

## IMPACT OF LAND DRAINAGE AND NATURAL FACTORS ON THE CHANGES OF THE HYDROLOGICAL REGIME OF THE TATULA RIVER

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**Abstract.** Impact of the land drainage on the river catchment in Lithuania has so far been evaluated as of rather mixed character as the impact is rather complex and multifaceted. When drainage systems are installed, the hydrographic network of the territory changes and conditions of the formation of catchment may change as well. Implementing naturalisation processes at the regulated sectors of the river, there appear places where the limit of the flood hydraulic conductivity might reach the line of the overflow of the river in the valley. In the article, using the analytical, statistical and mathematical methods of modelling, the impact of land drainage and natural factors on the changes of hydrological regime of the Tatula river is analysed.

Areas of the wet land in the basin of the Tatula river form 90 % of all the area. Analysis of the interchanges of excessively wet lands and drained area in 1960–2009 shows that until 1961, such drained areas reached only 12 % of all the area of wet land, and in 2000 such area reached 94 %. When the biggest part of the basin area was drained, there appeared no essential annual or seasonal differences of the catchment changes.

Using HEC–RAS programme for the modelling, it was determined that the coefficient of the hydraulic roughness in the Tatula river changes from 0.028 to 0.049. The water level in the river bed is in all the cases lower than that of the regulated river. Even when the spring debit is maximal, the water in the regulated bed of the river does not overflow. If the coefficient of the river roughness is made higher and reaches 0,160 the water in the bed overflows in all the regulated sectors of the Tatula river.

**Keywords:** river runoff, land drainage, coefficient of the hydraulic roughness.

### 1. Introduction

Climatic conditions and physic-geographical factors predetermine the situation in which 3.4 million ha of the Lithuanian territory or 86 % of the general agricultural area is too wet, and that area might be used in the intensive and productive way only if drainage is done. As economical and political circumstances changed, the volume of melioration work changed as well. In Lithuania, in 1970 1 million ha of land were drained using drainage, in 1978 the area of the drained land reached 2 million ha, and in 1990 it reached 2.6 ha. When the land drainage work was done and the trees and shrubs and other perennial green plantation of the natural small rivers eliminated, the structure of morphologic landscape was changed and became monotonous. Instead of natural, there appeared many of morphologic components of the anthropogenic character. Because there is fewer of flora in the meliorated areas, there appear favourable conditions for the wind erosion, pollution of the water pools, changes of the animal species and changes of the local microclimate. Now the new systems are nearly not installed, and only the most necessary recreation or renovation of the old systems is implemented. There is also no

enough funding for the system maintenance and recreation so some part of the drainage system became not functional.

Land drainage is one of the most active areas of the anthropogenic activities which influence the runoff of the rivers. Impact of the drainage of too wet lands on the rivers runoff is evaluated as of rather mixed character. Because of the reason that drainage work changes physical qualities of the soil and hydrographical network of the territory so the conditions of the formation of runoff change as well (Lukianas 2006). The scientists who conducted the research in this sphere come to the contradictory conclusions. Research of J. Macevičius and D. Lukianienė (1975) conducted at the time when drained lands in Lithuania formed not more than 30 % of the area of river basins showed that drainage does not has big impact on the annual river runoff and the modules of the maximal river runoff in spring. However, according to them, in the summer and autumn season the modules of the maximal runoff grow in 30–40 %, and the runoff coefficients grow in 30 %. V. Marčėnas (1991) who conducted the research later when the biggest part of the territory in Lithuania had bed drained using drainage, stated that drainage work and intensive agriculture diminish

annual and different seasons runoff. Research of A. Juozapaitis and V. Zelionkienė (1997) show that when areas of the drained lands become bigger in the basins of the rivers, the coefficients of the seasonal river catchment become lower and the coefficients of the summer and autumn season become higher. Their research shows that there is some noticeable correlative relation between degree of drainage implementation and hydrological characteristics. Foreign scientists also assume that with the installation of the drainage systems the structure of agricultural area changes. The changes predetermine the hydrological regime of the rivers (Oginski 2007; Pauliukevičius 2000; Ren *et al.* 2002).

According to some other authors (Dolgopoličienė *et al.* 2003), in more than 60 % of the part of relief network in the Lithuanian drainage systems the naturalisation processes take part, and the area in which the bushes grow in the canal beds is nearly 10–25 %, and in the South-eastern Lithuania nearly 20–25 %. The fact that trees and bushes grow in relief network of the drainage systems makes the problem of beaver (*Castor fiber*) breeding more severe. Even if beavers make ecological situation of the place better, the beaver dams are obstacles which make the hydraulic conductivity of the canal worse, and it is one of the sources for the bottom deposits (Lamsodis 2001).

