## Chapter 1

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# The Condition of Agroecosystems and Potential Threats

### 1. Introduction

In his book entitled *Losing Ground. Environmental Stress and World Food Prospects*, Erik P. Eckholm describes the blend of negative consequences of land use since the dawn of civilization as well as potential threats for the future. This problem is the main focus of this discussion, therefore, we will begin by quoting Eckholm's key arguments in reference to environmental degradation (1975).

*"In their relations with nature, as in their relations with their fellows, human beings appear to be poor students of history. Despite the all too visible diorama of ruined landscapes and abandoned civilizations, mistakes of the past seem time and again to serve as models instead of usable lessons. Deaf to the almost daily warnings of some looming new ecological threat, governments and individuals rarely change their habits accordingly. Studies of human-caused environmental degradation sometimes leave an aftertaste of near-misanthropy (...). Given the record, it is tempting to blame the continuing devastation on human ignorance or stupidity (...).*

*"Land-use patterns are an expression of deep political, economic, and cultural structures; they do not change overnight when an ecologist or forester sounds the alarm that a country is losing its resource base. In many countries, the deterioration of the land will not be halted until basic changes in land tenure and national economic priorities occur (...). Until the environment suddenly is the major national crisis, its deterioration may occur almost unnoticed, with the costs quite real but difficult to total up (...). Both governments and the public want dramatic production gains now, not an investment of scarce funds to satisfy what may seem hypothetical future needs (...). Even more crucial than the analytical failure has been the communication failure. Those who know the ecological score too frequently feel their job is done when a report is filed in a professional journal that is accessible, in terms of language as well as distribution, mainly to other*

*scholars. Those who most need to know about impeding ecological disasters and then act on their knowledge – particularly politicians, civil servants, journalists and farmers – are frequently almost totally ignorant of what is happening. Establishing the urgency of a critical problem not traditionally recognized as such requires the constant broadcast of the facts and their implications to as many people as possible, through all possible means (...). Ecologically sound planning requires concern for the next decade, the next generation and beyond."*

The above quote from E. P. Eckholm's book (Chapter 10. The Politics of Soil Conservation) masterfully outlines the problem of degradation and reclamation of farmland. The discussed issues fully apply to the existing and future threats in Poland's agroecosystems (Siuta, Żukowski 2008). Due to vast social, cultural, economic, historical and political differences across Poland, farmland modification practices produced both positive and negative consequences which vary significantly between regions. The most notable differences are observed in respect of farm size, plot fragmentation (checkerboard pattern), agricultural and environmental engineering projects (land improvement and drainage, construction of rural roads), adapting the land use regime to local soil conditions and relief features (landscape architecture), soil protection against water and wind-induced erosion, cultivation technology and crop yield. Our knowledge about the rise and fall of agrarian civilizations since the ancient times indicates that farming activities have both positive and negative implications for the soil and other components of natural environment. The durability of positive effects is determined by the manner of land use, cultivation regime, biomass management, measures undertaken to prevent land degradation, and a broad spectrum of both permanent and variable external factors. Civilization progress aimed to intensify farming production and industrial crop use significantly shortens the duration of positive effects which are delivered by the appropriate cultivation regime. The above is especially true of soils, and a vast portion of arable land in Poland is naturally susceptible to degradation. The dynamic increase in industrial demand (in particular in the power industry) for plant material, and the continued drive to maximize economic profit poses a serious threat for the ecological and productive status of soils due to the rapid loss of life-sustaining organic matter. Large-scale monocultures and intensive livestock production contribute to ecological degradation and minimize the productive capacity of soils.

In many Polish regions, outdated farm structure and land use practices pose the key barrier to modernizing agriculture and protecting soils from progressive degradation. Poland lags far behind other European Union Member States in this respect. The adoption and implementation of an "integrated program for the planning, use and development of rural areas" should be a priority undertaking if Poland wants to be seriously committed to the protection of its key natural and economic resources.

The following threats to agricultural soils are observed in Poland:

- ineffective structure of farmland,
- water and wind-induced erosion,

- landslide,
- flooding,
- loss of humus,
- structural degradation of soil, including hardpan formation,
- degradation of drainage systems,
- acidification,
- chemical and mechanical contamination,
- loss of biologically active soil surface,
- degradation of the soil's biological function.

## 2. Changes in the percentage share of farmland in Poland's total land area since 1960

Significant changes in the share of farmland were observed between 1960 and 2010, as illustrated below: 1) the area of arable land decreased from 49.6% to 44.6%, the share of permanent grassland was reduced from 13.4% to 12.5%, forest area increased from 23.6% to 29.7%, tree and shrub cover grew from 0.6% to 0.8%, the area occupied by water bodies increased from 1.7% to 2.7%, the share of roads increased by 0.4% and of railways – by 0.1%, the built-up area of residential estates increased from 0.8% to 3.3% and non-built-up area increased by 0.1%, the share of urban and residential green spaces remained constant, the share of miscellaneous land cover decreased from 2.4% to 0.3%, wasteland area decreased from 2.8% to 1.5%, and the difference between surveyed area and registered area was minimized from 3.2% to 0.15% (Table 1).

The discussed period witnessed a steady drop in farmland area with an increase in forest grounds. Afforestation projects were initiated mainly on soils of lowest class and in arid wastelands, and most of those schemes were carried out in 1949-1970 (Fig. 1). Forest cover statistics for Polish regions in 1999-2010 are presented in Figure 2. The significant increase in forest grounds is a major environmental and economic achievement. Nevertheless, further afforestation initiatives are much needed in most parts of Poland.

## 3. Causes and types of soil degradation

### 3.1. Ineffective structure of farmland

A system of highly fragmented land plots (checkerboard pattern) significantly obstructs effective cultivation, decreases the efficacy and profitability of farming production, contributes to environmental degradation and prevents the use of modern farming equipment. In countries and regions with effective farming systems, arable land had not been excessively fragmented in the past, and small plots and farms were consolidated in the process of building farming utilities, including roads and drainage systems, and landscape shaping. We shall refer to those processes as "integrated planning and use of rural areas".

Table 1. Changes in farmland structure in 1960 – 2010 based on land register data

