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POSSIBILITIES OF SHAPING THE WATER RETENTION IN AGRICULTURAL LANDSCAPE

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Summary. Scarce resources and growing demand for water indicate the need for its economical use and carrying out actions aimed at quantitative and qualitative protection. Possibilities of increasing retention within agricultural catchments, with particular attention to areas threatened with erosion were analysed in the paper. The retention was classified as natural and artificial, controllable and uncontrollable and landscape, groundwater, surface water and soil. In the case of loess high relief catchment the retention should be considered together with the protection against erosion. Admittedly, there are a significant amount of unproductive runoff and conditions for its accumulation, but there is a high risk of colmatation by soil material eroded from arable fields. In this situation, a condition to create reservoirs in the river valley bottoms is to increase the retention of slope basins, including introduction of biogeochemical barriers (eg. colmatation partitions).

Key words: agricultural catchment, water resources, retention

INTRODUCTION

Water plays numerous important functions in the natural environment, it is one of natural goods that determines the life on Earth. It affects the diversity of biological elements and is considered as one of the most significant factors of sustainable social and economic development. In Poland, protection and shaping of water resources become more and more important – domestic resources are considered as one of the smallest in Europe and in many cases waters are characterized by low quality. Drainage of large areas and occurrence of unfavourable changes within the natural environment results from the lack of an efficient system of water resources management within agricultural and urbanized catchments.

Growing deficit and expected increase of water resources utilisation indicate the necessity to establish some new rules of planning and realising any works related to water management in small catchments – at the site of formation of its resources. Special attention should be paid to retention issue, which is associated with any activity causing slower water and chemical compounds circulation within a catchment (e.g. replacement of surface runoff or outflow through storm water drainage to underground runoff). The water accumulation in reservoirs is crucial. Reducing water resources variability in time is a hydrological effect of retention increase.

Increased interests in problems of water resources protection reflect mainly in investment activity (technical) within large river catchments. In majority of cases, these activities refer to building reservoirs on main flows of a river basin. Unfortunately, issues associated with possibility of improving water resources at the level of agricultural partial catchments by means of non-investment methods (for example through landscape transformation, improvement of exploitation or renovation of neglected melioration systems), are often underestimated and skipped. In the case of the smallest catchments, which are usually not monitored, their retention abilities are not fully recognised. Besides small number of exceptions, there is little research on hydrological processes and conditions of water relations improvement within small catchments with periodical flows and intermittent reservoirs. For eroded agricultural catchments, due to a variety of not-fully recognised problems and potential threats, the issue of the development of the surface retention is undertaken reluctantly.

MATERIAL AND METHODS

The analysis of the possibilities of shaping the water retention and the importance of this process for functioning of agricultural land – with particular emphasis on areas at risk of water erosion was carried out in the paper. Considerations based on the data contained in the available literature and own research results presented in previous publications. The authors of this paper conducted observations in 2000–2004 within the loess agricultural catchments on the Lublin Upland. They included determining the quantity of unproductive surface outflow through middle-field flows, evaluating the possibilities of utilising small intermittent reservoirs for retention of runoffs, working out concepts of catchment management taking into consideration necessity to rational shaping water resources as well as protection against erosion. The detailed research included the following: determining physical parameters of selected catchments (geometry, soil cover, land management, etc.), measuring of water levels and flow rates, determining the extent of the reservoirs colmatation by eroded soil material, characterization of meteorological conditions, analysis of threats sources to water resources resulting from management and geo-morphological conditions.

TYPES OF WATER RETENTION

Types and forms of retention are classified in different ways in literature [Mioduszewski 1996, Łabędzki 1997, Radczuk *et al*. 1997, Mioduszewski 1999, Kowalewski 2003]. Considering the type, water retention can be usually divided into natural and artificial as well as controllable and non-controllable. Natural retention is determined by natural factors present on a given area. It is accepted that possibilities of its creation from grounds due to technical activity are negligible – only activities aiming at increasing the natural retention can be undertaken. Artificial retention is formed due to human activity that can include construing new objects as well as enhancing existing natural retention [Łabędzki 1997, Mioduszewski 1999]. A characteristic feature of controllable retention is a possibility of a water disposal in various objects at any time (e.g. artificial reservoirs equipped with regulation facilities). In the case of large-capacity reservoirs, it is possible to control the flow rate for a longer period. Small reservoirs usually retain water during its excess, and its outflow is a natural process. Non-controllable retention is represented by majority of literature-mentioned forms of so-called „small retention", along with very small reservoirs. In opinion of Mioduszewski [1999], that type of retention is out of control, it is working automaticly, and its capacity is difficult to estimate. Increasing the landscape or surface retention influences on the change of water circulation within a catchment, decreases flood-stages in a flow, and increases the low flows; however any regulation of this process is impossible.