The situation when the relief network is covered with trees should be evaluated as rather mixed character: this process positively influences the landscape structure, makes possibility of deflation, accumulation of deposits and pollution of the water pools less imaginable. At the same time, the fact that the canal slopes become covered with wooded areas is of negative character as the hydraulic conductivity becomes worse, and the conductivity is essential for the basic function of the drains, which is draining (Lamsodis 2002; Barvidienė *et al.* 2007).

Rapidity of the self-contained naturalisation depends on the relief, maintenance and other conditions. Spreading of the wooded areas and their location makes impact on the hydrological regime of the rivers, processes of recreation of the regulated sectors and their naturalisation.

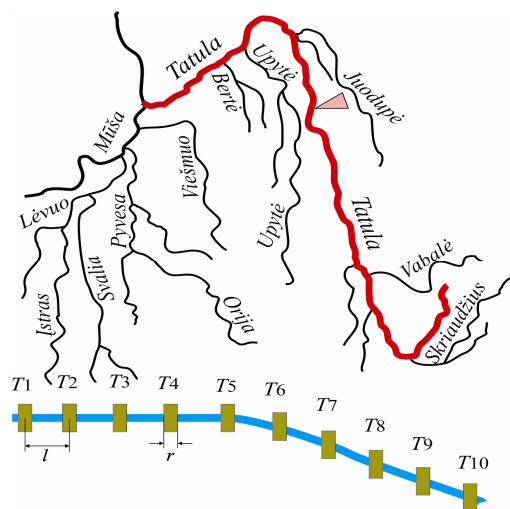
The aim of our work is to evaluate the impact of land drainage and natural factors on the changes of the hydrological regime of the Tatula river.

## 2. Research subject and methodology

In Lithuania, currently the data of monitoring of the river runoff for long period (40–50 years) have been collected, and there exist many river basins where the bigger part of the wet land (70 and more percent) is drained. With such amount of the data, there appears possibility to analyse changes of the river runoff when the size of the drained territories differs.

For the evaluation of impact of the excessively wet lands and natural factors on the hydrological regime the Tatula river has been chosen (Fig 1). It is the area of the river basin up to the Trečiūnių water measuring station of

404 km<sup>2</sup> and the wet land stock form 89 % of the basin territory. Length of the river is 64.7 km, and 25.9 km is the regulated sector (Gailiūšis *et al.* 2001).



**Fig 1.** Research place and location of the investigation sectors of the regulated river where:  $r$  is the length of sector (10 m) and  $l$  is the distance between the sectors (100 m)

The area of the excessively wet lands in the river basin up to the water measurement station was defined using the data from the cadastre prepared by A. Sakalauskas and L. Zelionka in 1980. In order to analyse changes of the drained areas, the data of the statistical registration of the drained lands was used.

For the investigation of processes of the river runoff and draining of excessively wet lands in the river basin, it is important to evaluate the changes in the abundance of water cycles. In order to analyse the changes in the abundance of water, the data of water debit measurement collected by the Lithuanian Hydrometeorological service during long period (1960–2009) were used. On the ground of these data, the annual, spring and summer season runoff depth and interdependency of its changes with the changes of the drained lands was analysed. The spring season comprised of March and April, and summer season of May, June, July and August months.

For the evaluation of the distribution of river runoff in a year and during different periods defined according to the abundance of water (period of 1960–1969 was of little abundance and period of 1981–1990 of the higher abundance), the changes of the river runoff unevenness coefficient  $d$  was analysed. The coefficient  $d$  defines the annual runoff distribution comprising watery and dry seasons (Gailiūšis and Kovalenkovičienė 1998) and in the quantitative way evaluates the runoff deficit up to the medium annual debit amount. It is calculated according the formula:

$$d = \frac{\sum Q_p - Q_{t_p}}{365(6) \cdot Q} \quad (1)$$

where:  $\Sigma Q_p$  is the sum of day and night debit during the period  $t_p$ ;  $Q_p$  debits are higher than the medium annual debit  $Q$ .

With the aim to evaluate the changes of the hydrological regime of the river during the naturalisation processes, 10 measuring sectors of the river (medium length was 10 meters) were investigated. In the most representative place of the sector, the characteristic profile was defined, with the basic morphometric parameters of the canals, quantitative and qualitative indicators of the wooded areas. Distribution rate of the separate species of the wooded flora at the places where it is found is defined as percentage proportion of the sample of drain slopes or protection zone where the species was found and the number of all investigated drain profiles. Density of the wooded flora at the places where it is found is defined as the total number of stems for 1 m<sup>2</sup> of all the drain slope area (the number is counted in one square meter, i.e. unit/m<sup>2</sup>).

