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Ecological systems of water management in rural areas

Abstract: *Poland has poor water resources. Moreover, they are unevenly distributed in space and time. Some types of human activity diminished water resources and increased the frequency of extreme phenomena such as floods and draughts. The development of rural areas depends on the quality and quantity of water resources. Suitable water management in rural areas can help enlarge water resources and minimize the negative effect of agriculture on natural flora and fauna. It should also allow for the increase of biological diversity.*

One of the methods to improve water conditions is by increasing the retention abilities (water harvesting) of small basins. Field studies and approximate calculations showed that treatments consisting in the increase of swampy areas, number of water pools and small water reservoirs, elevating water level in eroded rivers and canals, improvement of the soil structure, regulation of outflows from the drainage systems, etc. can significantly enlarge water resources in river basins. Proper water management should enable the supply of good quality water both for the natural environment and for the agricultural and municipal needs.

Key words: *water resources, water management, river basin, agriculture, environmental protection.*

Introduction

Water management in rural areas all over the world has been for many years focused on creating conditions for intensive agricultural production. Thus, large reclamation systems have been constructed to fit water content in soils to the requirements of crop plants without considering environmental effects. In countries of the temperate zone the draining systems were mostly of concern while in the dry climatic conditions the irrigation systems were developed. The aim of reclamation works was often to transform inaccessible swamps into cultivated meadows and pastures. A large water uptake for agricultural irrigation as well as dense draining networks, together with intensive farming, resulted in unfavourable changes of the natural environment. The greatest changes were noted in river valleys, where rich and biologically diversified habitats were replaced by monocultures of cultivated meadows. Therefore, new solutions are sought to

enable a compromise between agriculture and environmental protection and to secure the sustainable development of rural areas. Hence, a new role of water management in rural areas, which, apart from economic demands, should also consider natural aspects.

The system of organisation of water management has recently changed in Poland. Regional Boards of Water Management were called into existence in 1991 (Regulation of the Minister of Environmental Protection, Natural Resources and Forestry) to comprehensively manage water resources within the river catchments. New Water Law significantly strengthens the competence of these bodies. Polish legislation refers basically to Directive 2000/60/EC of 23 October 2000 of European Council, which established general framework of European water policy. The directive pays special attention to the protection of water quality and to maintaining natural values of rivers and water reservoirs. It is recommended that waters achieve "good ecological status" in a definite period of time. Implementation of Water Framework Directive is one of the basic tasks for institutions responsible for water management in Poland.

The role of institutions responsible for water management for agricultural purposes in maintaining appropriate water quality (good ecological status) has been not decided yet. According to the water act, water management is as a whole within the responsibility of Ministry of Environment and the Regional Boards of Water Management, subordinated to it. However, the role of Ministry of Agriculture and Rural Development is still extensive. The latter is responsible for water consumption in agriculture, for exploitation of the draining-irrigation systems, for the maintenance of small water reservoirs, channels and rivers for agricultural purposes.

When discussing water management in rural areas one can not miss the structural changes that are now taking place in agriculture. Since the important political changes of 1989, national economy including agriculture underwent significant transformations. During a short period of time, Poland - formerly a country of food deficits - became a country with excess food production. Agricultural production has been abandoned on large areas, including those equipped with draining or irrigation-draining systems. The views on the role of agriculture in the national economy should thus alter. It is now assumed that agriculture should not only produce food but also (sometimes mainly) maintain and develop naturally the valuable cultural landscape. The role of agriculture should be also to protect natural resources including water resources. This is particularly important since water resources of Poland are small in comparison with those of the neighbouring European countries.

Adaptation of Polish agriculture to European standards requires deep transformation, particularly the enlargement of farms and intensification of their production. The necessary intensification of agriculture and consolidation of farms may pose a risk of decreasing biodiversity of the natural environment. Formation of large monocultures may increase surface runoff and thus unfavourably

affect water balance. This process is also suspected to increase the frequency of the extreme phenomena like floods and droughts. On the other hand, implementation of proper technologies in plant crops and animal breeding in modern farms may result in decreasing nutrient emissions to the surface and ground waters. Restructuring of Polish agriculture and particularly the increase of the size of farms is a source of fear for ecological organisations and of hope for economists responsible for the development of the country.

As can be seen from the above remarks, the combined, integrated approach to the three elements i.e. water management, food production (agriculture) and environmental protection has become a necessity and a challenge for users and managers of rural areas. Sustainable development of rural areas depends largely on co-operation of specialists from these three sectors. The ecological systems of water management should play a significant role in rural areas.