Among small retention forms, the landscape (habitat), underground and surface waters, as well as soil retentions are the most frequent. According to Mioduszewski [1996, 1999], that classification is conventional, because in many cases the interaction with one form causes some changes within the other. For instance, changes in habitat retention (hydraulic roughness of the catchment's surface) may affect the change in the soil retention. Introducing middle-field afforestations or afforestation of arable lands exerts some effects on level of interception, evapotranspiration, and characteristics of a soil profile, and thus on retention features of the soil.

The landscape retention is closely connected with topographic features and land management. It was found that its increase is associated with reducing surface runoff, the effect of which should be the increase of water infiltrating into the subsoil [Mioduszewski 1999]. For instance, in afforested catchments, thawing and rainfall high waters are delayed in time, which is explained with a slower snow thawing, great litter retention capacity, as well as higher porosity and permeability of soils under the forest [Kucharska *et al*. 1984, Mioduszewski 1999, Ciepielowski *et al*. 2001]. Peatbogs localised in river valleys and land depressions are characterized by great retention ability. In opinion of Mioduszewski [1999, 2003], presence of peatbogs in a catchment makes high water flow lower due to a slower outflow from flooded area. It was found that 10% share of peatbog area in the whole catchment area results in 30–40% lower flood wave. The anti-erosional treatments can have a positive effect on water resources of high relief terrains – besides their principal function of soil washout reducing, they also decrease the water outflow from the area surface. Therefore, any activity aiming at counteracting the erosion such as slope terracing, middle-field afforestations or building the colmatation reservoirs, are those that should improve the water relations within a given area [Pałys 1980, Orlik and Węgorek 1995].

Retention of underground waters results from an ability of water-bearing layers to store the water within saturation zone. Resources of underground waters are considered as the least unreliable and they are the most effective security for water resources [Mioduszewski 1996, Chełmicki 2002]. Increase in alimentation of water-bearing layers can be observed when activities that reduce the surface runoff and accelerate the infiltration process, are undertaken. Chełmicki [2002] presents two examples of such enrichment: injection of water by means of absorbing wells and infiltration using infiltration basins. Presence of drainage system also has remarkable influence on water relations of a given area, thus some authors consider it reasonable to apply outflow-controlling devices (which is particularly important during drier summers and after no-snow winters) [Ilnicki 1989, Trybała 1996].

Retention of surface waters is associated with temporary water volume present in river beds, canals, flood waters, and various types of reservoirs [Mioduszewski 1999]. It is underlined that water retention in those objects increases water resources not only within them, but also adjacent areas – e.g. by increasing ground waters level [Nyc and Kamionka 1995, Ryszkowski *et al*. 2003]. Small reservoirs can be sometimes used for protecting against erosion. Due to a slower flow rate, a drugging debris and floating material – including fertilizers – is retained within a reservoir. That phenomenon gradually reduces the useful capacity (worse exploitation conditions), and intensifies the self-purification processes on the other hand [Bednarczyk *et al*. 1988, Kowalewski 1997]. An appropriate water management within melioration valley systems, where possibly maximum utilisation of own waters should be a priority in some author's opinion, is of a great importance for agricultural economy and protection of water resources. Early closing the damming structures in spring gives an opportunity to retain considerably large quantities of water meeting the plant's requirements during their fastest growth [Brandyk 1990, Nyc and Pokładek 1997]. Mioduszewski [2003] reported that due to regulation of outflow from the drainage system, it is possible to store 50–70 mm of water, and with it nutrients that are carried along from cultivated fields. In the case of wide river valleys built of organic matter, the increase of retention is possible due to activities that delay the flow of flood waters (building so-called „dry reservoirs", allowing to flood the poorly utilised agricultural polders, building dams and throats in river beds and its valley) [Trybała 1996, Laks and Wosiewicz 1997]. A great role of the valley retention in reducing the flood wave in small catchments, where water rises in a flow after heavy rainfalls are fast and short, is emphasized [Mioduszewski 1999].