| Year | Cropland | | | | Forests | Trees and bushes | Land under water | | | Mining lands | Roads | Railways | Urbanized areas | | | Ecolo-gical sites | Various areas | Fallows |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Arable lands | Orchards | Meadows | Pas-tures | | | Reser-voirs | Water-courses | Other | | | | Built-up | Non built-up | Green | | | |
| Thousands of hectares | | | | | | | | | | | | | | | | | | |
| 1960 | 15353,7 | | 2428,6 | 1768,0 | 7747,1 | 84,3 | 489,0 | 212,3 | 53,2 | 33,6 | 669,5 | 104,4 | 295,4 | 38,5 | 53,3 | - | 276,9 | 771,2 |
| 1970 | 15052,8 | 280,0 | 2534,5 | 1702,7 | 8563,0 | 48,4 | 222,6 | 416,2 | 155,4 | 27,7 | 765,0 | 122,4 | 605,2 | 42,5 | 45,2 | - | 264,3 | 369,2 |
| 1980 | 14732,6 | 304,9 | 2451,7 | 1663,9 | 8630,2 | 111,4 | 137,9 | 512,3 | 162,1 | 36,1 | 831,2 | 120,5 | 709,2 | 59,5 | 53,1 | - | 246,7 | 469,6 |
| 1990 | 14362,3 | 320,4 | 2424,9 | 1697,1 | 8705,0 | 170,8 | 141,7 | 523,2 | 160,1 | 40,9 | 865,8 | 121,7 | 815,1 | 68,3 | 60,6 | - | 254,9 | 503,5 |
| 2000 | 14136,6 | 314,5 | 2380,8 | 1705,1 | 8867,9 | 226,0 | 300,7 | 456,3 | 75,7 | 38,1 | 840,6 | 119,0 | 900,9 | 79,5 | 69,2 | 9,5 | 215,5 | 499,4 |
| 2010 | 13947,7 | 292,1 | 2290,6 | 1637,3 | 9270,7 | 254,6 | 273,3 | 495,0 | 80,2 | 29,1 | 776,1 | 115,2 | 1035,0 | 51,5 | 65,4 | 34,5 | 100,5 | 481,5 |
| Share in the structure (%) | | | | | | | | | | | | | | | | | | |
| 1960 | 50,5 | | 8,0 | 5,8 | 25,5 | 0,3 | 1,6 | 0,7 | 0,2 | 0,1 | 2,2 | 0,3 | 1,0 | 0,1 | 0,2 | - | 0,9 | 2,5 |
| 1970 | 48,2 | 0,9 | 8,1 | 5,5 | 27,4 | 0,2 | 0,7 | 1,3 | 0,5 | 0,1 | 2,5 | 0,4 | 0,1 | 0,1 | 0,1 | - | 0,8 | 1,2 |
| 1980 | 47,2 | 1,0 | 7,8 | 5,3 | 27,6 | 0,4 | 0,4 | 1,6 | 0,5 | 0,1 | 2,7 | 0,1 | 2,3 | 0,2 | 0,2 | - | 0,8 | 1,5 |
| 1990 | 46,0 | 1,0 | 7,8 | 5,4 | 27,9 | 0,5 | 0,5 | 1,7 | 0,5 | 0,1 | 2,8 | 0,1 | 2,6 | 0,2 | 0,2 | - | 0,8 | 1,6 |
| 2000 | 45,4 | 1,0 | 7,6 | 5,5 | 28,5 | 0,7 | 1,0 | 1,5 | 0,2 | 0,1 | 2,7 | 0,1 | 2,9 | 0,3 | 0,2 | 0,0 | 0,7 | 1,6 |
| 2010 | 44,7 | 0,9 | 7,3 | 5,2 | 29,7 | 0,8 | 0,9 | 2,0 | 0,3 | 0,1 | 2,5 | 0,1 | 3,3 | 0,2 | 0,2 | 0,1 | 0,3 | 1,6 |

Source: Main Office of Geodesy and Cartography

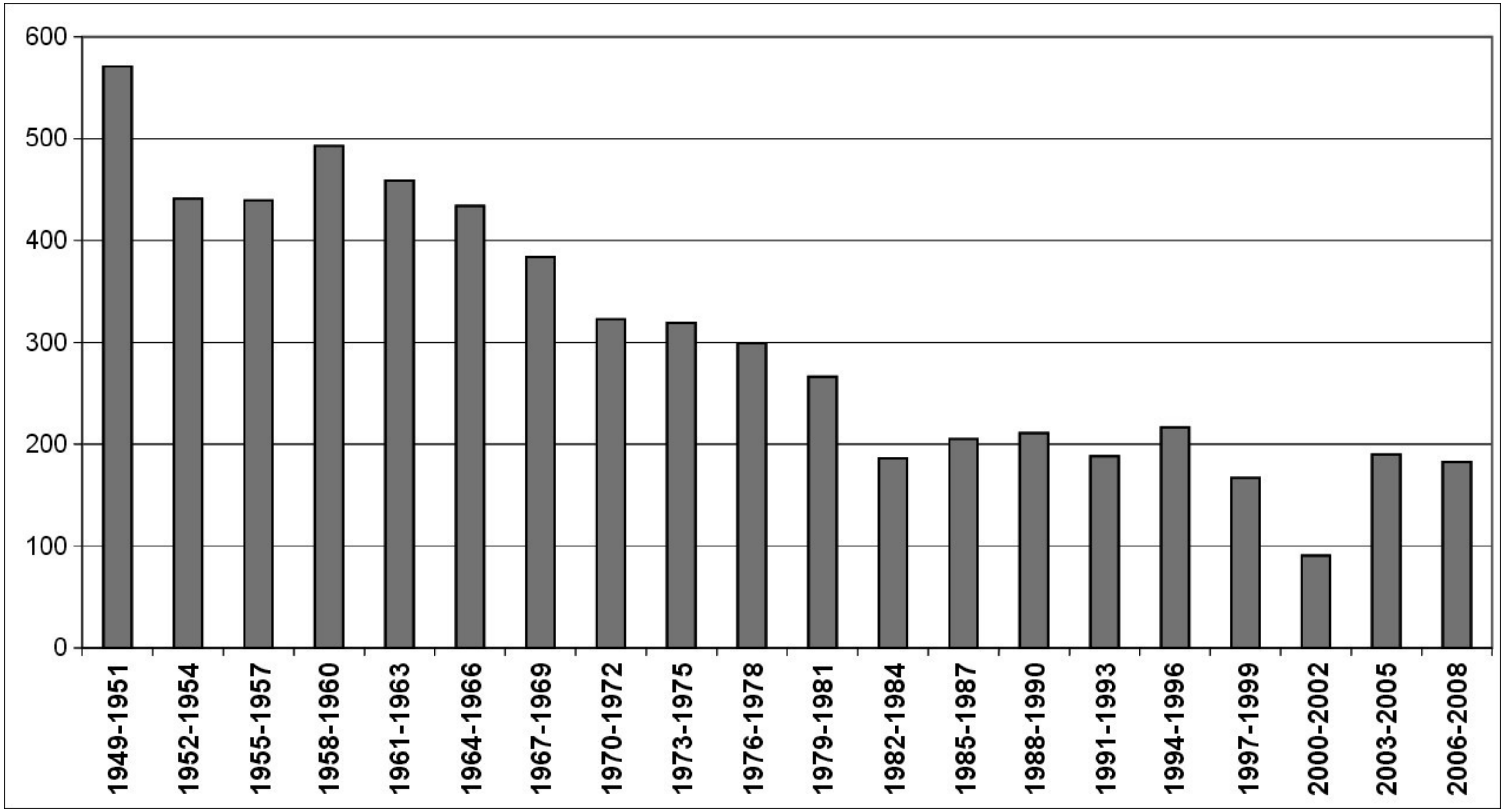


Fig. 1. Afforestation projects in 1949-2008 ('000 ha)
Source: Central Statistical Office (GUS)