Water resources

Poland is one of the European countries with low water resources. Renewable resources of surface water, i.e. mean annual per capita outflow from the area of Poland, are 1580 m^3 (data according to the Institute of Meteorology and Water Resources) whereas in Europe this index is equal to 4560 m^3 (Zieliński, Słota 1996). These poor water resources in Poland are, moreover, very variable in time and space. In our climatic conditions, the highest flows in most rivers take place in spring and the lowest in autumn and winter. The ratio between the maximum and minimum average monthly outflow from the area of Poland is about 2.3. The ratio is considerably higher for some rivers and reaches a two-digit value for mountain streams and small lowland rivers. Momentary flows vary even more and the ratio between the minimum and maximum flow is almost 1 : 1000 (Zieliński, Słota 1996).

Precipitation is also unevenly distributed in space and time. The average annual precipitation in Poland is around 600 mm, but there are years with precipitation below 400 mm and with more than 800 mm. Much bigger differences are revealed when short-term precipitation is analysed. Annual sum of precipitation in Poland is sufficient to cover water demands. For most plants, however, evapotranspiration exceeds precipitation during the growing season. Water deficit varies in time and space. There are years of distinct deficits of precipitation, particularly in central Poland.

Extreme phenomena like floods and droughts are relatively frequent in Poland. It has been estimated that floods in the catchment area of Vistula river occur every 5 years on the average and in the catchment of Odra – every 7 to 10 years. An excess of water in agriculture results not only from floods but also from the long-lasting excess moisture levels in the soil. Yet in the 19th century there were periods of starvation caused by wet years (Okruszko 1997). The last great flood took place in the Odra basin in July 1997 and caused enormous economic and social losses. On the other hand, in many regions severe atmospheric, hydrologi-

cal or soil draughts occur and result in considerable losses for national economy, and especially for agriculture. It has been estimated that the drought in 1992 that affected almost whole territory of Poland resulted in the decrease of yields by at least 20%. Especially susceptible to droughts (Kowalczak et al. 1997) are the regions of central Poland.

Water resources develop in a space occupied by croplands and forests as a result of spatially and temporally variable precipitation (rainfall, snow). Precipitation is partly stored and utilized on these areas. The ability to store water is termed retention and such ability in different degree characterises river catchments. Water is retained in forests, soil, aquifers, terrain depressions and in natural and artificial water reservoirs. Retention enables keeping water from the periods of its excess (snow melt, large precipitation) and use it in the "deficit" periods (with no precipitation). Nevertheless, momentary high water stages in rivers, high soil moisture are natural as are the periods of water deficit, low water flow in rivers, soil over-drying and low groundwater tables.

Natural retention capacity of river basins in many areas has been significantly decreased as a result of deforestation, construction of drainage systems, covering the earth surface with impermeable layers of asphalt and concrete, degradation of mineral and organic soils, overgrowing (filling up) of ponds and small lakes, etc. It is believed that human economic activity contributed significantly to enhanced irregularity of the water flow in rivers and that it increased the frequency of extreme phenomena such as floods and droughts.

The measures undertaken so far to prevent from unfavourable influence of droughts and floods have been mainly technical in character and have included, in particular: construction of water reservoirs, of levees and dams, irrigation and drainage systems etc. In many cases the results achieved were not satisfactory. It is believed that securing of water balance and ways to minimise losses due to water excess or deficiency must be attempted by some other methods that would be closer to nature. One of the pro-ecological methods is to increase or reconstruct the retention abilities of river basins together with implementation of suitable rules of water management in agricultural areas.

Water management issues in agricultural landscape

The amount and quality of water resources determine land use and management of rural areas. The reverse is also true and thus we may observe here a distinct feedback relationship. Agricultural development depends upon water resources but their quality relies on the ways of agricultural utilization of the river catchment. That is why the problems of water can not be dealt with apart from the existing or planned catchment management. For the same reason, water demands of various water users can not be looked at separately. Having this in mind, an integrated water management is undertaken. Integrated approach to water management calls for a combined treatment of water quantity and quality

and for considering all water users including forests and other elements of natural environment.

All these determinants allow for the assumption that basic tasks of water management in agricultural catchments should involve:

Protection of water resources. Water resources in agricultural and forested areas are formed from atmospheric precipitation. Therefore, protection of their quality and quantity is decisive for water availability within the boundaries of larger catchments. Protection means creation of water resources through e.g. increasing potential retention capacity of the catchment or technical measures of the surface and ground water storage. It means also all actions for protecting water quality through limiting the dispersal of pollutants, diffuse pollutants of agricultural origin included. Special attention should be given the sensitive areas, according the Nitrate Directive (91/676/EEC of 12.12.1991).

