, Sparganietum erecti, Sparganio-Glycerietum fluitantis community with: *Agrostis stolonifera, Alisma plantago-aquatica, Alopecurus geniculatus, A. pratensis, Anthriscus sylvestris, Apera spica-venti, Artemisia vulgaris, Bidens tripartita, Cirsium arvense, Festuca pratensis, Glechoma hederacea, Glyceria maxima, Holcus lanatus, Iris pseudacorus, Poa pratensis-Festuca rubra*
Phytocenosis, rare communities
Acoretum calami, Caricetum elatae, Caricetum gracilis, Cicuto–Caricetum pseudocyperi, Hottonietum palustris, Spirodeletum polyrhizae, Leonuro-Arctietum tomentosi, Ranunculetum circinati community with: *Anthoxanthum odoratum, Arctium major, Arrhenatherum elatius, Bromus tectorum, Capsella bursa-pastoris, Carex nigra, C. rostrata, C. vulpina, Cerasium arvense, Cirsium palustre, Conium maculatum, Epilobium parviflorum, Equisetum arvense, Hydrocharis morsus-ranae, Lemna gibba, L. trisulca, Lychnis flos-cuculi, Lysimachia vulgaris, Polygonum amphibium, Rudbeckia hirta, Solanun dulcamara, Symphytum officinale, Typha angustifolia*

Table 1. The frequency of occurrence of the phytocenoses on the ponds (by Gamrat 2009)

The water ponds, on their edges, are often accompanied by woodlots lanes or patches. The vegetation acts as a biological filter protecting water from pollution with agrochemicals from arable fields. Ryszkowski and Bartoszewicz [1989] found that the concentration of nitrates in water flowing under woodlots can be even 30-times lower than in the environment without that vegetation.

Water ponds also occur among marshlands. Those are very important landscape elements playing hydrological and ecological functions and can affect the biodiversity of plants both on a local and regional scale [Thiere et al. 2009].

2. Biodiversity of plants in agroecosystems

The agroecosystems are an essential element of agricultural landscape. Agricultural ecosystems are in mutual ecological relationships with other ecosystems and elements of the environment. This can be illustrated schema (Fig. 2).

The biodiversity of agricultural ecosystems depends on their kind, method of use and management. The basic kind of agricultural land in the world are grasslands; meadows and pasture. Grasslands cover more than 10% of the land area of the Earth. About one third is taken by arable meadows and pasture and one fourth – by semi-natural and natural extensive pasture [Mooney 1993].

