Oksana BARVIDIENĖ

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SUMMARY OF DOCTORAL DISSERTATION

TECHNOLOGICAL SCIENCES,
ENVIRONMENTAL ENGINEERING (04T)

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Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2005–2009.
Scientific Supervisor
**Assoc Prof Dr Valentinas ŠAULYS** (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T).
Consultants:
**Prof Dr Antanas LUKIANAS** (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T),
**Prof Dr Habil Saulius VAIKASAS** (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T).
**The dissertation is being defended at the Council of Scientific Field of Environmental Engineering at Vilnius Gediminas Technical University:**
Chairman
**Prof Dr Habil Donatas BUTKUS** (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T).
Members:
**Assoc Prof Dr Edmundas BARTKEVIČIUS** (Lithuanian University of Agriculture, Biomedical Sciences, Ecology and Environmental – 03B),
**Assoc Prof Dr Mindaugas RIMEIKA** (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T),
**Prof Dr Habil Dmitrijus STYRO** (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T),
**Prof Dr Habil Narimantas Titas ŽDANKUS** (Kaunas University of Technology, Technological Sciences, Environmental Engineering – 04T).
Opponents:
**Prof Dr Antanas MAZILIAUSKAS** (Lithuanian University of Agriculture, Technological Sciences, Environmental Engineering – 04T),
**Assoc Prof Dr Aušra ZIGMONTIENĖ** (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T).

The dissertation will be defended at the public meeting of the Council of Scientific Field of Environmental Engineering in the Senate Hall of Vilnius Gediminas Technical University at 1 p. m. on 13 November 2009.
Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.
Tel.: +370 5 274 4952, +370 5 274 4956; fax +370 5 270 0112;
e-mail: doktor@adm.vgtu.lt
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Oksana BARVIDIENĖ

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Disertacija rengta 2005–2009 metais Vilniaus Gedimino technikos universitete.
Mokslinis vadovas
**doc. dr. Valentinas ŠAULYS** (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T).
Konsultantai:
**prof. dr. Antanas LUKIANAS** (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T),
**prof. habil. dr. Saulius VAIKASAS** (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T).
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Pirmininkas
**prof. habil. dr. Donatas BUTKUS** (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T).
Nariai:
**doc. dr. Edmundas BARTKEVIČIUS** (Lietuvos žemės ūkio universitetas, biomedicinos mokslai, ekologija ir aplinkotyra – 03B),
**doc. dr. Mindaugas RIMEIKA** (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T),
**prof. habil. dr. Dmitrijus STYRO** (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T),
**prof. habil. dr. Narimantas Titas ŽDANKUS** (Kauno technologijos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T).
Oponentai:
**prof. dr. Antanas MAZILIAUSKAS** (Lietuvos žemės ūkio universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T),
**doc. dr. Aušra ZIGMONTIENĖ** (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T).

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el. paštas doktor@adm.vgtu.lt
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## Introduction

***Formulation of the problem.*** Intensification of agriculture in the world and in the most European countries has been very important during the last century and now. Drainage systems have been installed in many wet lands in order to increase harvest of agricultural plants. As a result many natural river beds were straightened and deepened, riverside plants, bushes and other perennial vegetation were removed. Capacity of drained lands increased with installation of drainage systems, but also landscape has changed and became more uniform, many new anthropogenic components have appeared, ecological variety in drained areas was decreased. Favorable conditions for soil erosion, water bodies pollution, changes on fauna species and undesirable changes of local microclimate have formed as a result of riverside vegetation degradation.

Recently the world and European countries recognized necessity to revise practices of maintenance of regulated streams used for drainage, and are looking how to reconcile agricultural capacity with at least partial restoration of lost ecological equilibrium. Therefore, even mechanical naturalization is performed in most developed countries – meanders and bays are being excavated for regulated rivers, swims and rifts are being formed, riversides are being planted with trees and bushes. Thus, former natural bed and floodplain are restored partially or fully. With decreased traditional maintenance of regulated streams, free meandering and other natural bed restoration processes become more intensive, slopes and riversides of regulated streams are overgrowing with grass and woody vegetation, and swims and rifts are being formed in a bed. All researches demonstrate that self-naturalization of regulated streams does not reduce their hydraulic conductivity, does not affect humidity conditions of drained land, but contributes to restoration of lost ecosystem stability.

***Relevance of the work***. Projects of stream restoration and naturalization are performed in many other countries. Projects of stream restoration and naturalization are not performed in Lithuania yet, however signs of self-naturalization (change of grass vegetation, spread of woody vegetation in slopes, bed silting), are observed in many beds. Regularities of overgrowth of regulated streams in a hilly relief with woody vegetation and their effect on hydraulic conductivity are not determined yet.

Before stimulating naturalization processes, which are already in progress in regulated streams it is necessary to evaluate impact of such naturalization processes, particularly spreading and distribution of woody vegetation in beds, would have on hydraulic conductivity of regulated streams. Therefore, works

that evaluate impact of naturalization processes in streams regulated for drainage purposes on their functionality and promotion of biological diversity should be the priority in the area of Environmental engineering and land-use planning.

***The investigation object.*** The investigation object – streams regulated for the purposes of drainage located in the Southern Lithuania in a hilly relief. This area is selected because self-naturalization is researched just in the Middle Lithuania, in a plain relief. Since naturalization processes are running differently, it was decided to evaluate them in a hilly relief in the region of the Southern Lithuania. Morphometric parameters of beds were studied, quantitative and qualitative parameters of overgrowth with woody vegetation and form of bed cross-section and distribution of woody and grass vegetation in it (exposition, foot, slope, buffer zone) were determined.