Protection of natural values. The demands addressed at water management for creating conditions for sustainable development of rural areas and particularly of compromising the interests of agriculture and natural environment tend to increase. The aims of water management encompass creating appropriate conditions for maintaining biodiversity of agricultural landscape and for protecting areas of high natural values. This refers particularly to wetlands and meandering rivers. Meandering rivers belong to the most valuable and rare systems on Polish and European scale. Wet meadows, rare in Europe, are still well preserved in Poland as a result of small-scale agriculture. Extensive areas have been recognised as valuable and are specially protected. Figure 1 presents a general map of

Figure 1. Protected areas
1 – areas protected for their natural values, 2 – areas of the ground water recharge

protected areas in Poland. These are national parks, areas of protected landscape and other forms of nature protection. The location of infiltration areas, on which main reservoirs of ground water are recharged, is also given. On all these areas agriculture is somehow restricted and water management assumes particular importance.

Meeting economic needs. This notion means all activities focused on creating optimum water content (irrigation, draining) for agricultural and forest production, preventing from floods and droughts and supplying rural settlements with water for municipal needs and breeding. Water use for recreation, tourism, filling fish ponds, production of energy etc. also falls within this category.

Agriculture and environment

Activities focused on improving rural environment including water resources require first of all to define precisely the role of agriculture in the natural environment and to define mutual relationships, both positive and negative, between the two. Agriculture, and in particular its intensive form pose a threat to water resources, to flora and fauna. Up to date experience shows that the main risk in Poland pertains to:

Water quality: it is commonly agreed that agriculture results in pollution of the ground and surface waters due to excessive use of mineral fertilizers and plant protection chemicals (Kajak 1998). Draining systems increase the loads of outflowing pollutants. It is estimated that, in spite of low rates of fertiliser use in Poland (below 80 kg N/ha), 50% of the nitrogen and phosphorus load released to rivers originates from agricultural production (diffuse sources). An especially high pollution was found in shallow farm wells, being an effect of improper fertiliser and sewage handling (*Ochrona środowiska* 2001). Fertiliser use on croplands is a less important source of pollution. It is commonly believed that with proper fertiliser application and after construction of sewage treatment plants and manure heaps this unfavourable effect of agriculture can be restricted.

Water quantity: agriculture is an important consumer of water and certainly affects water budgets of the river catchments. Water uptake for irrigation in Poland is relatively small (less than 15% of the total uptake for economic purposes). It is estimated, however, that intensification of agriculture (yield increase), even in non-irrigated areas, has affected the water budget. Increased water consumption is observed not only on irrigated objects but also in areas, where agriculture relies on rainfall. Increased yields (twofold in the last 20 years) should have as effect increased evapotranspiration. There is no detailed evidence on how rainfed agriculture contributes to the decrease of water flow in rivers or to the decline of the groundwater table. High natural variability of water flows in rivers and its dependence on many factors make the assessment of agricultural impact on water relations difficult. Nonetheless, many authors (Dynowska 1993; Kunkel and Wenland 2001; Mioduszewski 1999; Querner et.

al. 1997) speculated that the increase of yields in the last 30 years could diminish the outflow from agricultural catchments by 8–50 mm annually.

Landscape: due to the fragmentation of farms (small-scale agriculture), Polish rural landscape is quite diversified and displays high biodiversity. Arable lands interspersed with grasslands, woodlots and shrubs form a mosaic of often high natural values. On the formerly large state farms this type of landscape has been mostly destroyed, as it was on large drained projects. Woodlots and shrubs were removed, small water holes were filled to provide extent flat areas available for intensive agricultural production. Such actions resulted in unfavourable transformations of these areas. Many ecologists are of the opinion that monocultures formed on large grounds are detrimental not only to the environment but also to agriculture itself. Large-scale agriculture based on monocultures unfavourably affects flora, fauna and water resources. Most specialists are convinced that levelling of surface, liquidation of shrubs etc. accelerates water surface runoff, decreases recharge of groundwater resources and thus interferes with the total water balance (Dynowska 1993; Radwan, Lorkiewicz 2001).