THE WATER RETENTION IN LOESS AGRICULTURAL CATCHMENTS

In the case of areas threatened with strong erosion, the condition for formation of reservoir retention in river valleys should be to increase retention of partial basins. The favourable solution is water storage in slope valleys, for example through creation of floodings on the line of periodic surface flows [Zubala 2005a, b, Zubala and Palys 2008]. Small reservoirs may have beneficial effects on water balance in micro-catchments (prolongation of time and a route of the water cycle) and play role of biogeochemical barriers (reduction of contaminant migration from the area of croplands). The research of the capacity of unproductive runoff and the possibility of water retention in small agricultural slope basins was carried out in the Ciemiega Basin (Nałęczowski Plateau) in 2000–2003.

Unproductive outflows from single catchments with area of several square kilometers ranged 61 700–207 000 m^3 per year (27 000–46 000 $m^3 \cdot km^{-2}$). The bulk of surface runoff coincided with winter terms (80–98% of annual outflow). The average flow rates fluctuated in the 2.0–6.6 $m^3 \cdot s^{-1}$ range, but peak values amounted to approximately 200 $m^3 \cdot s^{-1}$. Flow measurement results show that the rhythm of outflow from basin is determined mainly by the nature of water supply. Its source is a rainfall, which in the cold season takes immediate participation in the outflow and a snowfall, which feeds runoff during thaws. In warmer months there is a gradual decrease of the outflow – summer precipitations are consumed in most part in the process of evapotranspiration. In July and August there are long periods of complete disappearance of the outflow [Zubala 2005a]. Favourable conditions for location of small reservoirs are highly wet estuaries of micro-catchments. In these places maintenance of drainage facilities has not been led for many years. The execution of a dam with a height of around 1 m would allow for accumulation of additional 4000–6000 m^3 of water with flooding surface area of 0.5–1 ha (Photo 1) [Zubala and Pałys 2008].

Division of the line of surface flows by the road embankment has created a temporary water body also in the upper part of the slope basin (Photo 2). The volume of retained water was on average 2600 m^3 (up to 4400 m^3). The surface of water-table at the highest state reached 0.7 ha. Surface water supply to the reservoir occurred mainly during snowmelts and heavy rainfalls. Only in those periods were observed sporadic outflows from the water body. Water states were characterized by visible annual and seasonal fluctuation, which was dictated by the variable precipitation supply. During a hydrological drought, complete disappearance of water in the reservoir was noticed. This phenomenon was preceded by a significant reduction in groundwater levels in its vicinity [Zubala 2005b].

The impact of erosion on the environment causes mainly reduction of soil production potential, but also of deterioration of water quality and of adverse changes of water balance in a catchment. One way to reduce a outflow of water and eroded soil from an agricultural catchment is the use of earthen barriers in

Photo 1. The estuary of slope valley – good place to locate a small flooding (T. Zubala)

Photo 2. The intermittent reservoir in the bottom of the side valley (T. Zubala)

Photo 3. The cascade of midfield reservoirs in the line of periodic flows (M. Patro)

lines of periodic flows. This type of antierosion measures was introduced in the Orchard Farm Euro-East in Olszanka on the Lublin Upland [Rubaj 2004]. Above barriers built of local soil there were reservoirs retaining summer and snowmelt outflows (Photo 3).

The research on the effectiveness of barriers in reducing erosion and retaining water was conducted in 2001–2004 [Patro 2004, 2007, 2008, 2010]. Has been shown high efficiency of the system of built-up of lines of periodic flows to reduce the outflow of eroded soil material outside the catchment. Moreover, the possibility of using this system (midfield reservoirs created above earthen barriers) to retain water in an agricultural landscape was stated.

In connection with periodic removal and deposition of silt accumulated in reservoirs on outside slopes and dam crowns, heights of barriers and maximum capacity of each reservoir have changed and amounted to 0.5–2.1 m and 102–740 m^3 respectively. Surface area of reservoirs filled with water up to the level of dam crowns was 0.69–0.79 ha, representing about 1% of the total catchment area (73.41 ha). The limiting factor in water retention capacity of the reservoirs was their colmatation with soil material carrying away from the micro-catchments (6–36% of the total tank volume). Taking into account colmatation of reservoirs, their retention capacity ranged from 3.3 to 4.9 mm per catchment area in each vegetation seasons [Patro 2007].