***Aim and tasks of the work.*** Aim of the work – determine and research quantitative and qualitative regularities of overgrowth of regulated streams in a hilly relief with woody vegetation during naturalization processes. Evaluate changes in regulated stream functionality (hydraulic roughness of slopes, hydraulic conductivity) using hydraulic simulation as well evaluate possibilities to influence naturalization of regulated streams.

Following tasks have been solved in order to achieve the aim of the work:

1. Determine composition of woody vegetation species growing on the slopes of regulated streams located in the Southern Lithuania and its dependence on natural factors.
2. Determine distribution of vegetation species composition and density through bed cross-section profiles of regulated streams.
3. Determine quantitative parameters of overgrowth of regulated streams with woody vegetation and regularities of dependency on slope exposition.
4. Determine dynamics of roughness coefficient of regulated streams in the Southern Lithuania.
5. Determine influence of woody vegetation on hydraulic conductivity of regulated streams.

***Methodology of research.*** Natural experimental research of overgrowth of regulated streams with woody vegetation was performed in the scope of work, this was processed using methods of statistical analysis with confirmation of data reliability, and research of functionality (hydraulic conductivity) preservation is based on hydraulic-mathematical simulation.

***Scientific novelty of the work***. The novelty of the work is such that distribution of woody vegetation in a bed and its influence on hydraulic conductivity in regulated streams of hilly relief in the Southern Lithuania have not been researched nor simulated up to now. Regularities of quantitative and qualitative parameters of woody vegetation spread in regulated streams, influence of woody vegetation on hydraulic roughness of beds were determined.

Simulation of bed hydraulic conductivity was performed, which allows to influence naturalization processes of regulated streams at the same time maintaining functionality of drainage systems.

***Practical significance of the work results.*** Influence of self-naturalization processes of regulated streams, when slopes of the beds are overgrowing with woody vegetation, on hydraulic conductivity was evaluated in the work. Regularities of overgrowth of regulated streams with woody vegetation were determined subject to various natural and anthropogenic factors. It is necessary when planning to install drainage systems in order to preserve biological diversity and when implementing bed restoration measures.

***Defended propositions***

1. Intensive processes of slope overgrowth and naturalization, that are taking place in regulated streams of the Southern Lithuania, increase their ecological diversity and, at current situation, they are not impairing functionality of drainage systems.
2. Composition, density and frequency of woody vegetation species of regulated streams depend on various natural (distance to a forest, position in a slope, slope exposition) and anthropogenic factors, influencing their distribution in cross-section profile of a stream, and in riverside buffer zone.

***Structure of the dissertation.*** The dissertation is composed of introduction, five chapters, general conclusions. Its overall volume is 136 pages, 53 figures and 36 tables. The bibliography includes 111 items.

## 1. Overview of stream regulation development

Stream regulation tendencies in Lithuania and in the world are described in the chapter. Morphometric parameters of regulated stream beds, spread of woody and grass vegetation are provided. Influence of riverside buffer zone to regulated streams is evaluated. Substantial attention is dedicated to influence of

woody and grass vegetation on hydraulic conductivity of regulated streams. Conclusions and recommendations are provided in the end of the chapter.

## 2. Research methodology

Subject of the research is streams regulated for the purpose of drainage in the Southeast Lithuania in the region of hilly relief. This area is selected because self-naturalization is studied just in the Middle Lithuania, in a plain relief. Since naturalization processes are running differently, it was decided to evaluate them in a hilly region of the Southern Lithuania. 210 measuring points were studied in regulated streams. Average studied section length was 10 meters. Analysed profile was chosen out from mostly representative part for which main morphometric measurements of the bed and woody vegetation quantitative and qualitative parameters were determined (Fig. 1).

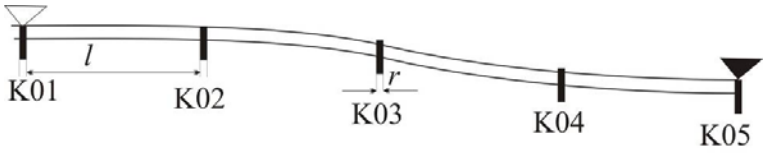



**Fig. 1.** Layout of researched sections of G-1 regulated stream: *r* – section length (10 m); *l* – distance between sections (100 m)

Number, density, frequency of species and their position in bed's cross-section profile were determined for species found in the beds, and riverside buffer zone's finding places. Density (*T*) – woody vegetation density in finding places was determined as total number of stems in 1 $m^2$ of bed's slope area (measured number of stems in one square meter, pc./$m^2$). Frequency (*D*) – woody vegetation spread frequency was determined as a ratio between bed's slopes or its parts (riverside buffer zone; top, middle part and foot) where specie was found, i.e. finding places, and a number of total studied sections, %; tree frequency ($D_M$) and shrub frequency ($D_K$ ) were also distinguished. Woody vegetation distribution character was determined in the researched profile. At the same time plant spreading was measured with a tape measure.

Following parameters were determined: 1) Lower limit of slope overgrowth with woody vegetation $r_a$ was determined – a distance from slope foot up to appearance of woody vegetation. 2) Top limit of slope overgrowth with woody vegetation $r_v$ – distance from the top of the slope down to appearance of woody vegetation. Width of overgrown slope strip $L_a$ is a

difference between total width of the slope and sum of following parts: part not overgrown with woody vegetation, top $r_v$, and lover $r_a$ parts.

Influence of a forest was estimated by sections up to 1 km every 100 m, excluding the first section, for which distance from the forest was taken 50 m. Forest, outskirt and field sections of regulated streams were distinguished according to performed measuring.

