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RIPARIAN BUFFER STRIPS – FOREIGN EXPERIENCE AND READJUSTMENT TO LITHUANIAN CONDITIONS

Nijole Bastiene[1], Juozas Kirstukas[2]

[1]*Water Research Institute, Faculty of Water and Land Management, Lithuanian University of Agriculture, Parko 6, Vilainiai, LT-58102, Kėdainiai Distr., Lithuania. E-mail: vegelyte@delfi.lt*
[2]*Department of Economics, Economics and Management Faculty, Lithuanian University of Agriculture, Universiteto str. 10, LT-53361, Akademija, Kaunas Distr., Lithuania. E-mail: juozas.kirstukas@lzuu.lt*

Abstract. Intensification of agricultural activity, increasing areas of cultivable land and reclamation works in the river valleys (canalizing and deepening of the river bed, installation of drainage systems) have a significant influence on the natural carcass. Destruction of riparian buffer strips in river valleys breaks the existing natural ecosystems, which function as natural biochemical barriers providing the landscape with aesthetic scenery, protecting the biodiversity and reducing pollution of surface waters. Vegetative buffer strips, located along the riversides, have been recognized to be the most effective measure for the water protection against non-point agricultural pollution in many countries of the world. Still, there is some uncertainty about the design of buffer strips, which is related with the variety of hydrological parameters of the river basins and with the factors determining the peculiarities of pollutants‘ flow (type and density of the strip vegetation, width and slope of the strip). The purpose of this paper is to review and summarise published research on the efficiency and management of riparian buffer strips and on the basis of the completed analysis, to formulate the main principles the riparian buffer strips‘ design, rehabilitation and management in Lithuania and to present calculations of their economical efficiency. The methods of logical analysis and synthesis, comparison, statistical analysis, calculation of relative indices and generalization have been used in this work. This study enables to distinguish the optimal buffer strips‘ management measures that are suitable to the particular Lithuanian conditions, to suggest approximate widths of riparian buffer strips in typical regions of Lithuania, and to estimate relative costs, expedience and priorities of the buffer strips‘ re-establishment and maintenance.

Keywords: costs, design, maintenance, re-establishment, riparian buffer strips, water bodies.

1. Introduction

The importance of research on natural ecosystems has been increasing in recent years. In 2008-2009 the authors of this paper took part in the Project „Possibility studies of the measures for water protection purposes“, implemented by the Environmental Protection Agency. Following the activity directions, foreseen in this study, the theory and practice of measures for management of riparian buffer strips of the water bodies in Lithuania and foreign countries were reviewed, the efficiency of the buffer strips in retention of biogenic materials, reduction of overgrowing and improvement of ecological (biological) condition was assessed, comparative costs of the buffer strips‘ establishment and management were evaluated. This paper presents the generalized material and the prepared insights.

According to scientific literature, anthropogenic activity has broken natural hydroregime and ecological balance in most surface waters (Eiseltova *et al*. 1995). Due to agricultural intensification riparian buffer strips in river valleys have been destructed, and the canalized and straightened waterways have become point pollution sources as water purification process does not complete there (Conley *et al*. 2002). Among a range of water protection measures (such as implementation of municipal and industrial waste water treatment, fertilize use and pesticide control, sustainable agriculture practice, artificial wetlands and water retention ponds), vegetated buffer strips along the margins of a water bodies are recognized as the most significant environmental management tools for reducing impacts of land use activities on aquatic resources in many countries (Hefting and Klein 1998; Nielsen 1995; Dillaha *et al*. 1988; Gustafson *et al*. 2000; Heraty 1993; Goel *et al*. 2004; Correll 2005). The importance of buffer strips as a part of ecological network has been constantly increasing. In foreign countries the programme of rivulets’ renaturalization and the projects aiming to reduce water pollution and to preserve the biodiversity were started a few decades ago (Vought *et al*. 1994; Fleischer 1995). Lithuania is far behind in this respect.