In order to define the coefficients of the hydraulic roughness in the regulated small rivers, methodology prepared for hydraulic measurement of the canals covered with bushes and trees and deformed canals at the Water Management Institute of Lithuanian was used.

In order to evaluate the impact of the wooded flora on the hydraulic conductivity of the small river, the water levels were defined (HEC–RAS 2008). The water levels are measured from the cross-section profile of one sector to that of the other according to the equation of the energy stability. Profiles of the water surface of the settled and slowly changing flow between the cross-sections are defined using HEC-RAS programme and methodology of direct approach. The main calculation procedure is based on inerratic solution adopting of the energy equation. Considering the given flow debit and water level in one of the cross-sections and using the direct approach methodology, the level of the water surface in the other cross-section is calculated.

The indicator of the water overflow in the investigated sectors of the river is defined. It is assumed as positive ( $h_v \leq h_G$ ) when the water level in the investigated bed of the sector of the regulated river ( $h_v$ ) is lower or equal to the depth in this sector of the river ( $h_G$ ) (the water does not overflow), and negative when ( $h_v > h_G$ ) (the water overflows out of the bed).

### 3. Results of research

Areas of the wet land in the basin of the Tatula river form 90 % of all the area. The analysis of interchanges of the excessively wet lands and drained lands in the period of 1960–2009 showed that until 1961, the drained areas reached only 7 % of all the basin territory or 12 % of all the area of wet land. In 1970, the drained areas grew up to 50 and 55 %, respectively, and in 1980 (in comparison with 1970) the area of the drained lands grew immensely up to 75 % from the basin territory or 85 % of the wet land area. In 2000, the drained lands of the Tatula river basin (up to the Trečionių water measurement station) already formed 94 % of the wet land stock. In the recent years the new drainage systems nearly have not been prepared so the area of the drained land changed very little.

One of the basic factors which influence the amount of the river runoff is precipitation. According to the data from Biržai Meteorological station, the average annual precipitation amount in the period of 1960–2009 was 656 mm or 8 % higher than the norm (605 mm). The bigger amount of the precipitation predetermines the bigger runoff. Concerning the basin investigated, the driest year was 1976 m. (415 mm), and the most watery – 1998 m. (870 mm or 1.43 time more than the norm).

Analyzing the impact of drainage on the river runoff, the amount of spring season runoff is especially important. Drainage systems play the most important role namely in spring (when the snow is melting) and summer (when the amount of rainfall is big) because of them the excessive amount of water is eliminated out of the arable layer of the soil. The scale of the changes of the river runoff depth was rather big. These changes depend a lot on the amount of precipitation. It is graphically illustrated in Fig 2, where, the changes of annual amount of the precipitation and the river runoff depth in spring and summer seasons is presented.

From the result gained, the similar tendencies of the changes of precipitation and runoff depth are clearly visible. The highest values of the river runoff depth are observed in the years when the precipitation amount is bigger than the norm.

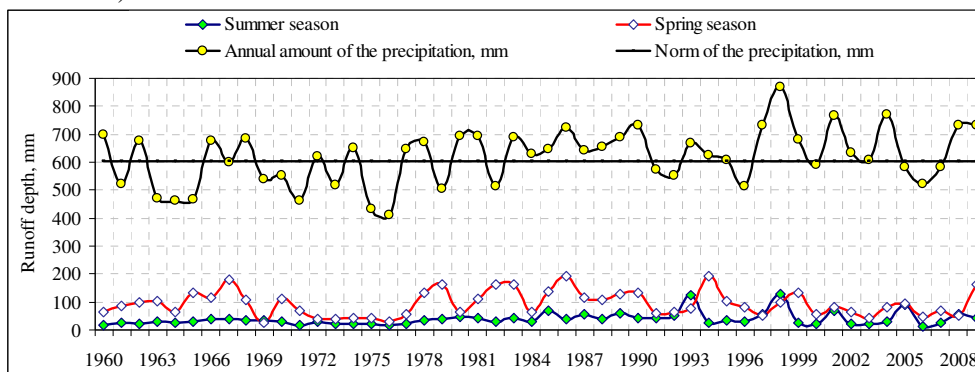
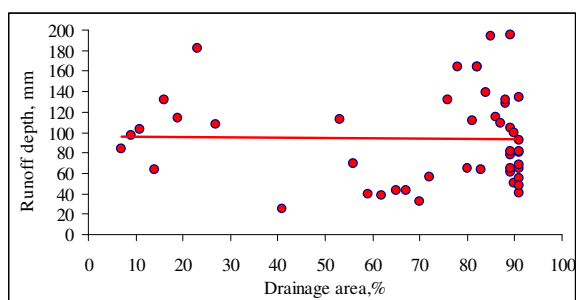