Regulated stream hydraulic roughness coefficients *n* were determined using hydraulic calculation methodology prepared by Lithuanian Water Management Institute for the trenches overgrown with shrubs and trees and deformed trenches. When we have determined hydraulic roughness coefficients of regulated streams, we have to forecast water levels in order to estimate influence of woody vegetation on hydraulic conductivity. Simulation software HEC–RAS was used for estimation of influence of woody vegetation (hydraulic roughness) on hydraulic conductivity of the stream with regulated water level.

Functionality of beds (conductivity) was evaluated according to water overflow parameter: it is positive ($h_V \leq h_G$), when water level in a bed ($h_V$) is lower or equal to regulated stream's depth ($h_G$), and negative ($h_V > h_G$), when water level in a bed ($h_V$) is higher than regulated stream's depth ($h_G$).

## 3. Results of the research of woody and grass vegetation distribution on regulated streams

Research of the Southeast Lithuanian regulated streams showed that slopes of the beds are covered with various trees and shrubs. Totally 33 woody vegetation species have been found: 16 species of trees and 17 species of shrubs. The most frequent tree species in the area of the research were sallow (*Salix caprea* L.), found in 41 finding places. Sparsely spread trees species: common fir (*Picea abies* (L.) H. Karst.), leaved lime (*Tilia cordata* Mill.), found in 1, 2 finding places respectively. The grey willow (*Salix cineria* L.), which was found even in 83 finding places, is considered to be the mostly spread shrub in the area. Following shrubs species are the sparsest: common Osier (*Salix viminalis*), plum-tree (*Prunus*), found in 1 finding places respectively. 210 sections of regulated stream slopes were researched in the Southeast Lithuania and woody vegetation was observed in 149 of them. Total frequency of all woody vegetation species on regulated stream slopes in the Eastern Lithuania is up to 71% (shrubs spreading frequency – 59%, and trees – 49%). Woody vegetation species spreading frequency in regulated streams, representing probability to find specie in a specific place, does not show its abundance yet. In order to estimate its abundance, we have calculated general density *T* of woody vegetation.

General density of stems is $T = 1.26 \pm 0.20$ pc./m$^2$ (trees – $T_M = 0.23 \pm 0.04$ pc./m$^2$, shrubs – $T_K = 1.04 \pm 0.20$ pc./m$^2$). Research data show that woody vegetation spread on slopes of regulated streams is highly influenced by slope location with regard to a forest (Fig. 2).

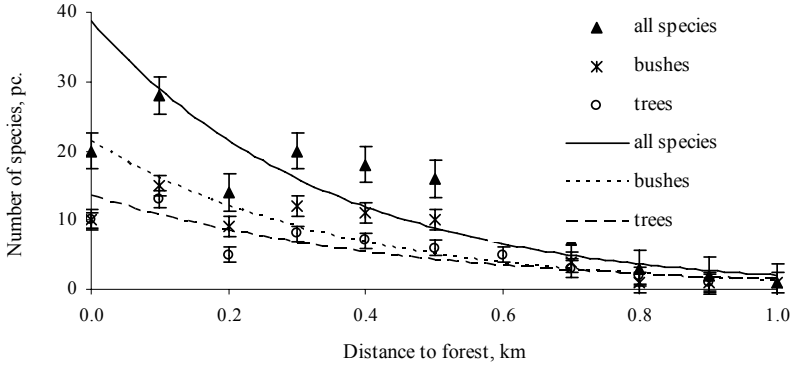



**Fig. 2.** Correlation between number of woody vegetation species on slopes of regulated streams and distance of their finding places to forest

Correlation between number ($r = –0.91$), frequency ($r = –0.70$) and density ($r = –0.88$) of woody vegetation and distance of finding places in slopes of regulated streams to a forest is very strong. Correlation between species of trees and shrubs and distance of finding places to a forest accordingly is ($r = 0.91–0.87$). The longer distance from a forest, the lower is general number of woody vegetation species, and numbers of tree and shrub species separately. Calculated correlation coefficients and values $p$ indicate that correlation is statistically significant between distance ($L$) and general number of woody vegetation species, and numbers of tree and shrub species separately at probability 95%.

We have observed, that woody vegetation distribution also depends on slope exposition. Woody vegetation density average for northeast exposition ($T_{ŠR} = 0.91$ pc./m$^2$) is 2.42 fold higher than for east exposition and 2.30 – than for south ($T_P = 0.39$ pc./m$^2$) exposition slopes (Fig. 3). Higher number of vegetation in north, northeast, southwest, northwest exposition slopes offers conclusion, that growing conditions for woody vegetation are more favourable on such slopes. West and southwest winds are predominant in Lithuania. It means that wind mostly is directed to west and southwest exposition slopes. These slopes receive more precipitation due to more frequent rains carried by

winds of such direction, and north and northeast exposition slopes are less warmed up, therefore are not dried out.

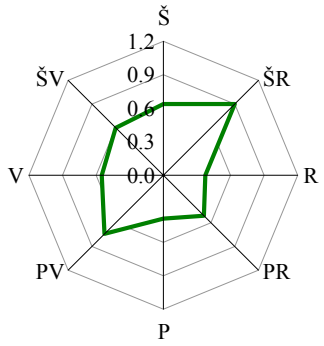



**Fig. 3.** Woody vegetation density in the slopes of different exposition

In order to assess if woody vegetation density differs substantially between different exposition slopes, we have performed analysis of variance. Analysis of variance for woody vegetation density data in slopes of different exposition showed, that averages of density for different exposition slopes does not differ significantly. Results of the research performed in Middle Lithuania which showed that regulated streams are more abundantly overgrown in west, northwest, north and northeast exposition slopes, were not confirmed for Eastern Lithuania. Accomplished research shows, that averages of that density in slopes different exposition do not differ significantly.