A riparian buffer strip is an ecotype, which has a unique specific biodiversity and separates water and land ecosystems (Gregory *et al*. 1991; Malanson 1993; Naiman *et al*. 1993). A relatively narrow riparian strip, where land is usually not suitable for any other activity, can be used to maintain good water quality, to reduce the flood damage and preserve areals of wild nature. Often is the case, when buffer strips are underestimated by setting only one task - to trap the erosion products. Actually, serious attention should be drawn to the multifunctionality of buffer strips giving economical, ecological and social benefit. The reluctance of landowners to lose intensively cultivated areas appears to be the main argument against the establishment of new buffer strips. New understanding of environmental protection and agricultural activity, based on consistency of economical and ecological interests, can change these attitudes.

Not many articles on riparian buffer strips have been published in Lithuania. Investigation of the efficiency of buffer strips was started approximately in 1980. Primarily they were investigated with respect to the erosion prevention (Račinskas 1983). Later the interest focused on the role of buffer strips in the retention of biogenic materials. The studies carried out in the Vardas stream basin in southeast Lithuania have shown that the riparian buffer strip may effectively retain and remove nutrients and sediment (Šileika ir kt. 1998). The permanent maintenance of channelized agricultural streams (open drains) is cost expensive, therefore, low cost solutions are of great interest (Šaulys and Bastienė 1998; Rimkus and Vaikasas 1995; Rimkus *et al.* 2003). Some researches propose alternative way of open drains maintenance: to grow woody vegetation on drain slopes. Correction of plant species composition on the slopes would maintain and recondition the open drains for their management to become ecologically reasonable, and sufficient receiving and discharging the capacity to be retained (Lamsodis *et al.* 2006).

Despite the number of completed investigations, there is some uncertainty about design of riparian buffer strips, which is caused by the variety of hidrological parameters in the river basins and the factors that determine the peculiarities of the pollutants' movement (Fennessy and Cronk 1997; Wenger 1999). The importance of buffer strips' investigation remains actual.

Objective of the work – to review the most important functions of the riparian buffer strips and their efficiency in retaining the nutrients and on the basis of the completed analysis, to formulate the main principles of the riparian buffer strips' establishment in Lithuania and to present calculations of their economical efficiency – relative costs, expediency and priorities.

2. Methods

This paper reviews results of the research on the main functions and efficiency of riparian buffer strips, carried out in various countries (Estonia, Sweden, Denmark, the Netherlands, the United Kingdom, Canada, the USA and Australia). Based on the literature review the main principles of riparian buffer strip readjustment to Lithuanian conditions are formulated.

The methods of logical analysis and synthesis, comparison, statistical analysis, calculation of relative indices and generalization have been used in this work.

The buffer strip re-establishment and maintenance costs have been calculated following the approved technologies, methods of estimate price calculation for the equipment of technical-engineering measures as well as rules and standarts for working time, machinery exploitation and materials for installation and maintenance of land reclamation structures (Darbo… 2007; Melioracijos techninis… 2006; Melioracijos objektų… 2007; Dėl melioracijos… 2007–2008; Dėl valstybei… 2008). Calculation of compensation costs for the lost income suffered by the land users due to low land use intensity in the buffer zones is based on the statistical data of respondent farms in Lithuania (difference between the average profit from 1 ha of cereals and profit from 1 ha of meadows makes approximately 320 Lt ha^{-1}).

To establish economical priorities of buffer strips, the relative re-establishment costs have been compared with their technical efficiency, i.e. the amount of biogenic materials retained from one area unit having evaluated the reduction of biogenic materials' concentration. The ratio of these values expresses the re-establishment costs per unit of pollution (1 kg of nitrogen and 1 kg of phosphorus). This understanding of costs efficiency has been approved following the conception used in water management institutions and partially corresponds to the theory of economics (Techninis… 1995).

3. Results and discussion

3.1. Functions and efficiency of riparian buffer strips

Riparian buffer strips have a number of multiple functions (Eiseltova *et al.* 1995; Wenger 1999; Sharpley *et al.* 2001; Mander *et al.* 2008):

- erosion prevention (sediment retention, streambanks stabilization),
- trapping/removal of nutrients that can lead to eutrophication of aquatic ecosystems and elimination of pesticides,
- improving ecological condition of water bodies (maintaining habitat for fish and other aquatic organisms, providing habitat for terrestrial organisms),
- improving landscape aesthetics and enlarging recreational opportunities.