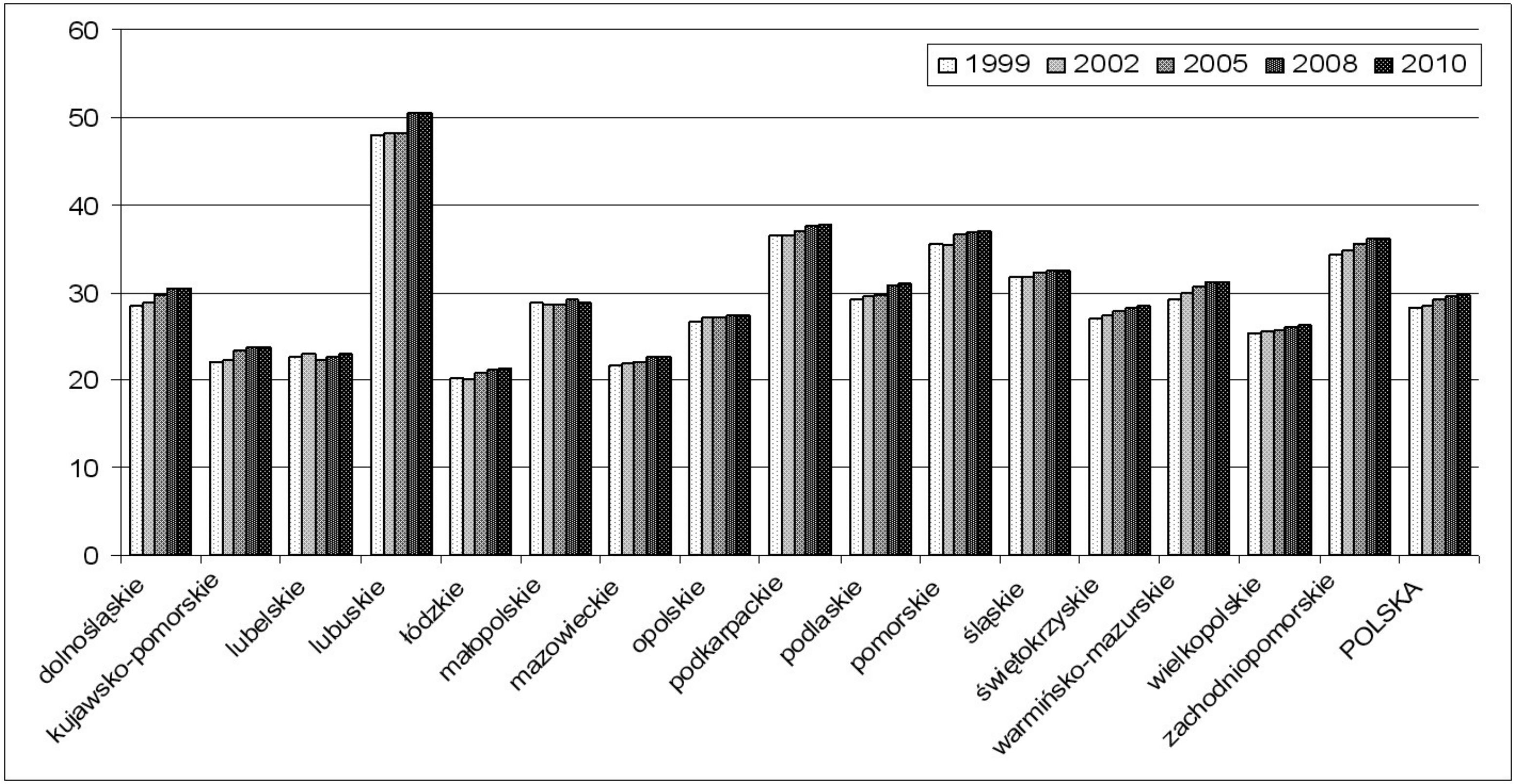


Fig. 2. Forest cover in Polish regions in 1999-2010 (% share of total area)
Source: Central Statistical Office (GUS)

In legal acts implemented in 1968 and 1982, Polish legislators focused mainly on consolidating fragmented farmland plots. In 1918-1939, checkerboard fields covering an area of more than 5.4 million hectares (including 11,000 villages and nearly 900,000 farms) were merged, mostly in the eastern provinces and the former territories of Congress Poland. Those measures resulted in the consolidation of more than 400,000 hectares of land in 1929, and more than 500,000 hectares of fragmented plots were consolidated in 1930 and 1931 (Dumański 1969).

In Polish territories annexed by Prussia, farms were consolidated as early as in the 19$^{th}$ century, which is why few measures of the type were launched in the region after Poland had regained its independence. The territories annexed by Austria were characterized by a very high degree of land fragmentation, and little progress was made to consolidate checkerboard ownership patterns between the world wars. The onset of communism in 1945 did not support farm development, and although the new authorities aimed to maximize food production, farmland was rarely consolidated. According to experts, consolidation of checkerboard ownership is a powerful stimulus for agricultural production which also lowers operating costs. The results of multi-year studies carried out between the world wars indicate that consolidation schemes increased crop yield by 30% to 50% or more (Dumański 1969).

In the past, land consolidation and replacement were regarded as workshop improvement methods. The rise of knowledge, environmental awareness, technological advancement and the introduction of environmental protection laws contribute to our belief that Poland is in dire need of an integrated program for the planning, use and development of rural areas. The traditional belief that every farmer has exclusive rights to his land needs to be eradicated from the Polish agricultural system where "the invisible hand of the market contributes to spatial chaos that poses a significant threat for the environment and the national economy".

A map of Polish municipalities where farm consolidation measures were most needed (according to 1988 data) is presented in Figure 3. Land consolidation and replacement projects carried out in 1968-2009 failed to satisfy the existing needs (Fig. 4). Land consolidation and replacement measures are regarded as a method for improving farmland productivity (legal acts of 1923, 1963, 1992). The rise of knowledge, environmental awareness, technological advancement and the introduction of environmental protection laws contribute to our belief that a traditional approach to land consolidation and replacement is no longer a sustainable alternative.

The postulates, recommendations and decisions formulated in various publications, programs, national and international papers (Dębicki, Gliński 1999; Agenda 21 1993; Eckholm 1978; European Commission 2004; European Commission 2007; European Commission 2002; Niewiadomski, Grabarczyk 1977; Pijanowski 1992, 2009; Siuta 1974; Żmuda 2005) in the area of soil and plant protection cannot be effectively implemented unless Poland adopts a strategic program for integrated planning, use and development of rural areas, modeled on the example of European leaders. This process requires long-term education at all levels of schooling and management, expert personnel, an effective system for project development and implementation as well as soil monitoring and protection measures. In this respect, the backwardness of Polish agriculture does not result from the lack of specialist knowledge, the experts' negligent approach to law-making or failure to provide the required funding, technical means or administrative solutions.

According to the draft act on planning agricultural production areas, developed by the Ministry of Agriculture and Food Economy in 1977, farmland management plans were to be developed at the municipal level, in particular in areas where the following measures were required:

a) land consolidation,
b) reclamation and fertilization of farmland, prevention of soil erosion,
c) construction and upgrading of access roads and other farm utilities, and provision of technical infrastructure,
d) construction and upgrading of drainage systems,
e) environmental and landscape protection.

The above draft comprehensively addressed modernization and planning requirements in rural areas. The explanatory statement to the proposed act reads: "The need to bring Polish agriculture up to European standards and increase its competitive advantage in trade relations with the European Union requires a legal framework that supports a structured approach to the reconstruction and development of rural areas". Unfortunately, due to the existing level of knowledge at the time and the lack of political will on behalf of the legislator, the draft was not revised, and the act was never adopted.