Analysis of woody vegetation coverage distribution on regulated stream slopes demonstrates that it is not uniform in the slope of a regulated stream. Conditions of plant growth are most favorable in the middle part of the slope, so woody vegetation is most abundant there. Width of overgrown strip is $L_a$ = 2.52±0.15 m. The changing conditions on the slope have determined the less location of woody vegetation due to moisture abundance at the bottom of the ditch slope (the most frequent contact spot of a depression curve with a slope). Lower limit of slope's overgrowth with woody vegetation is $r_a$ = 1.22±0.10 m. At the top of the ditch slope (almost always above the depression curve) woody vegetation appears to be also sparser due to lack of moisture. Top limit of slope coverage with woody vegetation is $r_v$ = 3.74 m, or 2.05±0.11 m from slope's top part.

The highest density and frequency of woody vegetation was determined in the middle part of the slope (Fig. 4). The highest density of woody vegetation

was measured in the middle part of the slope and it is $T = 2.00 \pm 0.48$, in the foot: $T = 1.53 \pm 0.27$ pc./m$^2$.

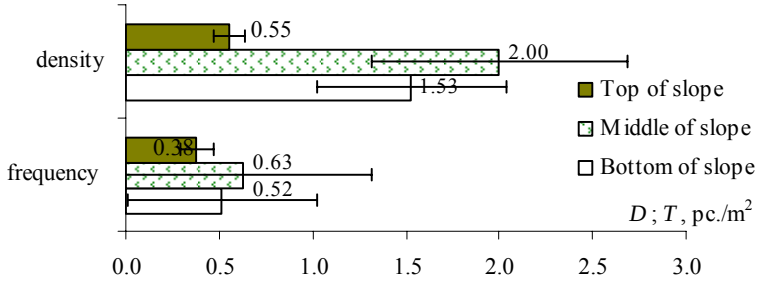



**Fig. 4.** Woody vegetation density and frequency distribution on the slope of the regulated stream

Lowest density of woody vegetation $T = 0.55 \pm 0.11$ pc./m$^2$, as well as frequency, are observed in top part of the slope. From the comparison of densities of trees and shrubs we can see that quantity of trees is always less than that of shrubs.

## 4. Research of riverside buffer zones of regulated streams

Research of riverside buffer zones of regulated streams showed, that in 81% cases of total studied sections (N = 420) regulated stream was near greenland or pasture, in 6% cases stream was roadside, 8% – arable land and in 5% cases – outskirts. Riverside buffer zone width in all cases of greenland or pasture, roadside, and outskirts was more than 2.5 m. It must be mentioned, that measured widths of riverside buffer zones with inclination less 5$^o$ are in agreement with minimal requirements set by riverside buffer zone rules.

Worse situation with buffer zones was found in cases of arable land. Most buffer zones near arable land were found alongside regulated streams Nemėža and Mažasis. Riverside buffer zone average measured for the stream Nemėža was 1.30 m, and Mažasis – just 0.77 m. It is just 52 and 31% of necessary zone width respectively. Only one studied section of the stream Nemėža was in agreement with environmental regulations and was not less than 2.5 m. Buffer zones for all sections of the regulated stream Mažasis was less than 2.5 m and were not in accordance with environment protection requirements. The shortest buffer zone width for the regulated stream was just 0.10 m. Calculated average of all riverside buffer zone widths for regulated streams alongside arable land was 1.72 m, variation coefficient – 0.75, standard error of average $S_{\bar{x}}$=0.24 m.

Error of average with reliability 95%, $S_{X95}$=0.48 m. Even in 79% cases of all researched regulated streams in arable land buffer zone width was less than 2.5 m (as required by regulation).

Calculated correlation coefficient between woody vegetation density on regulated stream slopes and riverside buffer zone is just 0.20, and this means that there is no dependency, or it is weak. This is because woody vegetation on slopes of regulated streams have not been removed (it is more abundant here), and furthermore its growth conditions on riverside buffer zones is adverse with regard to moisture and economical activity.

## 5. Simulation of hydraulic conductivity of regulated streams overgrown with small trees

Bed hydraulic roughness coefficient $n$ was determined for regulated streams with different woody and grass vegetation distribution using experimental research and the hydraulic simulation program for overgrown beds elaborated by Water Management Institute. Hydraulic roughness coefficient of researched sections of regulated streams varied between 0.030 and 0.094. In order to assess correlation between water level and hydraulic roughness coefficient, water level was simulated using program HEC-RAS. Hydraulic simulation of regulated stream beds showed, that at current roughness of streams Nemėža (0.030 to 0.045), Ž-2 (0.030 to 0.053), Girija (0.036 to 0.067) and Žalesa (0.033 to 0.042) spring flood water is contained in the streams and does not overflow. In all cases water level $h_V$ is lower than depth of stream bed $h_G$ (Table 1). When bed roughness is changed from 0.025 to 0.290 also water level changes ($H$, m) (Fig. 5).

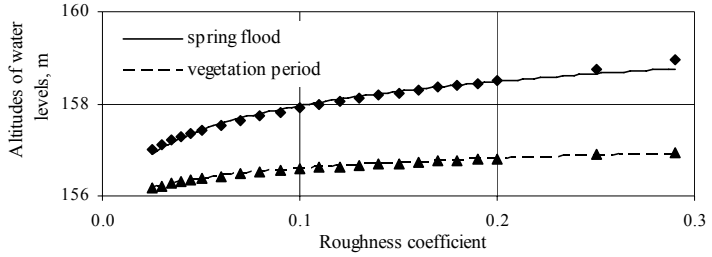



**Fig. 5.** Altitudes of water levels $H$ in the stream Nemėža for maximal spring flood of probability, 10% and minimal summer flow of probability 90% and with variation of hydraulic roughness coefficient $n$