There is no doubt about the efficiency of buffer strips in sediment trapping and prevention of banks' erosion. The potential to become saturated with fine sediment over time should be considered when establishing optimum buffer widths (White 1993; Williams 1993; Beeson *et al.* 1995). Gharabaghi *et al.* (2002) found that the first 5 m of the buffer strip were critical for sediment retention and efficiency did not increase much beyond 10 m strip widths. Whereas riparian buffer strips ability to trap erosion products may decline with age, sediments or organic matter periodically must be removed from the buffer zone (Muscutt *et al.* 1993; Barling and Moore 1994).

Riparian buffers also play a valuable role in preventing the contamination of watercourses with pesticides, heavy metals and other pollutants, toxic for aquatic wildlife. It should be noted that organic materials (woody debris, leafs, plant litter), which fall into water bodies from vegetated buffer strips, are valuable for the aquatic environment and wildlife (Barling and Moore 1994).

One of the most significant effects of reintroduction of riparian ecotones along the margins of watercourses is that it can reduce input of nutrients entering streams by surface and subsurface flow and drainage (Mander *et al.* 1997). The effectiveness of buffer strips for retention of nutrients varies according to the mechanisms by which these pollutants are transported. Surface runoff can be the major pathway for soluble pollutants also for sediment and particulate pollutants when the surface soil becomes saturated or when rainfall intensity exceeds the infiltration capacity of the soil. Sediment in surface runoff can carry particulate forms of phosphorus and a high proportion of total P loss has been found to occur during periods of high flow. According to Ulén *et al.* (2007) and Kronvang *et al.* (2007) erosion products carry approximately 40–88% of total phosphorus. Withers and Haygarth (2007) state that riparian buffer strips can effectively trap sediment bound phosphorus in surface flow. However, reducing efficiency of dissolved phosphates in buffer strips is low (Review… 2004; Agricultural… 2009; Chardon *et al.* 2007).

Subsurface flow is frequently the major pathway of nitrogen transport in catchment runoff. Subsurface flow paths are influenced by the surrounding topography and soil drainage characteristics: on land that is free draining, water and associated pollutants may bypass the riparian zone, whereas on poorly drained soils or where the water table is high, pollutants in subsurface water may be carried into the soils of the buffer zone. Removal of nitrogen in subsurface flow can partly be explained by vegetation uptake, but the main mechanism for removal is denitrification (Hanson *et al.* 1994; Søvik and Syversen 2008). The water bypassing the riparian ecosystem can trap approximately up to 74,2±4,0% of nitrogen. Retention of nitrogen in surface runoff directly depends on the width of buffer strips while in subsurface flow – on the soil hydrology characteristics. Nitrate content trapped in surface runoff is less compared to that in the subsurface flow. The buffer strips width of 15 m is referred, however, the width of more than 30 m is more effective. For the nitrogen control it is very important to extend stream valleys, to preserve existing and create artificial wetlands, because the large amounts of nitrogen are retained here (Gilliam 1994).

Literature sources provide fairly consistent evidence that the major part of the nitrate and phosphorus is removed with a 10 m buffer strip (Fig 1).

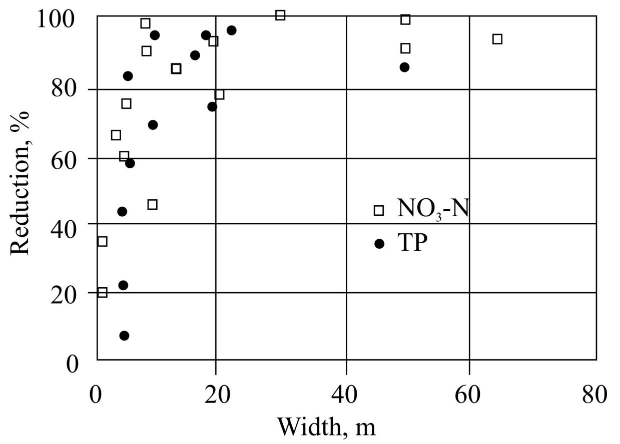

Fig 1. Reduction of total phosphorus (TP) in surface runoff and nitrate nitrogen (NO_3-N) in subsurface flow (Vought 1995)

The efficiency of nutrients removal varies by buffer vegetation type (Blaskerod *et al.* 2000). The grass buffer strips are effective at filtering sediment and sediment-associated pollutants, however, the greatest improvements in habitat diversity are likely to occur when riparian management involves planted trees or remnant forest (Castelle *et al.* 1993). Grass buffers are significantly less effective than forested buffers at removing nitrogen, wetlands – at removing phosphorus (Table 1).