CONCLUSIONS

Among causes of water deficit of the country is action causing acceleration of land phase of the water cycle. Improper management and exploitation of water resources within a small catchment resulted in drainage of larger regions and appearing of adverse environmental changes (increased erosion, reduced flows in streams, lowering water tables, drying of agricultural land). Growing demand for water indicates the need for its efficient use, but also carrying out actions aimed at protecting its quantity and quality. The important elements of proper water management are treatments to increase retention. They concern the rapid conversion of surface runoff into a much slower underground runoff and water storage in reservoirs. Selection of water retention methods has to result from potential abilities of a given area to retain it as well as real possibilities of its supplying in water.

Survey made within loess agricultural catchments revealed that the current status of management does not favour the water retention (no forest areas, cultivations and roads parallel to the slope inclination, etc.). Fast and unproductive surface runoffs directing to the main valleys should be expected namely during thawing and storm rainfalls, which may cause periodical floods. Possibilities to improve the water relations, and in consequence, conditions of functioning the natural-economic system should be found by means of reduction of the outflow quantity. Building systems of barriers in lines of periodic runoff allow to retain not only water, but also soil material eroded from the catchment. It is one of the most important conditions for creation of retention reservoirs in river valleys.

A spectrum of local conditions should be recognised in detailed prior to undertaking any correction of the water balance structure (analysis of associations between environmental components, or the character of spatial management). All actions should take into consideration also the need to maintain a biological diversity and sustainability of ecosystems within catchments, as well as protection and improvement of natural values of the landscape. In the case of agricultural catchments, these issues acquire particular significance. Restructuring of agriculture makes some conditions to a proper farm organisaing, including plot and rotation fields planning, appropriate croplands arrangement.

REFERENCES

Bednarczyk T., Lipski C., Madeyski M., 1988. An accumulation of load in small reservoir and its appraising based on denudation process in loess river basin (in Polish). Zesz. Probl. Post. Nauk Roln., 357, 45–55.

Brandyk T., 1990. Bases of the moisture regulation of valley soils (in Polish). Rozpr. Nauk. i Monogr., 116, Wyd. SGGW, Warszawa, 120 pp.

Chełmicki W., 2002. Water. Resources, degradation, protection (in Polish). PWN, Warszawa, 306 pp.

Ciepielowski A., Laskowski R., Stolarek A., 2001. Evaluation of retention condition in forest catchment areas (in Polish). Prace Inst. Bad. Leśn., seria A, 4 (923), 5–22.

Ilnicki P., 1989. Impact of arable land drainage on the changes in groundwater levels (in Polish), in: Rola melioracji w środowisku przyrodniczym. Zesz. Nauk. Komit. Melior. PAN, Warszawa, p. 255–274.

Kowalewski Z., 1997. Small water reservoirs as an element of improving of surface water quality (in Polish), in: Zbiorniki wodne – rola w krajobrazie rolniczym. Mat. sem. 40, Wyd. IMUZ, Falenty, p. 29–50.

Kowalewski Z., 2003. The effect of surface retention on the water balance of small agricultural catchments (in Polish). Woda–Środowisko–Obszary Wiejskie, 6, Wyd. IMUZ, Falenty, 126 pp.

Kucharska K., Tyszka J., Ciepielowski A., 1984. The role of forest in compensation of the outflow from the small catchment area in north-eastern Poland (in Polish). Gosp. Wod., 4, 107–110.

Laks I., Wosiewicz B., 1997. One-dimensional model of flow routing for a river net with set of polders (in Polish). Roczn. AR w Poznaniu, 19, 159–167.

Łabędzki L., 1997. Functions and effects of small water retention in agricultural areas in the aspect of small retention program for the Bydgoszcz province (in Polish), in: Woda jako czynnik warunkujący wielofunkcyjny i zrównoważony rozwój wsi i rolnictwa. PHARE-FAPA-IMUZ, Falenty, p. 38–45.

Mioduszewski W., 1996. Management of water resources in the agricultural landscape (in Polish), in: Ochrona i zrównoważony rozwój środowiska wiejskiego. Wyd. SGGW, Warszawa, p. 93–103.

Mioduszewski W., 1999. Conservation and shaping of water resources in the agricultural landscape (in Polish). Wyd. IMUZ, Falenty, 165 pp.

Mioduszewski W., 2003. Small retention. Protection of water resources and the environment. Wyd. IMUZ, Falenty, 49 pp.