We know, that woody vegetation density in studied stream Nemėža varies from 0.01 to 0.68 pc./$m^2$. Woody vegetation density in studied stream Ž-2 varies from 0.17 to 5.42 pc./$m^2$. Roughness coefficient of the stream Nemėža reached 0.035 at woody vegetation density 0.01–0.16 pc./$m^2$. With increase of woody vegetation density on the slopes up to 0.24–0.68 pc./$m^2$ roughness coefficient has reached 0.040. For the stream Ž-2, when woody vegetation density was 0.17–1.62 pc./$m^2$ roughness coefficient reached 0.040. When woody vegetation density was from 2.30 to 5.42 pc./$m^2$ roughness coefficient increased up to 0.050. Furthermore regulated streams Nemėža and Ž-2 are overgrown with coarse-stem grasses. Its influence on roughness coefficient was also estimated.

Simulation results show, that when roughness coefficient is close to 0.081, bed's conductivity is too small to pass spring floods of 10% probability. In order to correct that, hydraulic roughness coefficient must be reduced down to 0.025 in the stream Ž-2 and down to 0.080 in the stream Nemėža.

**Table 1.** Values of hydraulic roughness coefficient *n* for regulated streams Nemėža, Ž-2. Girija and Žalesa at maximal spring debits of 10% $Q_{Max}$

| Roughness coefficient *n* | Quantity of sections | Water level in the stream |
|---|---|---|
| 0.025–0.034 | 12 | water level < bed depth |
| 0.035–0.044 | 25 | water level < bed depth |
| 0.045–0.054 | 8 | water level < bed depth |
| 0.055–0.067 | 1 | water level < bed depth |

We see, that at such values of hydraulic roughness coefficient, maximal spring flood of 10% probability would overflow from the bed already. In order to avoid that woody vegetation should be thinned out or bed's roughness should be reduced otherwise. For example, if stream bed slopes would overgrow with woody and grass vegetation, and hydraulic roughness coefficient would exceed values 0.060–0.080, strip not covered with trees at the bottom slope should be formed or trees should be thinned out in all slope, or vegetation should be totally removed from one slope in order to follow requirements of bed's hydraulic conductivity and reduce bed roughness coefficient down to acceptable limit (0.060). It is recommended to leave southern slope overgrown when removing trees or shrubs, because, as it was mentioned above, woody vegetation grown on the southern slope will shade the bed more intensively, it will reduce overgrowth of the northern slope and bottom with grass and aquatic vegetation and will reduce bed silting at the same time. If stream overgrows with coarse-stem grasses (roughness can reach 0.290 and more), slopes could be

mowed off in order to avoid overflow when spring flood discharge probability is 10%. Mow frequency should be such that coarse-stem grasses would not establish (roughness coefficient would not exceed 0.080).

The Nemėža stream runs from the North-East to the South-West, therefore, in future the woody vegetation should be left on the south-eastern slope of the regulated stream. The Ž-2 stream runs from the West to the East therefore, in future the woody vegetation should be left on the south slope of the stream. At the moment the stream roughness coefficients have not reached the critical limit (0.060–0.080). Water overflowing indicator is positive in all sections of the investigated stream; therefore, removal of small trees and bushes is not necessary. From the hydraulic point of view they should not be removed yet. The regulated streams Girija and Žalesa run along outskirts, there are no arable fields around, therefore removal of woody or grass vegetation is senseless. Even significant density of woody vegetation, and as a result increase of hydraulic roughness are acceptable. And cycle of the regulated stream becomes analogous to natural stream cycle.

**General Conclusions**

1. 33 woody vegetation species have been found on the slopes of regulated streams in the Southeast Lithuania, including 15 trees and 18 bushes. The mostly spread tree specie is the goat-willow (*Salix caprea* L.) found in 41 (19.1%) finding places. The grey willow (*Salix cineria* L.), which was found even in 84 (40.0) finding places, is considered to be the mostly spread shrub in the area. Definite direct correlations between density and frequency of general (and separately for trees and shrubs) woody vegetation species and distance to forest were determined. Correlation coefficients varies from 0.65 to 0.91, and calculated values $p$ show, that correlation is statistically significant with reliability of 95%.
2. Study of woody vegetation spread on the slopes of regulated streams showed, that the most favorable conditions for the growth of the most species of woody vegetation were in the middle of the slope. The worst conditions were created in the top part of the slope due to lack of moisture (almost always above depression curve. Accomplished analysis of variance showed that averages of woody vegetation density in different parts of the slope differ significantly with reliability of 95%.
3. During the research it was determined, that average density of woody vegetation on the slopes of the northeast exposition ($T_{ŠR}$ = 0.905±0.304 pc./m$^2$) was the highest (or 2.42 fold higher than density on east exposition and 2.30 fold higher than density on south ($T_P$ = 0.393±0.118 pc./m$^2$) exposition slopes).

However analysis of data variance showed that averages of density on different exposition slopes did not differ significantly with reliability of 95%.

4. Calculated correlation coefficient between density of woody vegetation on slopes of regulated streams and on riverside buffer zone was just 0.20, and this means that there was no dependency, or it was weak.

5. With equal roughness of lower part of cross-section of a regulated stream and other morphometric parameters, hydraulic conductivity of the streams overgrown with woody vegetation in the Southeast Lithuania is more than 2 fold higher than that of overgrown trenches in the Middle Lithuania. With this regard planning of ecological measures in drainage network is more flexible in the Southeast Lithuania allowing growth of trees and shrubs on the slopes.

6. Hydraulic roughness coefficient of regulated streams, which was determined by natural research, varies from 0.030 to 0.094. It can be stated, that regulated streams in the Southeast Lithuania already contain sections where margin of flood hydraulic conductivity is close to the limit of overflow to the valley.