### 3.2. Soil erosion

Soil erosion is a hidden threat to agriculture. Since the dawn of farming, the ecological and economic consequences of erosion have been described (Eckholm 1978; Strzemski 1958, 1971) not only in scientific publications, but also in literary works. Erosion produces diverse relief structures which are much admired landscape features. Water and wind erosion is a natural phenomenon which may support the evolution of soil and vegetation. Farming destroys permanent plant cover by replacing it with plant species that have a short growing period and require various soil cultivation measures. The course, intensity, type and progression of soil erosion are determined by both natural factors and farming practices. Those factors have been well researched in Poland, and their geographic distribution has been documented in view of geomorphic and meteorological conditions as well as the local cultivation regime (IUNG 1992; Józefaciuk, Józefaciuk 1992, 1996; Lipski, Kostuch 2005; Niewiadomski, Grabarczyk 1977; Advances of Agricultural Sciences, Problem Issues 2002; Startel 1980; Stasiak, Szafrański 2005; Wawer, Nowocień 2006; Wnuk 2005). Most potential threats have been recognized and effective solutions have been proposed to prevent (minimize) erosion and reclaim strongly degraded areas.

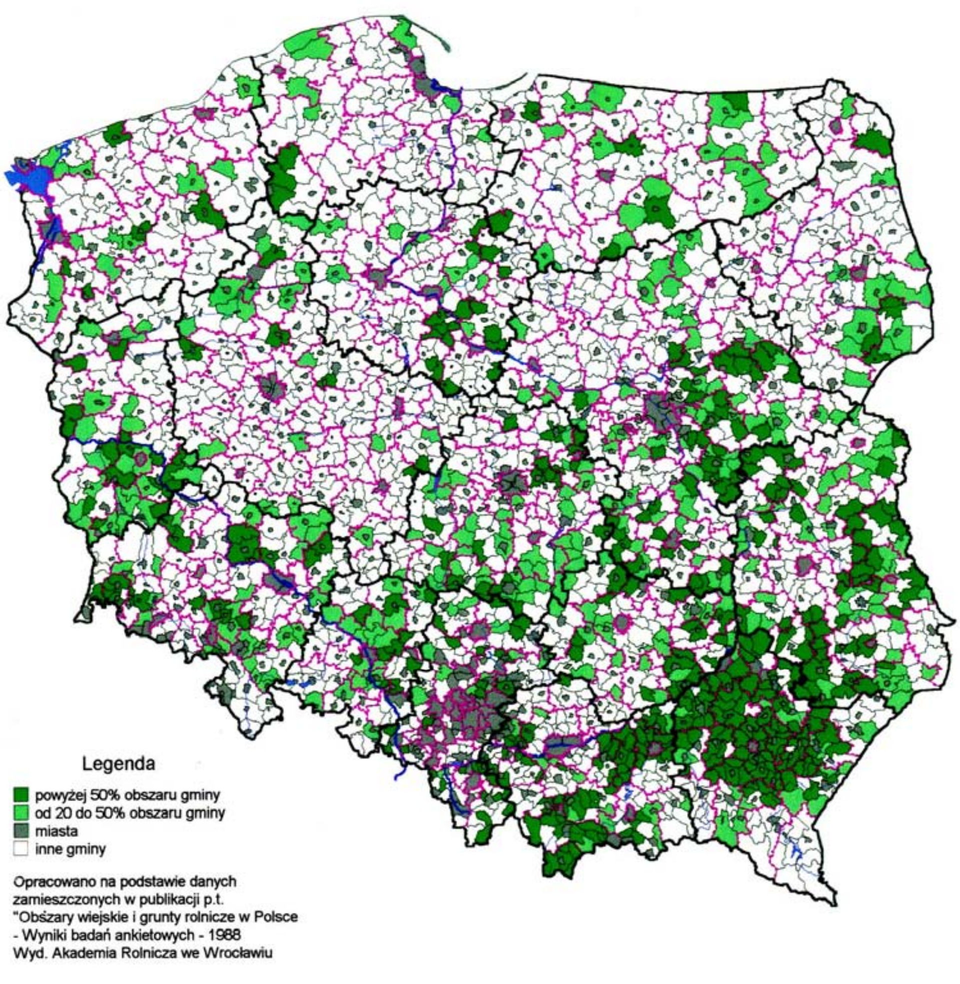


Fig. 3. Land parcels destined for consolidation in municipalities in 1988

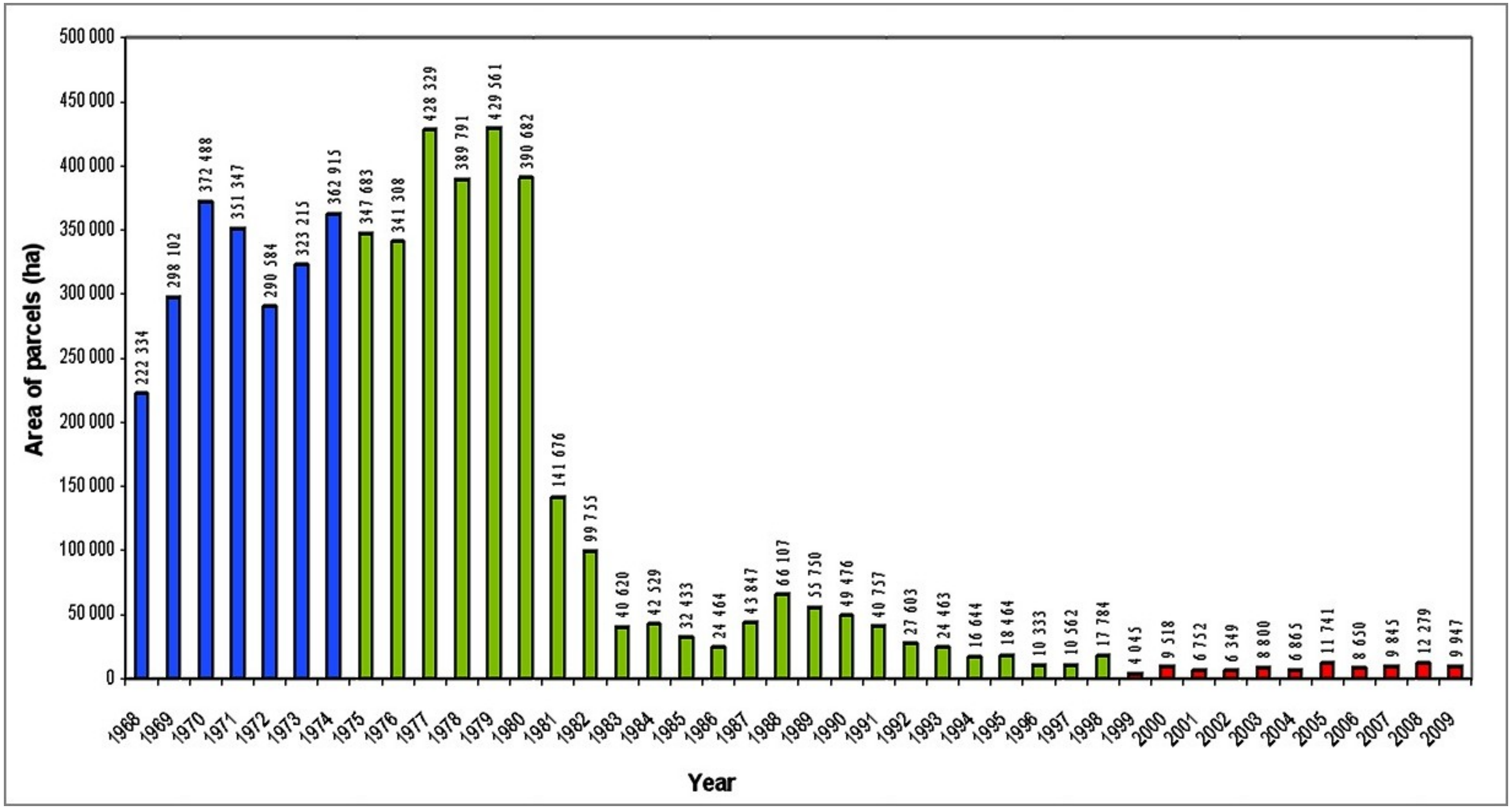

Fig. 4. Consolidation and replacement of arable land in 1968-2009 (ha)
Source: Ministry of Agriculture and Rural Development

Extreme precipitation events and violent downpours enhance wash-out from soils in locations that are seemingly not susceptible to water erosion. The movement of air from wet soil into the ambient additionally contributes to this adverse phenomenon.

It may seem that we have accumulated significant knowledge and technology to effectively protect farmland from erosion. However, erosion damage is not noticeable over short periods of time, and when its consequences are finally manifested, the required repair measures are very costly and time-consuming. The environmental and agricultural consequences of erosion will not affect those who are responsible for negligent agricultural practices, but the future generations. Effective erosion prevention requires greater awareness and motivation on behalf of land users. Extensive environmental and financial damage caused by erosion (such as gullying) requires costly and time-consuming remedies that exceed the capabilities of individual land users and farmer communities.

Soil erosion and the reclamation of degraded areas are complex problems that can be solved only by modernizing land use planning and introducing rational land management policies. This approach requires a strategic program for integrated planning, use and development of rural areas. In Poland, the legislative process is a long road paved with many obstacles, therefore erosion control and repair measures in degraded areas could prove to be relatively ineffective.

### 3.3. Landslide

Landslide is observed in areas where geological structure, relief and hydrological regime of land supports ground movement. It is intensified by human activity and land use practices that upset the natural structure of land. Specific forms of landslide degradation are noted in areas where underground mining takes place. Mining damage is documented and repaired in line with the provisions of the geological and mining law. Landslides occur mainly in mountains and foothills, along the Baltic coastline and sections of river valleys. They are sporadically noted at the base of very large banks of mineral waste and soil from surface mines. Advanced methods of neutralizing waste and reclaiming soils minimize the threat of erosion and landslide.

Timely control of soil erosion and landslide and the initiation of repair and preventive measures can counteract environmental protection and economic loss in the local community. Poland lags far behind in this respect, but recent legal acts have put the country on the right track. The risk of landslide affects relatively few areas in Poland, therefore, we can expect significant progress to be made as regards landslide prevention and repair.

### 3.4. Soil degradation and deterioration of drainage systems

The discussion about positive and negative consequences of land drainage raises much controversy for the following reasons: 1) the belief that drainage reduces groundwater resources, 2) the incorrect use of the term "drainage system" to denote a system that regulates air-water relations in soil, 3) insufficient knowledge about the soil environment and air-water relations in soil, 4) past use of non-selective draining techniques in soils that respond both positively and negatively to the above treatments, 5) adverse consequences of incorrect drain use, absence of drain reconstruction and upgrading measures which have been largely neglected over the past decades.