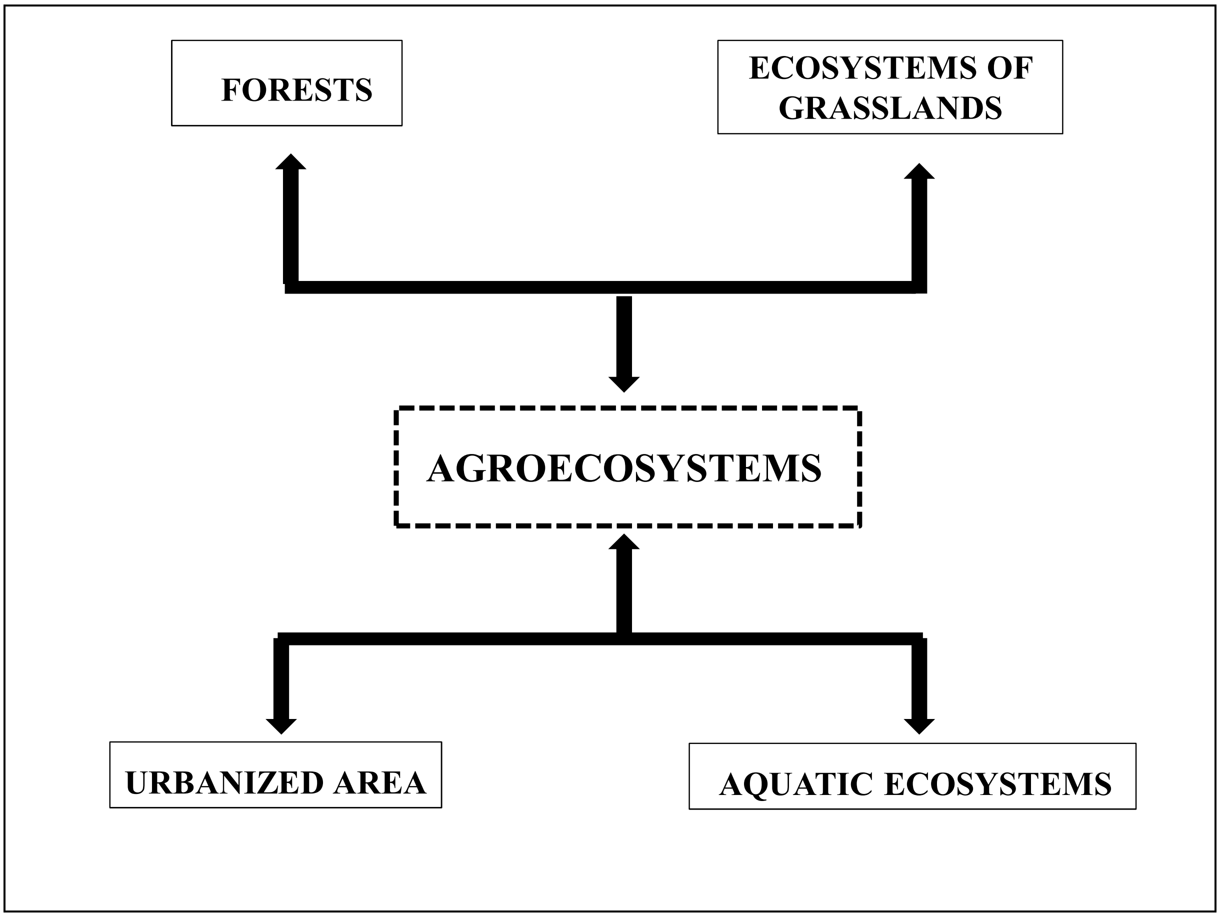

Figure 2. Depending agroecosystems in the environment

Grasslands play various non-production functions in the environment [Wasilewski 2009]:

- climatic, forming a mild microclimate, also covering adjacent areas,
- hydrological, with a large water-retention potential,
- protective; limiting the soil erosion and protecting the soil and water from pollution with agrochemicals and biogenes,
- phytosanitary, by stopping PMs and emissions of essential oils,
- health-enhancing, being the habitat of many herbs,
- landscape and aesthetic, due to the diversity of forms and colours of plant habitats.

The plant biodiversity of grasslands is, in general, greater than arable fields, which comes from the nature of meadow and pasture sward, made up of many species of grasses, papilionaceous plants, herbs and weeds. Many authors, cited by [Pärtel et al. 2005], show that per 100 cm^2 there can occur a few dozen or so plant species and per 1 m^2 – almost a hundred. The plant biodiversity of grasslands depends on the habitat conditions and on the method and the intensity of their use. The flora composition is greatly affected by soil properties; moisture, the rate of mineralization of organic nitrogen compounds, the kind of organic matter and the richness in nutrients [Pawluczuk and Alberski 2011]. In a moist habitat, frequently flooded or permeated there occurred, in general, the vegetation representing *Ranunculus, Equisetum, Carex* and *Rumex* genera and the grasses demonstrated a simplified flora composition. *Lotus uliginosus* Schkuhr, *Equisetum palustre* L., *Ranunculus acris* L. and *Ranunculus repens* L., *Lythrum salicaria* L., *Cirsium palustre* (L.) Scop., *Galium uliginosum* L. were abundant. In the habitat with a seasonally-changeable soil moisture, *Cirsium oleraceum* (L.) Scop., *Filipendula ulmaria* (L.) Maxim., *Geum rivale* L. were most abundant. When exposed to lower moisture and a greater organic matter mineralization dynamics, there were recorded numerous species of fodder grasses and other plants demonstrating high mineral nitrogen requirements: *Alopecurus pratensis* L., *Festuca pratensis* Huds., *Festuca rubra* L., *Poa pratensis* L., *Holcus lanatus* L., *Agropyron repens* (L.) P.Beauv., *Urtica dioica* L., *Agropyron repens* (L.) P.Beauv., *Cardaminopsis arenosa* (L.) Hayek. The plant biodiversity of grasslands also depends on their use: grazing, method and technique of cutting. The vegetation of grasslands is not permanent, climax in nature. Giving up the use leads to a secondary succession of those areas.