Table 1. Mean effectiveness of riparian buffers at removing nutrients (according to literature sources)

Vegetation cover type	Nitrogen removal effectiveness, %	Phosphorus removal effecttiveness, %
Complex buffer (trees, shrubs, grass)	98.0±1.3	95.0±3.4
Forest	90.0±2.5	80.0±8.3
Forested wetland	85.0±5.2	70.0±9.8
Shrubs	80.5±10.2	73.7±8.4
Grass	53.3±8.7	61.5±15.2
Wetland	72.3±11.9	50.0±12.3

When planning and designing buffer strips should be given priority in those Lithuanian regions, where the measures for water quality improvement are indispensable. These regions are characterized by the dislocation of risk watercourses. According to the data of the Environmental Protection Agency, the basins of risk watercourses due to agricultural pollution take one–fourth of the country area. These problem watercourses concentrate in the high fertility plains of the Middle Lithuania Lowland, where agriculture is highly developed and, consequently, non-point pollution level is high. There are more possibilities for planing of ecological means in southeast Lithuania, where agriculture activity is not very intensive (Survilaitė and Šaulys 2007). It is important to have the least possible amount of pollutants reach the smallest hydrographical network – small streams (up to 10 km length), therefore, implementation of pollution reduction measures starts in basins of the smallest rivers. To have complex evaluation of the criteria that determine the efficiency of buffer strips (relief, precipitation, soil), the hydrological zones distinguished in Lithuania (I – Coastal Lowland, II – Middle Lithuanian Lowland, III – Žemaičiai Upland, IV – Baltic Highlands) should be taken into consideration (Gailiušis ir kt. 2001).

3.2. Determination of buffer strips' width

The width required for nutrient and sediment removal can be quite variable. Foreign scientific literature recommends having the widest possible buffer strips at the watercourses (the wider strip – the higher effectiveness). However, in reality it causes numerous problems and appears to be unreasonable. Parkyn *et al.* (2000) recommend a buffer width of 10–20 m as the minimum necessary for the development of sustainable indigenous vegetation with minimal weed control, and to achieve many aquatic functions. Generally, it is recommended that planners and engineers use variable-width buffers, based on a topographic and soil data, to achieve a realistic representation of runoff generating areas. When riparian buffer strips perform the function of wild nature migration corridors, their width should be at least 100 m. In many agrarian territories maintenance of buffer strips of this width is not economically expedient, then, the minimal width is based on the water quality maintenance functions.

Variability in the forms, amounts and timing of nutrients from agricultural land is related to national differences in climate, soil, hydrological conditions and agricultural production (Ulén *et al.* 2007). According to the calculations that have been made for the Estonian conditions, the recommended buffer strip's width lies between 5 and 50 m (Fig 2).

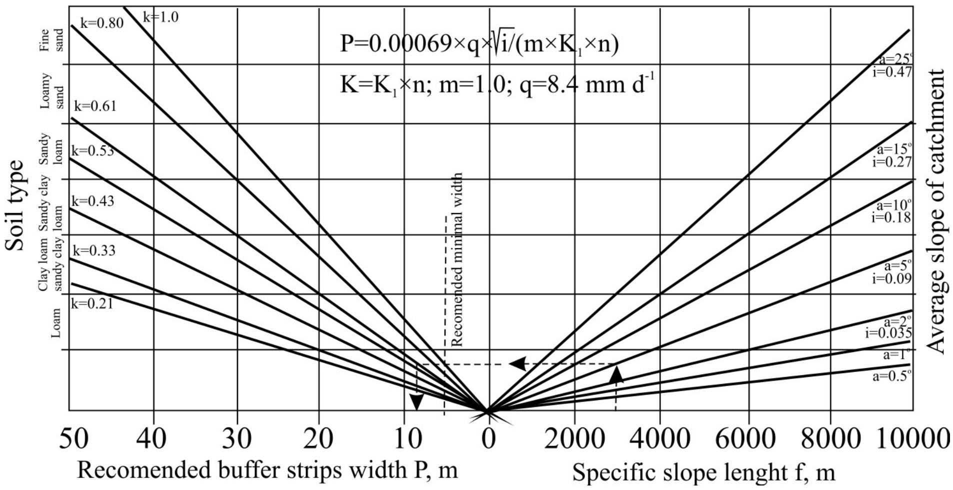

Fig 2. The nomogram for determination of the recommended buffer strip's width (Mander 1995)