Negative opinions about drainage systems are intensified as the public becomes more aware of environmental protection needs, nonetheless, those views are rarely rooted in thorough knowledge. They often coincide with the negative perceptions of legislative and administrative authorities who are reluctant to finance the recovery of degraded drainage systems.

Beginning in 1950, the quantity of drainage repair works has been clearly correlated with the economic situation in Poland. The number of reinstatement projects decreased dramatically in 1956-1959, 1979 and 1980, and hardly any repair measures have been initiated since 1991 (Fig. 5). According to the "Report on the government program for drainage system management", developed by the Ministry of Agriculture, Forestry and Food Economy (1986), around 1 million hectares of land were in dire need of drainage repair and reconstruction, and by 1996, this area increased to 2.68 million ha (Siuta, Żukowski 2009).

The number of drainage construction and renovation projects carried out in 1950-1989 is shown in Figure 6. The nearly complete absence of drainage recovery projects expands the acreage of low quality soils and contributes to environmental degradation. Due to the lack of a monitoring system, Polish legislators do not recognize it as a critical problem, although the issue raises much concern in expert communities (Kaca 2011). They recent lobbying efforts to protect and expand the acreage of productive soils have not been very effective.

The European Union's thematic strategy for soil protection does not list defective drainage systems as a potential cause of soil degradation. This is a growing problem in Poland, and we can only hope that it will be duly recognized and dealt with in the near future.

### 3.5. Soil degradation caused by flooding

Heavy precipitation may lead to the flooding of closed basins and flat areas with limited water outflow and slow infiltration rates. Flooding significantly contributes to the degradation of arable land, and it creates areas with highly diversified ecosystems and crop production requirements. An extreme example of the above are territories where spring thaw floods lead to the extinction of local vegetation. Dieback of rapeseed, agrimony and winter grain crops was observed in the spring of 2009, and massive land flooding took place in 2010. Flooding is not considered to be a true cause of arable land degradation because it occurs locally and with varied intensity, subject to precipitation patterns. It increasingly often affects fields with damaged drainage systems and ditches (Kaca 2011; Gospodarka Wodna 2011). Heavy-duty farming equipment contributes to structural deformation of soil (compaction, hardpan formation), it reduces soil permeability and leads to water retention on the surface. The loss of humic layers deteriorates soil's structural parameters, slows down infiltration and makes soils more susceptible to hardpan formation.

The gaseous phase plays a very important, but weakly recognized role in water retention and hardpan formation. Its significance has been demonstrated by the results of model studies and natural deformations of alluvial soils flooded in summer (Siuta, Terelak 1965). Air is forced out of the soil by the pressure of infiltrating water. During dry weather, the pore space of soil contains mostly the gaseous phase which is pushed out into ambient air by water entering the soil. In the summer, when deeply dehydrated soils are immersed in water due to flooding or heavy rainfall, the water-logged surface layer blocks the release of air from the soil. Water-saturated earth, in particular loamy soil, has a semi-liquid consistency with an abundance of air bubbles that reduce its bulk density. Soil colloids are easily lifted by air bubbles and gas particles, and they create sand wedges in loamy soils (Fig. 7). In extreme cases, the rapid flow of gas particles moves soil from deeper layers to the surface together with colloids (aquatic environment), silt and filtered sand (Fig. 8). In horizontal drainage systems, air forced out of soil by infiltrating flood or precipitation water is freely released into the ambient environment. Biogas produced by the anaerobic decomposition of organic matter in an oxygen-deficient environment also contributes to soil deformation. In compact soils, horizontal drains also minimize the adverse consequences of flood waves.