7. During simulation it was determined, that margin of hydraulic conductivity in the researched sections of regulated streams was lost, when hydraulic roughness coefficient reaches limit of 0.060–0.080. It can be stated, that if slopes would overgrow with woody and grass vegetation, and roughness coefficient would exceed value of 0.060–0.080, it can be necessary to reduce bed roughness down to acceptable limit (0.060) in order to ensure bed hydraulic conductivity.

**Recommendations**

1. The southeast Lithuanian regulated streams contain sections with rather large margin of hydraulic conductivity, therefore in order to improve ecological situation, it is recommended to perform the maintenance of regulated streams according to the naturalization processes.

2. It is recommended to allow growth of woody vegetation on bed slopes. If slopes of the streams would overgrown with woody and grass vegetation more abundantly, and roughness coefficient would exceed value of 0.060–0.080, bed roughness should be reduced in territories with intensive farming (clear the strip at bottom slope from the trees or thin out trees in all slope, or remove vegetation completely from one slope, etc.) down to economically acceptable limit so ensuring bed's hydraulic conductivity.

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**About the author**

Oksana Barvidiene was born on 4 of December 1979. In 2002, she was awarded the bachelor's degree in Ecology and Environmental at the Lithuanian University of Agriculture, the Faculty of Forestry. In 2004, she was awarded the master's degree in Environment Protection Engineering at Vilnius Gediminas Technical University, the Faculty of Environmental Engineering. 2005–2009, she was maintaining doctoral studies at Vilnius Gediminas Technical University. At present she is a Dean assistant in the Environmental Engineering Faculty and assistant in the Hydraulics department.

## REGULIUOTŲ UPELIŲ UŽAUGIMO SUMEDĖJUSIA AUGALIJA TYRIMAI IR VERTINIMAS

***Problemos formulavimas.*** Žemės ūkio intensyvinimas pastarąjį šimtmetį daugelyje pasaulio šalių buvo ir tebėra labai svarbus. Siekiant padidinti žemės ūkio augalų derlių, daugelyje šlapių žemių buvo įrengtos sausinimo sistemos. Dėl to daug natūralių upių vagų buvo ištiesintos ir pagilintos, pašalinti pakrantės želdiniai. Įrengus sausinimo sistemas padidėjo dirvožemių našumas, tačiau pakito ir suvienodėjo kraštovaizdis, atsirado daug naujų antropogeninio pobūdžio komponentų, sumažėjo ekologinė melioruotų plotų įvairovė. Sumenkus pakrančių augalijai, susidarė palankios sąlygos dirvų erozijai, vandens telkinių teršimui ir gyvūnijos rūšinei kaitai.

Pastaruoju metu pasaulyje tapo aktualu peržiūrėti sausinimo tikslams reguliuotų upelių priežiūros technologijas, ieškoma būdų, kaip suderinti žemės ūkio produktyvumą ir bent iš dalies atkurti prarastą ekologinę pusiausvyrą. Todėl daugelyje ekonomiškai išsivysčiusių šalių atliekama net mechaninė natūralizacija. Lietuvoje, sumažinus tradicinę reguliuotų upelių priežiūrą, intensyviau vyksta savaiminis vagos meandravimas bei kiti natūralios vagos atsistatymo procesai, reguliuotų upelių šlaitai bei pakrantės apauga žoline ir sumedėjusia augalija, o vagoje atsiranda sietuvos ir rėvos. Iki šiol atlikti tyrimai rodo, kad daugelyje vietų savaiminė natūralizacija nesumažina jų hidraulinio laidumo, nepablogina sausinamų žemių drėgmės režimo, tačiau prisideda prie prarasto ekosistemų tvarumo atkūrimo.

***Mokslo problemos aktualumas***. Pripažinus, kad reguliuojant upes ir upelius, pakenkta jų ekosistemoms, išsivysčiusiose šalyse mėginama kiek galima jas atkurti. Upelių atstatymo, jų natūralizavimo projektai jau vykdomi daugelyje šalių. Šie projektai Lietuvoje dar nevykdomi, tačiau savaiminio natūralizavimosi požymiai, pastebimi daugelyje upių vagų. Kol kas nėra nustatyti reguliuotų upelių apaugimo sumedėjusia augalija dėsningumai kalvotame reljefe, bei įtaka jų įtaka hidrauliniam laidumui.

Skatinant reguliuotuose upeliuose jau vykstančius natūralizacijos procesus, būtina įvertinti kokią įtaką natūralizacijos procesai, o ypatingai sumedėjusios augalijos plitimas bei pasiskirstymas vagose turės reguliuotų upelių hidrauliniam laidumui. Todėl, darbai, įvertinantys reguliuotų upelių, reguliuotų sausinimo tikslais, natūralizacijos procesų poveikį jų funkcionalumui bei biologinės įvairovės skatinimui, šiandieną Aplinkos inžinerijos ir kraštotvarkos kryptyje laikytini prioritetiniais.

***Tyrimų objektas***. Tyrimų objektas – sausinimo reikmėms reguliuoti upeliai, esantys Pietryčių Lietuvoje. Ši teritorija pasirinkta todėl, kad savaiminė natūralizacija tirta tik Vidurio Lietuvoje, lyguminiame reljefe. Kadangi natūralizacijos procesai vyksta skirtingai, nuspręsta įvertinti juos kalvotame Pietryčių Lietuvos regione. Juose buvo tiriami vagų morfometriniai parametrai, nustatomi apaugimo sumedėjusia augalija kiekybiniai ir kokybiniai rodikliai, vagų skersinio profilio forma bei augalijos išsidėstymas jame.