On a global scale, the arable land has a lower share in the total area than grasslands. However, in many countries it accounts for most agricultural land (Table 2). Agroecosystems are an area exposed to a strong anthropogenic impact on the environment. What is characteristic for those ecosystems is a low biodiversity, especially phytocenoses.

It covers a few crop species and a few, reduced by the farmer, non-crops. The anthropogenic impact on the environment concerns both the biotope and the biocenosis of those areas. The soil properties get changed according to the requirements of the crops. In the fields you will find mostly annual plants, shielding the soil only for some part of the year. Winter forms, e.g. wheat, rye, rape, occur in the field for about 300 days a year, spring crops with a long period of vegetation, including maize, beetroot, potato, for about 160 – 180 days. There exist, however, crops with a much shorter vegetation period. Spring barley stays in the field for about 100 days and some species – for a few weeks. Those crops have different ability to reduce soil erosion (Fig. 3). Most often, for a long period between the harvest and sowing of the successive crop, the soil remains with no vegetation. Only in some cases intercrops are grown or the mulch rests on the soil surface. The fields of crops are, in general, single-species. It is rarely the case that the mixtures of a few species or cultivars of the same crop are grown. Besides, non-crops; weeds and self-sown plants, are being removed.

Country	Agricultural land	of which	
		arable land	permanent pasture
Argentina	48,6	11,7	36,5
Australia	54,1	5,7	48,3
Belgium	48,8	27,9	17,4
Belarus	44,0	27,2	16,3
Brazil	31,2	7,2	23,1
Bulgaria	47,3	28,2	17,3
China	55,8	11,6	42,7
Denmark	63,7	56,6	7,1
Finland	7,4	7,4	0,0
France	53,1	33,3	18,0
Greece	35,7	16,3	10,9
Spain	55,8	25,0	21,2
India	60,5	53,2	3,5
Japan	12,6	11,8	0,0
Canada	7,5	5,0	1,7
Latvia	28,2	18,8	9,4
Mexico	52,9	12,8	38,7
Netherlands	54,6	31,6	23,0
Germany	48,6	34,2	13,8
Norway	3,5	2,8	0,7
New Zealand	38,8	1,7	37,1
Poland	49,9	38,7	10,2
Portugal	36,6	11,5	18,8
Czech Republic	54,9	39,2	13,1
Russian Federation	13,1	7,4	5,6
Romania	58,8	37,9	19,6
Slovakia	39,0	28,7	10,3
United States	44,9	18,6	26,0
Sweden	7,6	6,4	1,2
Turkey	50,7	28,0	18,9
Ukraine	71,3	56,1	13,6
Hungary	64,3	51,0	11,1
United Kingdom	73,2	24,8	47,9
Italy	45,7	24,2	12,3
WORLD	37,5	10,6	25,8

(based on Statistical Yearbook of Agriculture, CSO Warsaw 2010)