Wetland flora and fauna: wetlands are valuable nature areas and thus are protected all over the world. In Poland, 80% of wetlands were drained and transformed into meadows and pastures. Moreover, 60% of rivers and small streams were regulated. Replacing natural wetland vegetation with grasses, straightening and forming river channels markedly altered natural conditions of wetlands. Intensively agriculturally managed rivers and river valleys are poor from the point of view of nature. The situation was somewhat different in the valleys, where agriculture had an extensive character i.e. meadows were mowed once a year, very often manually until the most recent period. Valuable ecosystems of high biodiversity developed there. Some of the cultivated grasslands are the most important bird refuges. Areas abandoned by farmers quickly overgrow with shrubs and common reed and lose their assumed nature value. The example of the floodplain meadows is worth emphasising since in this particular case farming formed a valuable ecosystem, whose maintenance depends on periodical mowing. One may suspect that there are other examples demonstrating the role of agriculture in development of valuable ecosystems.

Transformation of Polish agriculture (through a decrease in the number of employed people, enlargement of farms and their mechanization, and improvement of living standards) is unavoidable. Problems of water and environmental protection play a significant role here. There is a justified concern that field consolidation may impoverish the agricultural landscape and decrease its biodiversity. Intensification of agriculture, on the other hand, may result in excessive water consumption. Finding appropriate ways for the development of agriculture, which should be effective and competitive, while protecting natural resources (including water resources) is a difficult task addressed to the whole nation but especially to specialists in water management, agriculture and natural environment.

Irrigation and drainage in Poland

The first hydraulic works for agricultural purposes were undertaken in Poland in the Middle Ages. The embankments were built to protect the lowland areas against flooding and some ditches were constructed to remove water from swampy areas. But the biggest area was drained after the World War II. More than 200,000 hectares of agricultural land were drained annually during some years, as shown in Table 1. Nowadays, 36.2% of agricultural land (18% of the whole country) are equipped with different kinds of drainage systems, and only some have irrigation systems. Most peatlands (wetlands) were drained and turned into grassland.

Table 1. The average area drained annually in Poland

Years	The area drained [hectares per year]
1951–1955	95 000
1956–1960	102 000
1961–1965	245 000
1966–1970	260 000
1971–1975	205 000
1976–1980	120 000
1981–1985	72 000
1986–1990	102 000
1991–1995	20 000
1995–2000	11 000

Source: *Ochrona środowiska (Environmental protection)*, 2001, Główny Urząd Statystyczny, Warszawa.

After 1990 drainage works on new lands have practically been abandoned. Not more than 3000 hectares of arable land are drained annually now. Draining of river valleys stopped completely. Most of water engineering undertaken is connected now with the reconstruction of irrigation systems, and construction of water reservoirs or weirs to rise the water level in some rivers. Some of the hydrographic systems are going to be re-naturalised for wetland protection.

Anyway, it is necessary to stress that a large area of agricultural land in Poland is equipped now with hydraulic structures mainly for soil dewatering. As can be seen from Table 2, most of the agricultural land is drained without the possibility of irrigation. Covered plastic or ceramic drainage networks were constructed for dewatering arable soils. Irrigation systems were built mainly in orchards and vegetable gardens. Grasslands situated mainly in river valleys were drained by open ditches. Some 25% of the drained grasslands can potentially be irrigated. Gravitational irrigation (regulation of water table in the ditches) is the only method used for irrigation of grasslands.

Table 2. Specification of the land reclamation structures

Land reclamation area and structures	Units	Amount
Area with drainage system	'000 hectares	6 690
• Arable lands	'000 hectares	4 725
• Grasslands	'000 hectares	1 965
Irrigated area	'000 hectares	480
• arable lands	'000 hectares	62
• grasslands	'000 hectares	418
Hydraulic structures managed by farmers		
• ditches and small water courses	Km	283 746
• pipes (without sprinkler irrigation)	Km	8 211
Hydraulic structures managed by the State for farming purposes		
• regulated rivers and canals	Km	49 588
• non-regulated rivers	Km	24 796
• levees (embankments)	Km	8 371
• area protected by flood control works	'000 hectares	1 200
• pumping station	number/$m^3 \cdot sec^{-1}$	592/170
• water reservoirs	number/10^6 m^3	185/170

Source: Ministry of Agriculture and Rural Development.

The numbers shown in Table 2 represent the totality of works carried out in the years 1950–1990. Large areas were reclaimed in those years in now non-existing large state farms. Many farmers from smaller farms also postponed conservation and utilisation of the irrigation and draining systems for economic reasons. Thus, the huge potential is presently used to a small extent. Only 20% of water facilities are estimated to be now in the state enabling their effective use for agricultural production. The extent of irrigation in the year 2002 is shown in Table 3.