A nomogram for the estimation of recommended width of riparian buffer strip has been compiled using the formula (Mander *et al.* 1997):

$$P = 0.00069 \frac{q \cdot f \sqrt{i}}{m \cdot K_i \cdot n}, \quad (1)$$

where P – the optimal width of buffer strip, m; q – mean intensity of overland flow during the thawing period, mm d^{-1}; f – specific slope length, m; i – mean slope in the catchment (i=tanφ); m – roughness coefficient of the surface; K_i – water infiltration within the buffer strip during the spring, mm min^{-1}; n – soil absorbtion capacity.

Mean value of the integrated soil parameter ($K_i \cdot n$) for main soil types is: coarse sand – 1.00, fine sand – 0.80, loamy sand – 0.61, sandy loam – 0.53, sandy clay loam and loam – 0.43, clay loam and sandy clay – 0.33, clay – 0.21.

The specific slope length f is defined using (2) formula. For homogeneous slopes, the f value will be calculated as the distance from the watershed border to the stream bank.

$$f = \frac{F}{l}, \quad (2)$$

where F – the elementary catchment area of a gully, m^2; l – width of a gully immediately on the bank of a stream, m.

As no investigations of this kind have been carried out under Lithuanian conditions, the suggestion can be made to relate the width of buffer strips with the purpose of their establishment (Bastienė and Kirstukas 2010). Here, recommendations of foreign scientists should be followed. In Lithuania at present the legislation recommends the width of riparian buffer strips of natural watercourses and regulated streams (depending on the inclination and length of the stream) varies within 2.5–25.0 m. The completed analysis suggests the following approximate widths of buffer strips in typical regions of Lithuania: at natural rivers and lakes in the Coastal

Lowland – 5–10 m, in the Middle Lithuanian Lowland – 10–15 m, in the Žemaičiai Upland – 15–25 m, in the Baltic Highlands – ≥25 m (narrow strips – woody vegetation, wider strips – grassy vegetation), at the regulated streams (in drained land) in plain regions – 3 m, in hilly regions – 10 m. These are guidance suggestions and they are not supposed for application in all cases. Determination of the most accurate necessary width of buffer strip requires evaluation of all parameters of the particular watercourse catchment (relief, soils, pollution loads, land use, etc.).

3.3. Re-establishment and management of riparian buffer strips

Riparian buffer strips can be overgrown with trees or grasses (intermediate variant – grassed buffers in conjunction with woody vegetation). Natural wetlands and foodplains also perform functions of buffer strips. The most effective are complex buffer zones that consist of different buffer strips with different plant communities. However, they occupy big areas, which make their application limited. In the lands of intensive agriculture this measure is recommendable only in specific cases, e.g. high pollution level, spread of slurry. This type of management system can offer a fexible avenue for land use planners. Such an approach would make it possible to meet environmental goals, while maintaining a productive use of part of the area covered by the buffer: farmers can get some wood for fuel or biofuel, fodder for animals, etc. With respect to water quality improvement the forested buffers are the best of the rest variants that have been mentioned.

The following variants of buffer strips re-establishment are possible:

- the strips may be formed from the existing (naturally growing) vegetation;
- anew formed strips (afforested or sowing of grasses;
- the strips are formed by leaving the streams for self-naturalization;
- formation of artificial wetlands by making affluents in floodplanes;
- natural forested wetlands resulting from beavers' activity.

From economical poin of view the least expensive is self-naturalization of streams, when strands of the required width are left uncultivated. In this case, a man does not interfere in the formation of riparian strips from naturally spreading vegetation, which, at the same time, is the areal of wildlife. The only drawback – long process of streams' renaturalization: formation of the required buffer strips may take decades. Besides, during this entire period compensations (equal to the lost profit) for the unused land have to be paid to the landowners.