Summer rainstorms destroy crops and degrade the soil environment which is naturally regenerated over time, subject to the applied farming regime and drainage technology. Permanent vegetation cover on land used for agricultural purposes speeds up environmental recovery. The above method is not effective in reclaiming areas that have been damaged by massive soil movement during a flood, as observed in Poland in the summer of 1997.

### 3.6. Loss of humus and the quality of mineral soils

The role and significance of humus has been widely discussed by publications in the field of soil science, agricultural chemistry, microbiology, biochemistry and crop production (Marszewska-Ziemięcka 1969; Musierowicz 1964; Świętochowski 1968; Mysków 1984).

In mineral soils used for agricultural purposes, the quality, content and distribution of humus are determined by natural processes as well as human activity. Humus parameters are a measure of soil's fertility and productivity, and they constitute the basis for land classification and determining the soil's quality class (Komentarz 1963; Strzemski, Siuta, Witek 1973). The vast majority of mineral soils in Poland are deficient and highly deficient in humus.

Detailed data regarding humus characteristics in Poland's mineral soils have been published by Pondel et al. (1979, 1985), Dobrzański et al. (1973) and Adamczyk (1966). Pondel, Terelak and Wilkos (1979) determined the humus content of 2600 soil profiles.

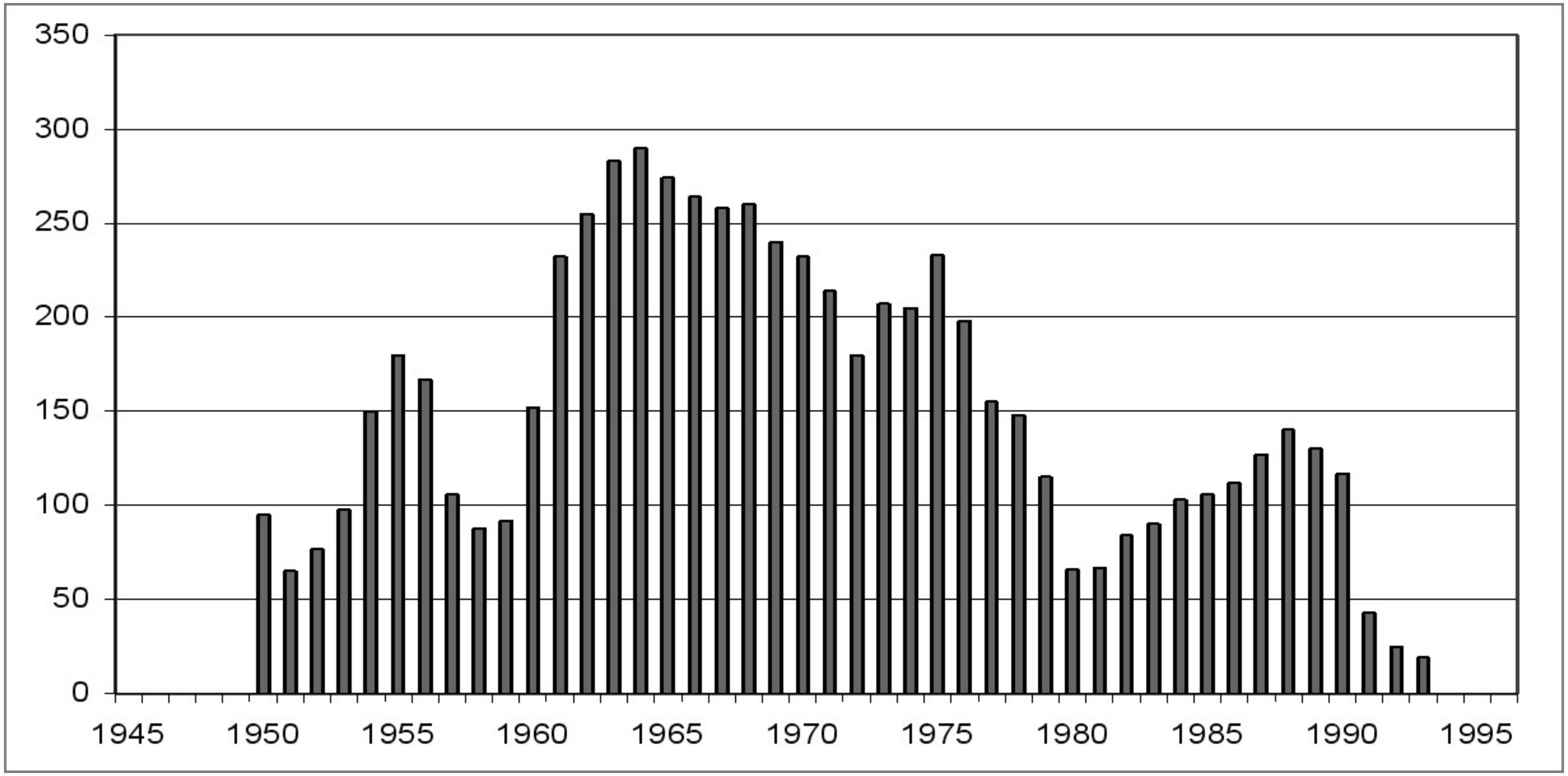

Fig. 5. Drainage networks built between 1950 and 1993

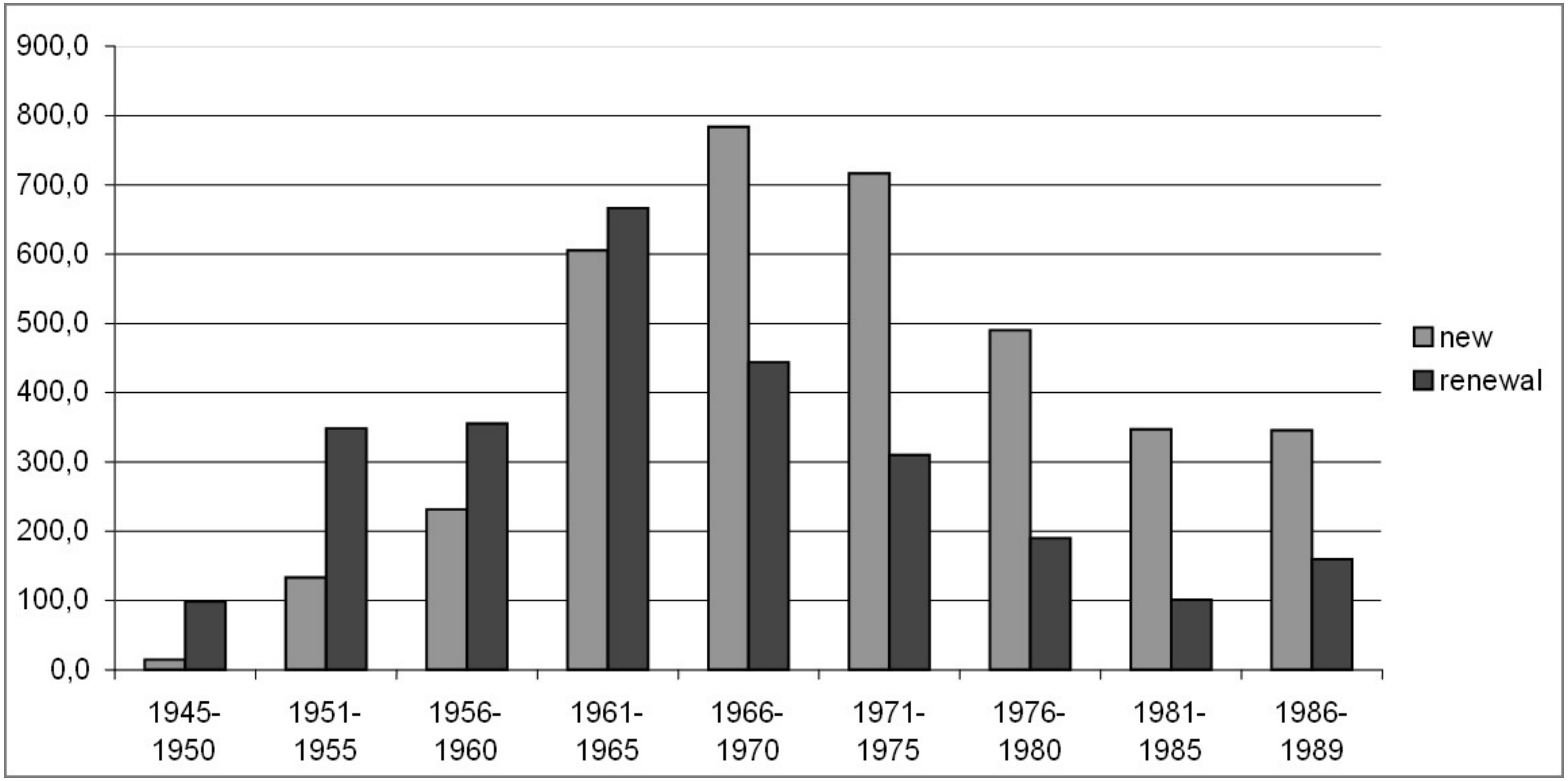

Fig. 6. Drainage works performed in 1945-1989 ('000 ha)

Fig. 7. Sand wedge in a layer of loamy soil, formed by air which was forced out of soil during seasonal flooding

Fig. 8. Sand washed out from fertile alluvial soil during a summertime flood of 1962 caused by the rupture of a flood embankment on the Vistula River in the area of Puławy

They concluded that "the average humus content of all soil classes (...) ranges from 1.58% in pseudopodzolic loamy soils to 2.07% in pseudopodzolic loess soils (...). Mineral soils with the highest humus content include alluvial soils, rendzinas, mountain soils, black earth and chernozems (...). In those soils, humus can be found also in the horizons below the ploughing layer."

The percentage content of humus in the topsoil is not a comprehensive indicator of the soil's quality and farming suitability. The thickness of the humus horizon and the total humus content per unit area of land give a much fuller picture of soil quality (Adamczyk 1996, Dobrzański et al. 1973). The average humus content of the analyzed brown and grey-brown podzolic soils ranged from 52 to 85 t/ha. Black earth (thickness of the $A_1$ horizon: 25-70 cm) contained 150 to 245 t/ha of humus, and chernozems – 204 t/ha. The average humus content of alluvial soils was 136 to 170 t/ha.

Soil quality is also significantly affected by the thickness of the humus horizon and humus transition into the soil profile (Siuta 1967, 1995). Most deforested mineral soils contain 1.4-1.6% humus in the topsoil (0 – 25 cm), i.e. around 52.5-60 t/ha. The above data point to the low agricultural value of deforested soils, and many other soil types have an even lower humus content. Non-sustainable use of vegetative parts of plants (straw, post-industrial waste, consumption waste), grain monocultures and the declining use of manure and green manure deplete humus resources and reduce the fertility of Polish soils (Maćkowiak 1997, 2000; Rabikowska, Wilk 1991).

The Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, entitled "Towards a Thematic Strategy for Soil Protection", COM(2002) 179 final, Brussels, 16.04.2002, states that: "Figures for England and Wales show that the percentage of soils with less than 3.6% organic matter rose from 35% to 42% in the period 1980-1995 (...). In the same period, in the Beauce region south of Paris, soil organic matter has decreased by half (...). Specialization in farming has led to the separation of livestock from arable production, so that rotational practices restoring soil organic matter content are often no longer a feature of farming (...). There is no evidence of significant reversal in negative trends in degradation processes. On the contrary, the