Table 2. The share (%) of agricultural land in the total area of some countries

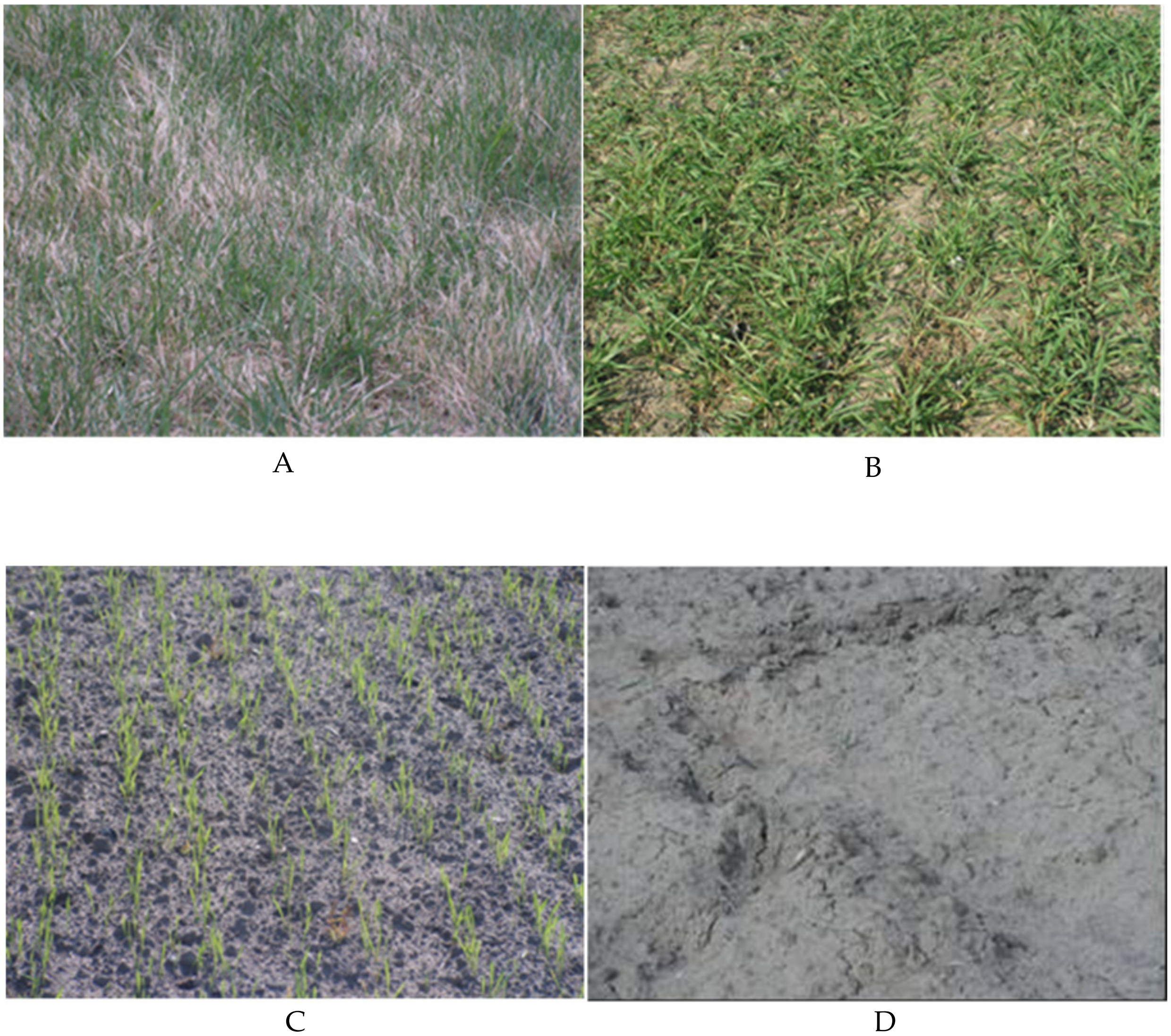

Figure 3. Covering the soil by vegetation in early spring, A - grassland (full coverage), B - winter cereal (good coverage), C - spring cereal (poor coverage - the risk of erosion), D - without plants (signs of erosion)