Table 3. The extent of irrigation

Type of irrigation	Irrigated area		Volume of water	
	[ha]	%	Dam^3	%
Sub-irrigation (upstream control)	94 370	95.24	109 246	97.05
Sprinkler	4 458	4.50	2 594	2.30
Surface (floods)	241	0.24	671	0.60
Furrow	20	0.02	50	0.05
Total	99 089	100.00	112 561	100.00

Source: *Ochrona środowiska* (*Environmental protection*), 2001, Główny Urząd Statystyczny, Warszawa.

It is worth emphasising that the reclamation facilities in Poland have a specific character, markedly different from those of other European countries. Two types of systems are distinguished:

- Typical drainage projects made of covered ceramic drains or perforated plastic tubes. Drainage facilities were mainly constructed on arable lands. To enable gravitational outflow of water, small watercourses were sometimes

regulated. The regulation consisted in deepening and broadening of the stream channel and in straightening its course. Sometimes, irrespectively of draining, sprinkling irrigation was performed there.

- Reclamation projects made in the river valleys. Basic draining facilities were the open ditches often combined with the regulated river. Such objects were usually designed to drain grasslands. On 30% of the area of these projects, hydraulic structures were built to enable water regulation through the so--called sub-irrigation, which consisted in delivering water from the river to the ditches and in maintaining its high level there. Another applied method was to regulate the outflow of water from the existing drainage network in spring i.e. to retard snow-melt waters there (regulation with the upstream control). Both these methods are ineffective, require a large number of structures, frequent mowing of the ditches and moreover, are associated with large, non-productive water losses.

During the last years some agricultural lands equipped with the draining systems have been abandoned for various reasons. The question is – what to do with this land, especially with open ditches constructed on peatlands. It is a complicated problem from the economic and ecological points of view. For example, some of these areas should be used for extensive agriculture to maintain their high natural values (Radwan and Lorkiewicz 2001).

In order to protect water resources and to provide adequate amounts of water for plant production it is necessary to implement new methods of management and maintenance of the reclamation systems. This means mainly the installation of such facilities on the draining network that would enable controlled water outflow (Mioduszewski 1996; Querner et al. 1997). Common use of this method may decrease high water flows, may fulfil plant requirements for water and improve the surface and ground water quality.

Ecological methods of improving the water balance

The extreme weather phenomena and the resulting floods or dry periods with small precipitation and low river water flows are all natural. Moreover, periodical flooding of the river valley is often a prerequisite for maintaining natural equilibrium. We may think of threats only when such extreme phenomena exert a negative effect on human economic activity. Only in relation to this activity one may consider the excess or the deficit of water. In other words, "natural extreme phenomena" become "natural threats" in case when they negatively affect human activity and bring accountable losses.

Having this in mind, we may distinguish two groups of methods for protection and prevention against these threats:

- to adapt extreme phenomena to human needs i.e. to free from variable natural conditions; technical solutions like flood control dikes, water reservoirs, reclamation systems play a decisive role here,

- to adapt human activity to natural phenomena i.e. to develop such land management and utilization as to minimise the negative impacts on life and economic activity of man.

To meet the requirements of sustainable development, more attention should be paid to the second method. This is especially valid for agriculture and water management.

Restoration of water retention in a catchment seems to be the most environment-friendly and to fulfil the best the requirements of sustainable development among all methods of improving water balance and counteracting natural threats (Mioduszewski 1999). It should be stressed, however, that with the present status of management in catchments and river valleys and high population densities, implementation of this method seems to be rather difficult in some areas. Regardless of the way and intensity of economic land use (including croplands) one has to retard the rapid outflow of snow melt and precipitation water, which means restoration of the natural retention capacity of the river catchment.

Improving water balance with technical methods means a possibility of decreasing high floodwater stages and increasing low discharges in rivers. This is equivalent to the increase of surface water resources. Less attention is paid, however, to the possibility of increasing the effective infiltration (recharge of aquifers), which increases the ground water resources. Resources of water in the aeration zone of soils are not mentioned at all.

Ecological methods of affecting water balance in small catchments consist in impeding the turnover of water through the retention of surface waters, soil water and ground waters. In that way one increases the retention of the whole catchment. Three types of actions aimed at improving water balance can be distinguished: technical, planning and agrotechnical.

Technical. Most hydrotechnical and reclamation works undertaken to inhibit the outflow of surface waters fall within this category, which includes, in particular:

- retention of surface waters through construction of small water reservoirs, lifting the water tables in lakes, water courses, ditches and channels (channel retention),
- regulated water outflow from the draining systems and from the network of draining ditches, and proper management of water reservoirs,
- increase of recharge of groundwater reservoirs through construction of ponds and infiltration wells, management of runoff from waterproof surfaces (roofs, streets, squares) to enable water infiltration on permeable grounds (Geiger and Dreiseite 1999).