Nyc K., Kamionka S., 1995. Effect of fish ponds operating on the ground retention of adjacent areas (in Polish). Zesz. Nauk. AR we Wrocławiu, 8 (266), 201–210.

Nyc K., Pokładek R., 1997. The controlled outflow as an element of enrichment the resources of ground-water retention and the agriculture environment protection (in Polish), in: Przyrodnicze i techniczne problemy ochrony i kształtowania środowiska rolniczego. Wyd. AR w Poznaniu, p. 261–268.

Orlik T., Węgorek T., 1995. Erosive threat in the Ciemięga river catchment and the concept of prevention (in Polish), in: Proekologiczne zagospodarowanie zlewni rzeki Ciemięgi. Wyd. AR Lublin, p. 51–63.

Pałys S., 1980. Impact of soil erosion and long-term anti erosion treatments on the formation of the outflow, sculptures and loess soil cover (in Polish). Rozpr. Nauk., Wyd. AR w Lublinie, 64 pp.

Patro M., 2004. The water quality in small water reservoirs in agricultural catchment (in Polish). Zesz. Nauk. AR we Wrocławiu, Inżynieria Środowiska XIII, 502, 381–389.

Patro M., 2007. The earthen barriers in flow line as the element of shaping the retention and the anti-erosional protection (in Polish). Doctor's thesis (typescript), Akad. Roln. w Lublinie, 184 pp.

Patro M., 2008. Influence of in-field retention reservoirs on soil outflow from a catchment. Ann. Warsaw Univ. Life Sci. – SGGW, Land Reclam., 39, 103–109.

Patro M., 2010. Influence of earthen barriers in the water-course lines in the agricultural catchment (in Polish). Zesz. Probl. Post. Nauk Rol., 548, 445–453.

Radczuk L., Szczegielniak C., Olearczyk D., 1997. Proposal of uniform scheme of small storage capacity stock taking (in Polish). Gosp. Wod., 3, 74–77.

Rubaj J., 2004. The method of protecting land against surface and gully erosion. The device to protect land against surface and gully erosion (in Polish). Patent nr P.345788.

Ryszkowski L., Bałazy S., Kędziora A., 2003. Shaping and protection of water resources in rural areas (in Polish). Wyd. PRODRUK, Poznań, 70 pp.

Trybała M., 1996. Water management in agriculture (in Polish). PWRiL, Warszawa, 255 pp.

Zubala T., 2005a. The possibilities to increase water retention in small loess agricultural catchments (in Polish). Doctor's thesis (typescript), Akad. Roln. w Lublinie, 227 pp.

Zubala T., 2005b. Possibility of surface run-off retention on an example of selected loess micro-basin (in Polish). Acta Agrophysica, 5 (1), 219–228.

Zubala T., Pałys S., 2008. Natural and economic conditions of water retention shaping in dry loess valley (in Polish). Zesz. Probl. Post. Nauk Rol., 528, 341–347.

MOŻLIWOŚCI KSZTAŁTOWANIA RETENCJI WODNEJ W KRAJOBRAZIE ROLNICZYM

Streszczenie. Niewielkie zasoby oraz rosnące zapotrzebowanie na wodę wskazują na konieczność jej oszczędnego wykorzystania, a także prowadzenia działań zmierzających do ochrony ilościowej i jakościowej. W pracy poddano analizie możliwości zwiększania retencji w obrębie zlewni rolniczych, zwracając szczególną uwagę na tereny zagrożone erozją. Retencję sklasyfikowano jako naturalną i sztuczną, sterowalną i niesterowalną oraz krajobrazową, wód podziemnych, powierzchniowych i glebową. W przypadku urzeźbionych zlewni lessowych temat retencji powinien być rozpatrywany łącznie z ochroną przed erozją. Wprawdzie stwierdza się znaczne ilości jałowego odpływu wody oraz warunki do jej gromadzenia, jednak istnieje duże ryzyko kolmatacji materiałem glebowym wyerodowanym w obrębie upraw rolniczych. W tej sytuacji warunkiem tworzenia zbiorników w dnach dolin rzecznych jest zwiększenie retencji zlewni zboczowych, w tym wprowadzanie barier biogeochemicznych (np. przegród kolmatacyjnych).

Słowa kluczowe: zlewnia rolnicza, zasoby wodne, retencja