information available suggests that, over recent decades, there has been an increase of some degradation processes (...). The principle of sustainable development is at the core of Community policy. The achievement of this objective will require policies delivering appropriate levels of soil protection (...). Soil protection requires an integrated approach based on existing knowledge and the adjustment and improvement of existing policies. However, it also requires the development of a more long-term approach whereby protection is based on a more complete knowledge both of the direct and indirect impacts of human activities and of the best practices and measures to address soil protection problems".

The European Union's appeals to minimize the threat of soil degradation stand in clear contrast to carefree "environmental protection" programs which advocate the use of biofuels. Plant biomass, the raw material for biofuel production, is needed to preserve the biological function of farmland (soil, vegetation cover, microorganisms, fauna). Whereas the use of plant waste for biofuel production is justified, intensified biomass production (in particular schemes funded by the State) as a source of renewable energy poses a serious threat for agroecosystems, food safety and the water cycle.

### 3.7. Adverse consequences of biomass cultivation and burning

The rapidly growing demand for electricity and heat as well as $CO_2$ emission reduction targets spur the search for alternative renewable sources of energy, including biofuels. Intensive biomass production and burning is regarded as a method that will largely satisfy the demand for energy and limit $CO_2$ emissions. The public opinion and the EU's optimistic plans are shaped by power engineers and visionaries who are oblivious of the consequences of intensified monoculture farming and biomass burning. The progressing industrialization of plant and animal production removes large quantities of biomass from the soil environment and generates massive amounts of waste. The use of waste biomass as a renewable source of energy is justified, nevertheless, it eliminates humus-generating organic substances which contribute to soil fertility. Although industrial-scale biomass burning seems to be a rational alternative today, it may lead to the degradation of biologically active soil surface in the near future. Organic matter is the main source of nutrition for soil fauna which maintains ecosystem homeostasis.

Monocultures, intensive and long-term farming regimes (on large areas) and biomass burning will:

- reduce humus resources which are necessary for the preservation and repair of the soil's biologically active surface,
- intensify mineral fertilization,
- deplete soil and ground water resources,
- eradicate wetland ecosystems, cause adverse changes in local climate,
- deform vegetation structure,
- decrease food production,
- have adverse economic and environmental effects which may be very difficult to reverse.
- intensive biomass production requires:
- large amounts of water for plant growth (the production of 1 kg of dry biomass requires, subject to environmental factors, from several hundred to one thousand liters of water). Excessive depletion of soil water resources will not only decrease soil productivity, but it will also deteriorate water relations in adjacent areas, in particular in wetlands, thus permanently lowering groundwater levels and contributing to soil drying over extensive areas,
- significant nutrient resources, which is why intensive mineral fertilization is needed,

- high soil quality to improve yield (vast farmland areas in Poland have very low productive potential, therefore, they are unsuitable for biomass production),
- chemical disease and pest control (Pruszyński 2007).

Further discussion and targeted actions are needed to reconcile biomass production with environmental protection and sustainable development goals. There is no doubt that environmental protection and preservation of ecological potential should take priority over short-term economic gains and seeming environmental advantages. Humus-forming biomass is the key determinant of soil's biological function, therefore, it should be managed in a sustainable manner to protect the present and future soil and plant resources.