The impact on agrophytocenosis and its biodiversity depends e.g. on the farming system. On many conventional farms plant production dominates. Animal production, if any, often includes battery farming with the use of manufactured feedingstuffs or produced on arable land. The rotations of commodity and fodder crops get simplified even down to 2-3 species. Those are intensive single-species technologies with high inputs of mineral fertilizers and pesticides eliminating weeds and other agrophages. Intercrops are rarely grown; if so – to improve the stand value. In the sustainable farming system, especially in organic farming, the farm is perceived as an organism. Animal production should be its integral part, including ruminants, which require the animal feed base in a form of grasslands. Animal feed production on arable land involves perennials; e.g. *Fabaceae*. Crop rotations are multispecific, with legumes and intercrops being essential. The fields are quite frequently mixed and include species representing various genera. Weeds are their integral component. They are being limited in the fields of crops when they pose a threat to yields and their quality. To do so, there are applied various methods, also or only non-chemical. A greater biodiversity in organic than in conventional agriculture is mostly seen on a local scale, on the agricultural farms where there is a greater weed species richness; on a regional scale it can be similar in both farming systems and, to a greater extent, it depends on habitat conditions [Hawesa et al. 2010]. Irrespective of the farming system, weeds are an integral component of the agricultural landscape and agroecosystems. Especially on integrated and organic farms, their ecological role is noted, by incorporating e.g.:

- filling in the ecological niches and enhancing the diversity of flora and the quality of animal feeds from grasslands,
- allelopathic favourable effect on the crops coexisting in the field,
- a further development of ecological relationships between fauna and flora, enhancing the biological agrobiocenosis stability,
- soil protection from erosion and unproductive water evaporation, limiting non-point pollutions of soil and water,
- carbon sequestration in the environment,
- bioindication of the conditions and the state of the environment,
- application to the production of composts, biopreparations and herbal medicine.

A high biodiversity of agroecosystems in organic farming is not only due to the diversity of flora and fauna in arable fields but it also comes from the presence of a greater number of habitat components; e.g. woodlands, boundaries, hedgerows [Boutin et al. 2008]. Although the biodiversity of those components on organic and conventional farms can be similar, in organic farming the abundance of plants and their species in the fields is often many-times greater than in conventional farming [Hald 1999]. Krauss et al. [2011] found a five-time greater plant species richness in the triticale grown in organic fields than in the conventional ones, which, in turn, resulted in a greater richness and abundance of insects, including the pollinating ones. The greater number of predator insects resulted in a decrease in the number of aphids. It is especially precious that the biodiversity on organic farms is made up by the rare species of flora, broad-leaved weeds, pollinated by insects and legumes. Numerous research cited by Hole et al. [2005], and providing a comparison of the occurrence of non-crops in the fields in various farming systems, demonstrate that it is more diverse on organic than on the conventional farms. In the intensively-cultivated fields there decreases especially the number of broad-leaved weeds easily eliminated by the herbicides application, and to less extent – of grasses. A high diversity of flora in organic fields is found all over their area. On traditional farms it mostly focuses on the crop edges where the effect of herbicides is lower [Romero et al. 2008]. The farming system affects not only the plant abundance but also the abundance of their seeds. In organic fields a greater number of weed seeds is consumed by fauna, mostly birds [Navntoft et al. 2009].

The biodiversity of agrophytocenosis on arable land, especially in intensive farming, is determined by crops. The richness and diversity of crop species depend on habitat conditions and the plant production organization on the regional scale and on an agricultural farm. The diversity of crops defined by Jaskulski and Jaskulska [2011] in the Kujawy and Pomorze Province, in Poland, applying the algorithm of the Shannon-Weaver index depended on many features of the landscape, e.g. the share of components of high ecological value, including woodland, grasslands in the total area and the features of the agroecosystem and the farm; the soil quality and the crop structure. The number of crops and their diversity were an effect of the interaction between the habitat conditions and the farm organization. The number of crops in the arable fields in the region depended on the share of the woodland, woodlots and meadows in the total area and crops in the total acreage of arable land. The crop diversity index was an effect of the interaction between the soil quality index, the share of woodland in the total area, the share of pasture and set-aside land and crops in the total acreage of agricultural land or arable land.