Planning. Appropriate spatial planning may play a role in water management. This role may consist in creating such a spatial organisation as to prevent rapid outflow of rainfall and snow melt waters. The actions should involve:

- shaping an appropriate setting of arable lands, grasslands and forests (maintenance of the mosaic character of landscape),

- constructing protective plant strips (shrubs, trees), restoration of possibly numerous areas of ecological use,
- establishing the areas of ground water recharge and their proper management,
- identifying the areas vulnerable to agricultural diffuse pollution and implementing proper methods of cultivation,
- reconstructing and preserving wetlands and peatlands, maintaining grassland management in the river valleys.

Agrotechnical. Appropriate agrotechnical methods (*Polski Kodeks*... 1999) may improve water quality and increase water quantity. Basic actions within this group include:

- increase of the soil retention through improvement of soil structure and increase of humus content in soils; this goal is usually achieved by proper ploughing, agro-reclamation measures, fertiliser application and liming,
- restriction of the surface runoff by counter-erosion measures and aftercrops,
- decreasing evapotranspiration through proper plant selection and restriction of evaporation from the soil surface.

Actions aimed at the increase of retention capacity can also be shown in terms of the medium, in which water is to be stored. One may thus distinguish landscape, soil, ground water and surface water retention (Table 4).

Table 4. Systems of water retention in rural areas

Water resources	Systems
Landscape (habitat) retention	Systems creating appropriate land use structure through the set up of arable lands, grasslands, forests, areas of ecological use, water holes
Soil retention	Crop systems affecting water management in soil profile, particularly the increase of potential water retention in soils
Ground waters	Cultivation and reclamation systems to decrease surface runoff and increase the recharge of ground water reservoirs
Surface waters	Hydrotechnical water distribution and management systems including construction of small reservoirs, outflow control from drainage systems

Measures proposed to improve the retention capacity of the catchment do not introduce significant changes in the natural water regime but only bring necessary corrections in water balance in such a way so as not to disturb the biological equilibrium of the ecosystem. Pro-ecological actions of stimulating small retention may to a degree help recreating (restoring) some elements of the water system disrupted by the human economic activity to date.

Actions undertaken to implement the ecological system of water management in rural areas

The calculations and analyses performed demonstrate that the actions here presented may be important for proper formation of the water balance structure

(Graham and Lest 1995; Kowalewski 1998; Kunkel and Wenland 2001; Mekotova and Sterba 2001; Mioduszewski 1996, 1999; Szymczak and Kowalewski 1999). Water harvesting as a method of improving agricultural water supply has a long tradition in tropical regions and is recognised to be the most natural method of satisfying agricultural water demand. The analyses show also that under the temperate European climatic conditions the methods similar to water harvesting may be efficiently used as the basic measure to improve water balance (restriction of harmful flood waters and the increase of low flows) and to protect the quality and quantity of surface and ground waters.

Actions meant to improve the structure of water balance on agricultural lands are undertaken in Poland, though on a small scale. Some of them may be prescribed within the ecological system of water management in rural areas, in spite of the fact that they have been undertaken for other purposes than water protection. Nonetheless, indirectly or directly they affect water cycle in nature. The ecological system of water management consists in:

- Elaboration and implementation of the "Code of good agricultural practice" (*Polski Kodeks* 1999). The code contains detailed actions aimed to limit emissions of nutrients and plant protection chemicals to surface and ground waters. Courses and trainings for farmers are organised by Agricultural Advisory Centres. A few demonstration farms are also organised in various regions of the country to implement suitable methods of storage of organic fertilisers. These actions are not common yet, nevertheless they are expected to bring definite beneficial effects. The "Code..." elaborated in Poland pays little attention to the problem of water quantity, to erosion, development of agricultural landscape or management of the draining and irrigating systems. It seems that the "Code..." should be supplemented with topics concerning water protection and management of irrigation-drainage systems.
- Problems associated with the protection of water quantity have been reflected in the agreement signed on 11th April 2002 by the Minister of Environment, Minister of Agriculture and Rural Development, President of the Agency for Restructuring and Modernisation of Agriculture and President of the National Fund for Environmental Protection and Water Management concerning the development of small retention. Small retention is meant here as all actions undertaken to limit the outflow of precipitation waters from the small river basins. The actions fall within the scope of „water conservation" and „water harvesting". They encompass small reservoirs (of a volume less than 10^6 m^3) and ponds, rising water level in rivers and channels by construction of hydraulic structures, but also modernisation of draining systems to enable the regulation of water outflow. The agreement was signed in view of improving water balance in small catchments for the needs of agriculture and improvement of natural values of rural areas. The parties to the agreement took the responsibility of supporting any action associated with improvement of the catchment retention capacity. Moreover, two institutions, namely the Agency for Restructuring and Modernisation of