The method that ensures quick, but expensive improvement of watercourses' ecological condition is planting riparian strips with certain plant species, which reduce the nutrients inflow. The area and species of vegetation must be selected considering the relief, soil characteristics, etc. It is generally recommended that native species be chosen to plant in riparian buffers.

Management requirements will be dependent on the purpose for which the buffer strip was established. When the aim is the improvement of ecological (biological) conditions of water body, natural woody vegetation, which does not require any care, is left in both cultivated and in forested land. When the buffer strip is aimed for other purposes (erosion prevention, trapping of pollutants), it requires special maintenance to stay healthy and competitive. Requirements for grassy vegetated buffer strip management:

- grass cover in the upland part of the buffer should ensure filtering efficiency and to trap erosion products;
- moving early in the summer and in the fall at a heigh of 15 cm will promote the densification and vigorous growth of the grass. Periodic harvest of buffer vegetation removes trapped nutrients preventing eventual release to the soil and potential movement to water. Harvesting also controls the spread of weeds from the buffer to the field;
- sediment that has built up in the buffer must be removed periodically in order to maintain its effectiveness. A buildup of 10 cm is enough to block and redirect overland flow. This may leds to the concentration of the runnof at low points;
- it is important to avoid disturbing established buffer strip by inappropriate agricultural practices. Surrounding farming practices may favour the concentration of flow which may in turn significantly reduce the effectiveness of the buffer as a filter;

Requirements for forested buffer strip management:

- selective felling, pruning and removal of bushes is recommended, which periodically renews tree populations, because plant uptake of nutrients in younger stands is significantly higher than that in older forests;
- the selective tree thinning should not destroy the upper humus-rich soil layer;
- to increase stability of the eroded banks, periodic pruning of bushes and hardwood trees can be considerd to maintain or increase stem density.

The accumulated erosion products and macrophites should be periodically removed from the wetland. They should be taken as far as possible from the watercourses to avoid the pass of sediment products and plant residuals back to the water.

3.4. Economical calculations of buffer strips' re-establishment and maintenance

The expenses of buffer strips' re-establishment at the shores of natural watercourses were calculated:

- when trees grow on both banks of the stream – 3474.72 Lt ha^{-1},

- when trees grow on one side of the stream (meadow is on the other side) – 1978.54 Lt ha^{-1},
- formation of grass and forested strips alternately (20% of length) – 761.20 Lt ha^{-1},
- formation of the continuous grass strip (removal of existing woody vegetation) – 2326.00 Lt ha^{-1}.

Relative costs of buffer strip's maintenance subject to vegetative cover type:

- grass (meadow) – 993 Lt ha^{-1},
- shrubby meadow – 1583 Lt ha^{-1},
- forest and shrubs: on both sides of the stream – 1109.54 Lt ha^{-1}; on one side of the stream – 1051.27 Lt ha^{-1}; grass and forested strips alternately – 440.28 Lt ha^{-1}; continuous forested strip – 2256 Lt ha^{-1},
- wetland – 1284 Lt ha^{-1}.

Average relative costs for maintenance of buffer strips at regulated streams and open drains – 1235 Lt ha^{-1} (Aplinkos… 2009, p. 169–172).

With application of different buffer strips' maintenance measures the relative cost efficiency for nitrogen retention varies from 46 to 203 Lt kg^{-1}, for phosphorus retention – from 305 to 902 Lt kg^{-1} (most – the maintenance of the existing forested buffers).

Calculations show that a specific priority order is expedient for the re-establishment and maintenance of buffer strips near watercourses (Table 2). The priority should be given to the measures, which require the lowest cost capacity for retention of 1 kg of nutrients. In the Middle Lithuania zone, where cereals and cultivated crops predominate, the following sequence of relative cost efficiency for retention of 1 kg of nitrogen has been established: 1) when the existing wetlands in floodplanes are left (46 Lt kg^{-1}); 2) riparian strips where the arable land is converted to grassland (54 Lt kg^{-1}); 3) the existing shrubby meadows are maintained near watercourses (63 Lt kg^{-1}); 4) the existing forested strips are maintained (102 Lt kg^{-1}). These measures should be applied in the same sequence for the phosphorus retention purposes. It has to be noted that conversion of arable land to meadows and pastures is three times more effective than maintenance of the existing forested strips. It is important to consider adding a constructed wetland component to riparian buffer system to intercept tile outlets. The design for the wetland component is flexible and can provide incredible long-term benefits at a very low cost.