To maintain the diversity of crops on arable land not only a high number of crop species is essential but also a lack of a strong domination of the crop structure by single crops. The analysis of changes in the crop diversity on arable land in Poland over 1960 – 2009 confirms that hypothesis. Despite the production intensification and an increased farm size (Fig. 4A), the crop diversity index H′ value from 1960 to 1990 was increasing (Fig. 4B), which must have been due to the share of rye in crops getting strongly decreased and that of a few other crops getting increased, to include wheat, barley, triticale, cereal mixtures, and rape. At the beginning of the 21st century the diversity index value got slightly lower due to an increase in the domination of wheat in crops (Table 3).

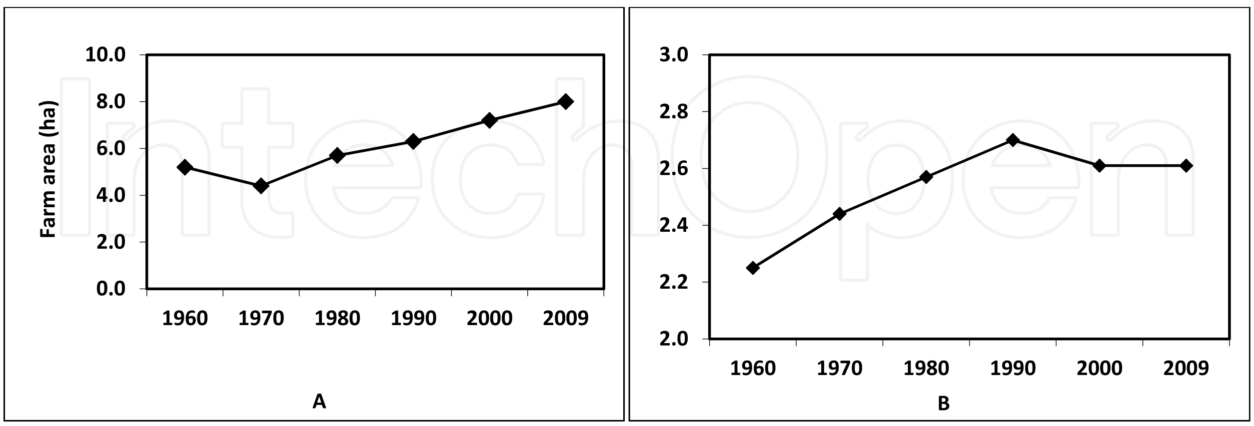

Figure 4. Changes in farm size - A and index of crop diversity by Shannon-Weaver H′ - B

Crop	Year					
	1960	1970	1980	1990	2000	2009
Wheat	8,9	13,3	11,1	16,0	21,2	20,2
Rye	33,4	22,8	20,9	16,3	17,2	12,0
Barley	4,7	6,2	9,1	8,2	8,8	10,0
Oat	10,7	10,2	6,9	5,2	4,6	4,5
Triticale	-	-	-	5,3	5,6	12,6
Grain mixtures	1,7	2,7	5,1	8,2	11,9	11,5
Potato	18,8	18,2	16,2	12,9	10,1	4,4
Sugar beet	2,6	2,7	3,2	3,1	2,7	1,7
Oil plants	0,9	2,2	2,3	3,5	3,5	7,0
Fodder	4,7	4,9	5,5	4,9	2,4	3,6