***Tikslai ir uždaviniai.*** Tikslas – nustatyti ir ištirti reguliuotų upelių savaiminio apaugimo sumedėjusia augalija kiekybinius ir kokybinius dėsningumus kalvotame reljefe, vykstant natūralizacijos procesams. Naudojant hidraulinį modeliavimą įvertinti reguliuotų upelių funkcionalumo (šlaitų hidraulinio šiurkštumo, hidraulinio laidumo) pokyčius bei galimybes įtakoti reguliuotų upelių natūralizaciją.

Darbo tikslui pasiekti buvo sprendžiami šie uždaviniai:

1. Nustatyti Pietryčių Lietuvos reguliuotų upelių šlaituose augančios sumedėjusios augalijos rūšinę sudėtį ir jos priklausomybę nuo gamtinių veiksnių.
2. Nustatyti augalijos rūšinės sudėties ir tankio pasiskirstymą reguliuotų upelių vagų skersiniuose profiliuose.
3. Nustatyti reguliuotų upelių šlaitų apaugimo sumedėjusia augalija kiekybinius rodiklius ir priklausomybės nuo šlaito ekspozicijos dėsningumus.
4. Nustatyti reguliuotų upelių šiurkštumo koeficiento dinamiką.
5. Nustatyti sumedėjusios augalijos įtaką reguliuotų upelių hidrauliniam laidumui.

***Tyrimų metodika***. Darbe atlikti reguliuotų upelių apaugimo sumedėjusia augalija parametrų natūriniai eksperimentiniai tyrimai, kurie apdoroti statistinės analizės metodais, patvirtinant jų patikimumą, o funkcionalumo (hidraulinio laidumo) išsaugojimo tyrimai pagrįsti hidrauliniu – matematiniu modeliavimu.

***Mokslinis naujumas***. Darbas yra naujas tuo, kad sumedėjusios augalijos paplitimas vagoje bei jos įtaka hidrauliniam laidumui kalvoto reljefo reguliuotuose upeliuose iki šiol nebuvo tirtas bei modeliuotas. Nustatyti sumedėjusios augalijos plitimo reguliuotuose upeliuose kiekybinių ir kokybinių rodiklių dėsningumai, jos įtaka vagų hidrauliniam šiurkštumui. Atliktas vagų hidraulinio laidumo modeliavimas, leidžiantis, išsaugant sausinimo sistemų funkcionalumą, įtakoti reguliuotų upelių natūralizacijos procesus.

***Praktinė vertė.*** Darbe įvertinta reguliuotų upelių savaiminių natūralizacijos procesų, kai vagų šlaitai apauga sumedėjusia augalija, įtaka hidrauliniam laidumui. Nustatyti reguliuotų upelių apaugimo sumedėjusia augalija dėsningumai priklausomai nuo įvairių gamtinių bei antropogeninių veiksnių. Visa tai būtina planuojant įrengti sausinimo sistemas, siekiant išsaugoti biologinę įvairovę ir diegiant ant vagos atkūrimo priemones.

***Ginamieji teiginiai***

1. Pietryčių Lietuvos reguliuotuose upeliuose intensyviai vykstantys šlaitų apaugimo bei natūralizacijos procesai didina jų ekologinę įvairovę ir, esant dabartinei situacijai, nekenkia sausinimo sistemų funkcionalumui.
2. Reguliuotų upelių sumedėjusios augalijos rūšinė sudėtis, tankis bei dažnis priklauso nuo įvairių gamtinių (atstumo nuo miško, padėties šlaite, šlaito ekspozicijos) bei antropogeninių veiksnių, darančių įtaką

jų pasiskirstymui upelio skersiniame profilyje bei apsauginėje pakrantės juostoje.

***Disertacijos struktūra.*** Disertaciją sudaro įvadas, penki skyriai, bendrosios išvados, rekomendacijos. Darbo apimtis yra 136 puslapiai, 53 paveikslai ir 36 lentelės. Rašant disertaciją buvo panaudoti 111 literatūros šaltiniai.

Įvadiniame skyriuje aprašoma darbo problema, aktualumas, tikslas ir uždaviniai, naujumas, praktinė reikšmė, ginamieji teiginiai.

Pirmasis skyrius skirtas literatūros apžvalgai. Jame pateiktos natūralių upelių reguliavimo ar natūralizavimo tendencijos, raidos apžvalga, augalijos paplitimas reguliuotuose upeliuose bei jų įtaka hidrauliniam laidumui. Skyriaus pabaigoje formuluojamos išvados ir konkretizuojami tyrimų uždaviniai.

Antrajame skyriuje pateikta tyrimų metodika. Aptariama tyrimų vieta, eksperimentinių tyrimų metodika, duomenų patikimumo, hidraulinio šiurkštumo koeficiento nustatymo, bei reguliuotų upelių pavasario potvynių vandens lygių hidraulinio matematinio modeliavimo metodika.

Trečiajame ir ketvirtajame skyriuose pateikiami Pietryčių Lietuvos reguliuotų upelių sumedėjusios augalijos pasiskirstymo šlaituose ir apsauginėse juostose (rūšių skaičiaus, dažnio, tankio) tyrimų rezultatai.

Penktasis skyrius skiriamas apaugusių medeliais reguliuotų upelių hidraulinio laidumo modeliavimo klausimams.