Table 2. Expedience of riparian buffer strips re-establishment and maintenance

Land use	Vegetative cover type	Retention efficiency, %		Re-establishment cost, Lt ha^{-1}	Maintenance cost, Lt ha^{-1}	Cost capacity Lt kg^{-1}	
		N	P			N	P
Riparian buffer strips near natural watercourses and ponds							
Arable land	Forest	90	80	existing	2256	102	902
	Wetland	72	50	existing	1284	46	321
	Shrubby meadow	80	73.7	existing	1583	63	583
	Grass	53	61.5	1047	993	54	305
Grassland	Forest	90	80	existing	2256	203	902
	Wetland	72	50	existing	1284	92	321
	Shrubby meadow	80	73.7	existing	1583	127	583
	Grass	53	61.5	100	993	58	305
Riparian buffer strips near regulated streams and drainage channels							
Arable land	Grass	53	61.5	1047	1235	60	702
Grassland	Grass	53	61.5	100	1235	65	411

In the remaining part of the Lithuanian territory (Coastal Lowland, Žemaičiai Upland and Baltic Highlands), where meadows and pastures predominate, the following sequence of riparian buffer strips' relative cost efficiency (retention of 1 kg of phosphorus and nitrogen) should be followed: grass → wetland → shrubby meadow →forested strip.

Re-establishment and maintenance of buffer strips at the watercourses are not only of environmental but also of economical benefit. This benefit can be result of increasing land market value, state payoffs for participation in environmental programmes, profit from the use of buffer strip vegetation: growing bioenergetical plants, as raw material for small trades (wood, bark, wicker), food products (fruits, mushrooms, berries, nut crops), medical stock (drug plants), animal fodder, trees can provide landowners with valuable biomass, timber etc.

4. Conclusions

For the design of riparian buffer strips in the Lithuanian territory, the typical cases (regions) of similar hydrological conditions, relief and soils are expedient to distinguish.

Priorities of riparian buffer strips‘ re-establishment are based on the ecological state of the watercourses, environmental needs of the territory and coordination with the interests of the riparian land users. The most serious attention should be focused on those Lithuanian regions, where the measures for water quality improvement are indispensable (in the basins of risk watercourses).

According to the prices of 2008, including compensation for the change of the land use, relative costs of grass buffer strips re-establishment in arable land make 1047 Lt ha^{-1}, in existing meadows and pastures – 100 Lt ha^{-1}. Re-establishment of forested strips on the both sides of the stresam – 3474.72 Lt ha^{-1}, on one side (on the other side - meadow) – 1978.54 Lt ha^{-1}, re-establishment of grass and forested strips alternately (20% of length) – 761.20 Lt ha^{-1}, re-establishment of continuous grass strip (removal of existing woody vegetation) – 2326.00 Lt ha^{-1}.

Relative costs of buffer strips‘ maintenance at natural watercourses and ponds depend on vegetative cover type and vary from 440.28 Lt ha^{-1} (grass and forested strips alternately) to 1109.54 Lt ha^{-1} (forested strips on both sides of the stream). Average relative maintenance costs of strips at regulated streams and open drains – 1235 Lt ha^{-1}.

In the Middle Lithuania zone, where cereals and cultivated crops predominate, conversion of arable land to meadows and pastures is three times more effective than maintenance of the existing forested strips. In Coastal Lowland, Žemaičiai Upland and Baltic Highlands, where meadows and pastures predominate, the sequence of riparian buffer strips‘ maintenance measures based on the relative cost efficiency (retention of 1 kg of phosphorus and nitrogen) is similar: grass → wetland → shrubby meadow →forested strips.

Special additional investigations are expedient for the evaluation of the economical benefit of riparian buffer strips re-establishment in Lithuania.

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