Table 3. Share (%) of the main crops in the crop structure in Poland

The genetic variation pool within a given species is made up by cultivars. Creative breeding gives rise to new genotypes meeting the expectations of producers and consumers. Breeding work involves not only the plant yield-forming potential but also the physiological and morphological traits determining the reaction of the plants to habitat factors. The cultivars of a given species differ in their vegetation period length. The phenotype variation is seen from the morphology of the underground and above-ground parts. The size, the extent and the physiological activity of the root system differ. Cultivars vary in the habitat, height, foliage, and the colour of flowers. Breeding differentiates the resistance of the plants to abiotic stress habitat factors, including: low temperature, water deficit, soil reaction. The resistance to diseases, pests and weed infestation varies. The richness of cultivars of crop species demonstrating varied biological and functional traits facilitates the plant production compliant with the principles of various farming systems using the advantages of the agricultural production space. To maintain the biodiversity in agroecosystems, it is especially important to grow old traditional crop cultivars. They are adapted to local habitat conditions and extensive agrotechnical practises. At present there is a need to breed cultivars adapted to organic farming. They should differ in terms of physiology and morphology from the cultivars in conventional farming, which guarantees easily available nutrients and the protection from agrophages [Konvalina et al. 2009]. They should demonstrate a fast initial growth, a high foliage index and high stems. Such plants are competitive towards weeds, which allows for eliminating the application of herbicides from agrotechnical practises. Such cultivars should also show high resistance to diseases and pests.

Numerous breeding directions meeting the requirements of producers and consumers make, on the regional scale of respective countries, the cultivation of a few dozen or so and even over a hundred cultivars of some plant species possible. The real diversity of cultivars of a given species in field plant production is, in general, lower. It depends, on the one hand, on the desired quality and the methods of yield use as well as habitat-economic growing conditions and, on the other hand, on the available scope of cultivars with genetic-phenotypic traits allowing for such production.

In the Kujawy and Pomorze Province, in Poland, Jaskulska et al. [2012] found a variation in the richness of cultivars of crops grown on agricultural farms. They were determined as a ratio of the number of cultivars of a given species grown to the number of its plantations. The highest value of the cultivar richness index was recorded for potato plantation (0.71). It means that per 100 plantations there were 71 various cultivars. A high value of the richness index also concerned sugar beet (0.65) and maize (0.64). Lower cultivar richness was reported in cereals and in winter rape. The index value for rye cultivar richness was only 0.31 and it must have been due to a low number of cultivars and a high domination of crops by one of them. A strong domination by single cultivars was also reported for sugar beet and potato crops, which resulted in relatively low cultivar diversity. The diversity index was determined using the Shannon-Weaver algorithm; it ranged from 2.39 for rye to 3.98 for winter wheat. A high diversity was also found for spring barley, maize, winter rape, and winter triticale.

In contemporary agroecosystems, dominated by single-species crops, the cultivation of mixtures plays a very essential ecological role. On arable land it is possible to find the fields of genetically-diversified crops. They can be made up of the crops of various, even systematically distant, species or of the same species, however, of various cultivars. Not only the production but also ecological role of that kind of plant growing method are considered both in the agri-environmental research and the policy [Østergård and Fontaine 2006]. In the interspecific mixtures most often various species of cereals and cereals with papilionaceous plants are grown. The mixtures of single-species cultivars are usually arranged for cereal crops but also for others [Sobkowicz and Podgórska-Lesiak 2007]. Undersown crop is also a kind of mixed crop.

A positive ecological role of mixtures in agroecosystems comes from:

- complementary effect of various plant genotypes in the field,
- a better filling-in of the ecological niche by the stems of a few morphologically verified genotypes and their root systems, which facilitates the production of a greater amount of biomass,
- conditions facilitating the presence of a greater number of fauna,
- conditions for the self-control and maintaining the biocenotic equilibrium in the fields,
- a greater plant resistance to agrophages and a possibility to limit the application of pesticides,
- the possibility of restricting mineral fertilization, especially with nitrogen in the multi-specific fields with papilionaceous components.