Agriculture and the National Fund for Environmental Protection and Water Management took obligation of supporting some of these actions financially. The map of small retention priorities has been elaborated (Figure 2). This map was the basis for distribution of financial support for water investments. It is estimated that an additional retention of 20 million m^3 will be formed annually within the project. The retention will consist of small water reservoirs built for recreational purposes, fish ponds and the elevation of water level in lakes. Facilities for water lifting in rivers and channels will be of lesser importance.

- A fund to support some environmental actions in agriculture has been established in the framework of preparations of Poland to the access to EU. Financial support from the programme called "agro-environmental fund" will be addressed to farmers who take the obligation of conforming to some agricultural technologies like decreased fertiliser use, restricted mowing of meadows in the period of bird hatching etc. The rules of distribution of financial aid are now being elaborated. Agro-environmental schemes are exclusively focusing on biodiversity and landscape protection of rural areas. The ways and scopes of financing specific agricultural technologies to improve water quality and increase its volume are under discussion.

Figure 2. Priorities for small retention investment projects
1 – high priority, 2 – medium, 3 – low, 4 – mountain areas

- Minister of Environment can establish a protected forest, playing protective role for surface and ground waters. Special regulations of management approved by the Minister of Environment apply to these forests. Afforestation of the former croplands is a separate problem. It is estimated that over two million hectares of the presently utilised croplands should be forested. The act of Polish parliament obliges local authorities to pay financial equivalents to farmers for afforestation of croplands. The increase of the forest cover may result in significant changes in the water balance of some small catchments. Afforestation of poorly permeable loamy grounds, particularly those situated in the watersheds may result in moderating water flows in rivers (decreasing floodwaters and increasing low flows). Planting forests on sandy grounds, the areas of infiltration, may on the other hand unfavourably diminish the volume of water in aquifers.
- Development of protected areas like national parks, landscape parks, natural reserves or areas of ecological use. Sometimes protected areas include privately owned grounds. In such cases cooperation between the manager of a protected area and a farmer is required. In particular, a large part of legally protected wetlands (wet meadows) are the farmers' private property. Sometimes it is necessary to motivate farmers to at least extensive utilisation of such grounds to prevent expansion of shrubs and reeds. In most cases the establishment of protected areas, extensive agricultural land management, and protection of natural river valleys and wetlands contribute to improvement of the structure of water balance.
- Education is one of the most important factors decisive for the success of actions within the scope of „water, agriculture, environment". The proper methods of management should be demonstrated to farmers. Such training has recently been developed in the agricultural advisory centres. The courses are, however, restricted to agrotechnical measures and problems associated with protection of water quality. Proper management of draining and irrigation systems, methods of water retention and saving obtain there much less attention. It was an initiative of the Ministry of Environment, resulting from the discussions conducted to elaborate a manual on water retention (water harvesting) and to organise training courses for farmers in various parts of the country.

Conclusions

The role of agriculture is not limited to production of food. It is also necessary to envision and define "the public function of agriculture". The public function is to protect biological diversity and high value of the present cultural landscape. From this point of view there is a need to define new functions of water management in agricultural landscape.

Water management in rural areas in this novel approach encompasses complex technical, planning and agricultural actions. They all aim at protecting water

quality and improving the structure of water balance in the river valleys through restoration and increase of their potential retention capacity. The so-called small retention (water harvesting) focused on increasing the resources of surface, ground and soil waters plays a great role here.

The positive effect of increasing the retention capacity of small catchments on water quality and water balance is widely accepted. Numerical assessment of the undertaken actions is, however, very difficult. It often results from a lack of adequate knowledge and from complicated and complex relationships between physical and biotic catchment parameters and the processes of surface and ground water flow.

Water management in rural areas should be considered in economic decision making and planning of rural development. Particularly important is the consideration of these determinants of economic growth, which originate from the availability of water resources (water quantity and quality) in the local spatial planning. Water should be one of the elements decisive for the directions of agricultural restructuring, for recommendations formulated in the Code of good agricultural practice, plans of afforestation of former croplands, land use in the river valleys and infiltration areas, from which aquifers are recharged.