***Bendrosios išvados***

1. Pietryčių Lietuvos reguliuotų upelių šlaituose rastos 33 sumedėjusios augalijos rūšys, iš jų 16 medžių ir 17 krūmų. Labiausiai paplitusi medžių rūšis yra blindė (*Salix caprea* L.), aptikta 41 (19,1 %) radvietėje. Labiausiai paplitusi krūmų rūšis yra pilkasis karklas (*Salix cineria* L.), rastas 84 (40,0 %) radvietėje. Nustatyta aiški tiesioginė bendros sumedėjusios augalijos bei atskirai medžių ir krūmų rūšių skaičiaus tankio bei dažnio priklausomybė nuo atstumo iki miško. Koreliacijos koeficientai svyruoja nuo 0,65 iki 0,91, o gautos *p* reikšmės rodo, kad koreliacija statistiškai reikšminga, kai patikimumas 95 %.
2. Ištyrus sumedėjusios augalijos pasiskirstymą reguliuotų upelių šlaituose nustatyta, kad daugeliui sumedėjusios augalijos rūšių palankiausios sąlygos augti yra vidurinėje šlaito dalyje. Dėl drėgmės trūkumo blogiausios sąlygos (beveik visada aukščiau depresijos kreivės) susidaro viršutinėje šlaito dalyje. Atlikta dispersinė sumedėjusios augalijos tankio analizė parodė, kad skirtingose šlaito dalyse tankio vidurkių skirtumas 1,45 vnt./m$^2$, kai patikimumas 95 %, yra esminis.
3. Atlikus tyrimus nustatyta, kad šiaurės rytų ekspozicijos šlaituose sumedėjusios augalijos tankio vidurkis ($T_{ŠR}$ = 0,905±0,304 vnt./m$^2$) yra

didžiausias (arba 2,42 karto didesnis nei rytinės ir 2,30 karto didesnis nei pietinės ($T_P$ = 0,393±0,118 vnt./m$^2$) ekspozicijos šlaituose). Tačiau atlikta dispersinė duomenų analizė parodė, kad skirtingos ekspozicijos šlaituose tankio vidurkiai, kai patikimumas 95 %, iš esmės nesiskiria.

4. Gautas koreliacijos koeficientas tarp sumedėjusios augalijos tankio reguliuotų upelių šlaituose ir pakrantės apsaugos juostose tesiekia 0,20, o tai rodo, kad priklausomybės nėra arba ji labai silpna.

5. Kai apatinės reguliuotų upelių skerspjūvio dalies šiurkštumas ir kiti morfometriniai parametrai vienodi, upelių, apaugusių sumedėjusia augalija, Pietryčių Lietuvoje hidraulinis laidumas daugiau negu 2 kartus didesnis negu apaugusių griovių Vidurio Lietuvos žemumoje. Šiuo požiūriu Pietryčių Lietuvoje yra daugiau galimybių planuoti ekologines priemones sausinimo sistemų nuvedamajame tinkle leidžiant augti medžiams ir krūmams ant šlaitų.

6. Remiantis reguliuotų upelių vagų morfometriniais parametrais, sumedėjusios augalijos pasiskirstymu skersiniame vagos profilyje ir jos tankiu nustatytas upelių hidraulinio šiurkštumo koeficientas kinta nuo 0,030 iki 0,094. Galima teigti, kad Pietryčių Lietuvos reguliuotuose upeliuose jau yra ruožų, kuriuose potvynių hidraulinio laidumo atsarga sumažėjusi iki išsiliejimo į slėnį ribos.

7. Modeliuojant nustatyta, kad tirtuose reguliuotų upelių ruožuose hidraulinio laidumo atsarga prarandama, kai hidraulinio šiurkštumo koeficientas pasiekia 0,060–0,080 ribą. Galima teigti, kad jei upelių vagos šlaitai apaugtų sumedėjusia ir žoline augalija, o šiurkštumo koeficientas viršytų 0,060–0,080, gali tekti mažinti vagos šiurkštumą iki priimtinos ribos (0,060) užtikrinant vagų hidraulinį laidumą.

***Rekomendacijos***

1. Pietryčių Lietuvos reguliuotuose upeliuose yra ruožų su pakankamai didele hidraulinio laidumo atsarga, todėl, gerinant ekologinę situaciją, rekomenduojama vykdyti reguliuotų upelių priežiūrą, toleruojant juose vykstančius natūralizacijos procesus.

2. Rekomenduojama leisti augti sumedėjusiai augalijai ant vagos šlaitų. Jei upelių vagos šlaitai gausiau apaugtų sumedėjusia ir žoline augalija, o šiurkštumo koeficientas viršytų 0,060–0,080 reikšmę, teritorijose, kuriose intensyviai praktikuojama žemdirbystė, reikėtų mažinti vagos šiurkštumą (padaryti neapaugusią medžiais juostą šlaito apačioje arba medžius retinti visame šlaite, arba nuo vieno šlaito visai pašalinti augaliją ir t. t.) iki ūkiniu požiūriu priimtinos ribos, taip užtikrinant vagų hidraulinį laidumą.

**Trumpos žinios apie autorę**

Oksana Barvidienė gimė 1979 m. gruodžio 4 d. 2002 m. įgijo ekologijos ir aplinkotyros bakalauro laipsnį Lietuvos žemės ūkio universiteto Miškų fakultete. 2004 m. įgijo aplinkos inžinerijos mokslo magistro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. 2005–2009 m. – Vilniaus Gedimino technikos universiteto doktorantė. Šiuo metu dirba dekano padėjėja Aplinkos inžinerijos fakulteto dekanate ir asistente Hidraulikos katedroje.

Oksana BARVIDIENĖ

RESEARCH AND EVALUATION
OF OVERGROWTH OF REGULATED STREAMS
WITH WOODY VEGETATION

Summary of Doctoral Dissertation
Technological Sciences, Environmental Engineering (04T)

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Vilniaus Gedimino technikos universiteto
leidykla „Technika“, Saulėtekio al. 11, LT-10223 Vilnius
Spausdino UAB „Baltijos kopija“,
Kareivių g. 13B, 09109 Vilnius