Current biomass management practices are highly disadvantageous from the environmental, sanitary, economic and social point of view. The above is particularly true of crops produced for food processing, industry, animal rearing and direct consumption in urban areas. Waste biomass from urban and industrial greens is equally mismanaged. Those practices produce huge quantities of plant waste which contaminate soils, surface and ground water resources. The sludge produced by biological treatment of municipal and industrial wastewater also poses a growing ecological, sanitary and economic challenge.

Industrial animal farming and crop monocultures obstruct sustainable management of hazardous waste. Organic matter is not recirculated into the soil, posing an environmental threat. Burning of waste biomass is not only justified, but it is also highly recommended, yet it should not be the most preferred method of handling discarded plant material. Systems and technologies for the acquisition and processing of waste biomass should also be developed to support sustainable soil management. The production of biomass as an alternative source of energy should be closely monitored to minimize adverse ecological consequences.

Biomass can be used to generate energy in an environmentally sustainable manner. On the one hand, the energy potential is contained in plant parts that are unimportant for the soil environment, and on the other hand, plant material supplies humus and nutrients. The former can have harmful effects on soil. By consuming large amounts of oxygen in the process of biological decomposition, they impair the growth of plants and soil microbes. Farmers are well aware that insufficiently fermented manure is a less effective fertilizer than well rotted manure. The above also applies to compost and organic substrates.

High-calorific components are easily released from biomass during anaerobic (methane) fermentation without impairing the humus-forming and fertilizing properties of solid and liquid residues. The released methane is a valuable energy resource. Methane fermentation with biomass decomposition is the simplest way to protect the environment. It requires advanced biogas plants and technologies for processing fermented solid and liquid residues which are a rich source of humus and nutrients (Janczar 2009).

The positive and negative consequences of intensive biomass production for energy generation and the burning of inedible plant residues from agriculture and forestry should be carefully analyzed in view of environmental changes over time, in particular the degradation of soil, vegetation, water resources and local climate changes. The above processes are usually slow and difficult to observe, and for this reason, the resulting damage is often recognized too late for any preventive measures to be taken. Modern biomass production and burning facilities will limit those adverse changes.

### 3.8. Soil compaction and hardpan formation

Soil compaction results directly from the operation of farming equipment and the pressure exerted by machine wheels on the topsoil. Soil's susceptibility to compaction is determined by various factors, mainly its mechanical properties, colloidal content, moisture content during field works, humus content and structure of the organic horizon. Moisture content is a factor that is subject to greatest variation over time. It is determined not only by the season and weather, but also by water infiltration rates and surface runoff. Water infiltration rates are largely influenced by mechanical properties, genetic horizons of the topsoil profile, water saturation and the release of air which is forced out of the soil by the pressure of infiltrating water. Horizontal drainage and surface evacuation of excess precipitation water (from surfaces with no outflow discharge) play a key role in this process (Siuta, Żukowski 2009). Mechanical cultivation and livestock treading of water-logged soil deforms its texture and decreases porosity, it inhibits water infiltration and access to atmospheric oxygen which is necessary to sustain the soil's biological function. Sporadic deformations are easily reversible, yet if repeated on a seasonal basis, they contribute to the degradation of soil texture and porosity in the ploughing layer as well as in deeper horizons. The content and distribution of humus across the soil profile determines soil's resistance to structural deformation and its ability to self-repair.

Hardpans are formed on soils that are compact and periodically silted by surface runoffs, including in flat areas with obstructed outflow and slow infiltration rates. Colloids transferred from the semi-liquid soil phase are accumulated on the surface, mostly in the early spring. Soil compaction and hardpan formation significantly lower the quality of arable land, and this problem is deepened by simplified crop rotation regimes, inadequate management of humus-forming resources and agricultural mechanization.

The potential threats to soil quality driven by compaction and hardpan formation raise international concern and spur the search for preventive measures (European Commission 2002, European Commission 2004, European Commission 2007).

### 3.9. Soil acidification

The level of natural and anthropogenic acidification of Polish soils is high (even very high), and lime-based treatments are not regularly performed to neutralize excessive acidity. In many parts of the country, leaching loss of calcium exceeds the amount of lime fertilizers used per unit area of land. Soil acidification reduces crop production, and it adversely affects the soil's biological function, nutritional value and processing suitability of plants, and the circulation of mineral and organic components in soil, surface and ground waters. Acidification has serious implications for the environment, economy and consumers. It is an issue of public concern, which is why a government-funded lime fertilization program is needed to counteract the problem. The results of scientific studies and statistical data clearly indicate that lime fertilization improves the yield potential of Polish soils (Boguszewski, Kac-Kacas 1966; Siuta, Żukowski 2010).

The effect of lime fertilization on the yield potential of soils in Polish regions (in 1975-2007) is presented based on statistical data (Siuta, Żukowski 2010).

## 4. Conclusions

Land degradation can result from natural processes as well as human activity. Based on the knowledge of the local environment, land users can adapt farming methods to minimize structural deformation and degradation of soils. Short-lived and fragmentary measures do not serve environmental protection or agricultural production. Integrated programs that are adapted to local conditions should be implemented with the involvement of advanced technical means. Poland has been in dire need of such solutions since 1945.

The threats posed by water and wind-induced erosion have been long recognized, but due to the fragmentation of Polish law, unavailability of funding and absence of relevant investment projects, effective remedies are rarely put to practice.

Soil degradation is increasingly often caused by flooding and storm water inundation which are difficult to forecast. The construction of flood control systems in the wrong locations and the use of potential inundation areas contribute to environmental and economic damage. Damaged drainage systems, including ditches and open trenches, deepen the problem. In 2009, Poland adopted a new environmental policy which aims to address those problems and implement the relevant remedies.

The environmental and economic consequences of land degradation caused by landslides have been fully recognized and legally sanctioned only in recent years. One of the tasks of the new environmental policy will be to complete the development of the system for monitoring areas that are prone to landslide.

The progressing degradation of field drainage systems, including local networks, is a vital concern in many parts of the country. The absence of drain reconstruction measures has a devastating impact on the soil environment, nevertheless, this problem is rarely recognized by farmers and environmental protection experts.

Intensive production of energy crops for biofuel production and burning of plant parts that cannot be used as food or feed will degrade the soil environment, decrease the quality and availability of ground water resources. Burning of biomass waste is justified, but it may not be the priority goal of economic or environmental protection policies. Biomass, the key determinant of soil's biological function, should be recirculated back into the earth.

Soil compaction and hardpan formation are very slow processes that significantly contribute to the degradation of agroecosystems. Their intensity is determined by various natural and anthropogenic factors. This type of soil degradation can be minimized by optimizing land use patterns, improving access to technical infrastructure, selecting the appropriate farming machines and refraining from land cultivation in a wet soil environment.

Soils become excessively acidic due to natural factors as well as human activity, including farming. The share of acidic and highly acidic soils in farms that apply regular lime treatments is much lower than in other regions. Progressing changes in crop structure and the removal of biomass from agroecosystems contribute to soil acidification. The unfounded view that lime fertilization is ineffective, or even harmful, has decreased lime consumption from 118-202 kg CaO/ha in 1975-1998 to 37-104 kg CaO/ha in 1999-2007.

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