Basic and urgent tasks, which need to be accomplished in order to improve water balance are:

- continuation of the programme of small retention – construction of reservoirs and rising of water levels in eroded water courses,
- implementation of proper exploitation methods of the irrigation-drainage systems, the equipment of drainage systems with facilities to control water outflow,
- protection of the infiltration areas (to increase recharge of ground water reservoirs),
- obligatory introduction of water issues (protection of water quality and quantity) into local spatial planning,
- elaboration of the restitution programme for wetlands, water holes, small lakes etc.,
- liquidation of water outflow from the draining systems on abandoned meadows, river restoration and recovery of the natural meandering of water courses.

To sum up, water management in small rural catchments can be a fundamental element decisive for water resources in the country. Hence, the necessity of appropriate and complex management of these resources should be stressed. Water management plans (water use conditions) should consider not only the technical (hydrotechnical, reclamation) activities but also all those planning, agricultural and natural factors, which might affect water balance.

References

Dynowska I. (ed.), 1993, *Przemiany stosunków wodnych w Polsce w wyniku procesów naturalnych i antropogenicznych* (*The changes of water conditions in Poland as a result of natural and man-made processes*), UJ, Kraków.

Geiger W., Dreiseitl H., 1999, *Nowe sposoby odprowadzania wód deszczowych* (*New methods of discharging storm water*), Wyd. Proj.-Przem. EKO, Bydgoszcz.

Graham W., Lest L., 1995, *Non-structural aspects of flood management in India*, ICID Journal, 44, 1.

Kajak Z. 1998, *Hydrobiologia – Limnologia. Ekosystemy wód śródlądowych* (*Hydro-biology – Limnology. Ecosystems of inland waters*), PWN, Warszawa.

Kowalczak P., Farat R., Kępińska-Kasprzak M., Kuźnicka M., Mager P., 1997, *Hierarchia potrzeb obszarowych małej retencji* (*The hierarchy of space demands of small retention*), Materiały Badawcze, IMiGW, Warszawa.

Kowalewski Z., 1998, *Możliwości zwiększenia zasobów wodnych w województwie łomżyńskim* (*The possibilities of increasing water resources in the Łomża voivodship*), Proceedings of the Conference, „Przyrodnicze i techniczne problemy gospodarowania wodą", SGGW, Warszawa, 125–129.

Kunkel R., Wenland F., 2001, *Impact of land cover scenarios on the catchment water balance of the river Elbe basin*, Proceedings of the Conference „Sustainable use of land and water", Brno (CD plate).

Mekotova J., Sterba O., 2001, *Possibilities to ecologically minimize flood impact in the Morava river landscape*, Proceedings of the Conference „Sustainable use of land and water", Brno, (CD plate).

Mioduszewski W., 1996, *Ochrona i kształtowanie zasobów wodnych w krajobrazie rolniczym* (*Protection and development of water resources in agricultural landscape*), IMUZ, Falenty.

Mioduszewski W., 1999, *Reconstruction of retention capacity of small river basins as a protection measure against floods and droughts*, Int. Agrophysics, 12, 37–48.

Ochrona środowiska (*Environmental protection*), 2001, Główny Urząd Statystyczny, Warszawa.

Okruszko H., 1997, *A woda płynie do morza* (*And water flows to the sea*), Nauka i Przyszłość, nr 9, 63–64.

Polski Kodeks Dobrej Praktyki Rolniczej (*Polish Code of Good Agricultural Practice*), 1999, IUNG, Puławy.

Querner E.P., Talleksen L.M., Kasparek L., Van Lanen H.A.J., 1997, *Impact of land – use, climate change and ground-water abstraction on stream flow droughts, using physically based-models*, Friend'97 – Regional Hydrology, IAHS Publ., 246, 171–179.

Radwan S., Lorkiewicz Z., 2001, *Problemy ochrony i użytkowania obszarów wiejskich o dużych walorach przyrodniczych* (*The problems of protection and management of rural areas with high nature value*), Wyd. Uniwersytetu M. Curie Skłodowskiej, Lublin.

Szymczak T., Kowalewski Z., 1999, *An impact of small water reservoirs on reduction of storm flow hydrographs and increase of a base flow*, Proceedings of the Conference „A new approaches in irrigation, drainage and flood control management", Bratislawa, 127–134.

Zieliński J., Słota H., (eds), 1996, *Stan i wykorzystanie wód powierzchniowych w Polsce* (*The status and utilization of surface waters in Poland*), IMiGW, Warszawa.