According to FAOSTAT, the greatest share of mixtures in crops in Europe is found in Poland; in 2010 out of a total of about 1.54 million ha of grain mixtures, 1.33 million ha - in this country. Those are mostly the mixtures of spring cereals: hulled barley with hulled oats or naked oats, hulled barley + naked or hulled oats, oats with triticale, barley with triticale, wheat + oats or barley [Szempliński and Budzyński 2011]. In the mixtures also cereals with legumes or fodder grasses are grown. For the biodiversity of crops in arable fields, growing mixtures of a few cultivars of the same species is of similar importance.

The diversity of crops on arable land is supplemented by intercrops. In contemporary agriculture those are important components of field plant production essential for the environment and agroecology. They demonstrate a direct and indirect effect on the biodiversity of agroecosystems and agricultural landscape. They are an element of agri-environmental programs. In Poland in the mid of the first decade of the 21st century intercrops accounted for about 4.5% of arable land. Many plant species representing families *Fabaceae, Brassicaceae, Poace*, and others, are sown as intercrops. In crop rotation placed between two main yields, they increase the biodiversity of plants in rotation significantly. The effect of intercrops in the agroecosystem is comprehensive. It concerns both the period of their vegetation and the effect of the biomass remaining on the surface or introduced into soil. A short review of agricultural and environmental research [Jaskulska and Gałęzewski 2009] includes its numerous examples.

Intercrops limit non-point pollutions. They play the function of a biological filter. At present in the fields in the periods between successive production cycles they intake nutrients from soil protecting them from leaching to drainage and ground waters. The surface soil layer bound with the root system and covered with the stem biomass is secured from water and wind erosion, protecting not only directly arable fields but also indirectly landscape components limiting the eutrophization of reservoirs and watercourses, midfield ponds shallowing. The phytomass of vegetating plants, post-harvest residue and mulch stimulate the occurrence of other organisms in the habitat, which increases the agroecosytem stability. The biomass can increase the count, diversity and the activity of bacteria, fungi, protozoa and the nematodes. It also enhances the presence of parasitoids and pollinating insects.

Growing intercrops affects the carbon economy in agroecosystems and in the environment. The production of phytomass by those plants is an ecological method of carbon sequestration. Carbon dioxide bound in the biomass increases the content of organic carbon in soil. The plants and mulch decrease the amplitude of temperature of the soil surface layer, restrict its heating. It reduces the intensity of organic matter mineralization and the emissions of carbon dioxide to the atmosphere, which can decrease the contribution of agriculture to global climate warming.

3. Conclusions and recommendations

Agricultural landscape in many countries is the dominant landscape. As a result of human activity it has been transformed. Currently, it is primarily the production function. For the realization of social and cultural needs of the human need to preserve the natural values of those areas. It should cultivate and reclaim mosaic character of agricultural landscape and agroecosystems. They must be a lot of ecological islands and natural landscape components. The particular is the role of forest enclaves, midfield shelterbelts, avenues of trees, wetlands, swamps, bogs, ponds, streams, ditches, roads midfield, borders, etc. Their values are a large diversity of plants. Those components demonstrate a high flora diversity; aquatic plants and land plants of various stands. There exist clusters and single trees, shrubs, herbaceous communities of annual and perennial plants. High richness and diversity of plants determines the occurrence of many fauna. Those components play the role of microclimate and protection. They limit the effects of extreme weather events, soil degradation, pollution, greenhouse gas emissions. In agricultural ecosystems must be maintained semi-natural grasslands with their rich of flora and fauna and the preservation of environmental functions. In the field production should be limited assemblage of single crops in large fields. It should be kept of multispecies crop rotation in small fields with plants belonging to different botanical taxonomy, use groups, and cultivars. In addition to new varieties of crops should be present the old local genotypes. In crop canopies and their mixtures is also possible occurrence of non-cultivated plants. The interval between production cycles should be used for the cultivation of intercrops.

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