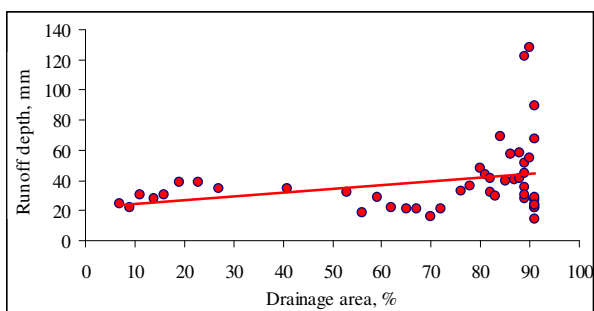
Fig 2. The changes of annual amount of the precipitation and the river runoff depth in spring and summer seasons

In the spring season, the amplitude of the river runoff depth changes was from 25 to 195 mm, and in the summer season it was from 15 to 125 mm. The bigger amplitude of the runoff depth changes in this river might be predetermined by the small basin area as the small basin areas are very sensitive to the impact of nature factors.

Analysing the interchanges of the river runoff depth in spring and summer seasons and the drained land area, the same regularities were found (Fig 3 and 4).



**Fig 3.** Relationship between the spring runoff depth of the Tatula river and drained area in the river basin (in percent of wetland area)



**Fig 4.** Relationship between the summer runoff depth of the Tatula river and drained area in the river basin (in percent of wetland area)

In the spring season, the correlative interdependency between the river runoff depth and drained land area (calculating according to the part of the wet land area in all the river basin and according to the part of the drained land area in comparison to the wet land stock in the basin) in the case of the river investigated is very weak as the coefficient of the correlation reaches only 0.01 and – 0.02. Basically, the same regularity was found analysing the changes of the river runoff depth in the summer season. The correlative interdependency between the river runoff depth in the summer season and the drained land area is also weak. In this case, the correlation coefficients change from 0.25 to 0.26 (reliability with 95 % probability level). When the area of the drained lands in the river basin grows, no essential changes of the river runoff in the spring and summer seasons are defined. The impact of drainage on the river runoff might be evaluated analysing what part of the water in comparison to the annual runoff forms that water which is flown in the river during the spring flood and summer overflow. The interdepen-

dency analysis of the changes of these values in the relation to the drained area showed that in spring as well as in the summer seasons, the growth of the drained areas has no impact. Correlation between these values is weak, respectively 0.26 and 0.06 (reliability with 95 % probability level).

In order to evaluate the distribution of the river runoff in a year, the calculation of the values of coefficient  $d$  of runoff unevenness during two periods which differ in the drained land area was done. The result was that in 1960–1969 when the part of the drained land was little, the value of the coefficient of the river runoff unevenness was 0.51. In 1981–1990, when the amount of the drained land was already 2 times bigger, the value of the coefficient of runoff unevenness was 0.43, i.e. relatively smaller in 16 %. If to compare those changes with the value defined during the period of many years (Gailiušis *et al.* 2001) which for this river was 0.46, we see that there appeared no essential changes. Such values of the river runoff coefficient unevenness mean that, drainage has no essential impact on the changes of the runoff distribution in a year.

The experiential research of the Tatula river showed that it is the place of intensive naturalisation processes. In the part of the regulated sectors of the river bed, the meandering started and slopes are covered with the wooded flora, trees and bushes. Density of the wooded flora in the sectors of the Tatula river investigated reaches 60 %, and density of the wooded flora in the river varies from 0.11 to 3.55 unit/m<sup>2</sup>. The interdependency between the density of wooded flora and value of the hydraulic roughness coefficient is noticed.

Natural measurement and hydraulic calculation in the Tatula river allowed defining that the coefficient of the hydraulic roughness  $n$  here changes from 0.028 to 0.049. With the existing coefficient of the hydraulic roughness (0.028–0.049) evaluated in the course of natural research, the indicator of the water overflow is positive in all the sectors of the river. The water level in the bed ( $h_v$ ) in all the cases is lower than the depth of the regulated small river ( $h_c$ ). So even when the spring debit is maximal, there is enough room for the water in the regulated bed of the river and it does not overflow.

Changing the roughness of the bed from 0.028–0.049 to 0.160, the water levels change as well ( $H$ , m). Increasing the coefficient of the hydraulic roughness, the water level in the regulated bed of the river becomes higher and overflows when reaches some limit. Increasing the coefficient of the river roughness up to 0.070, the water level of the bed in three sectors of the Tatula river ( $h_v$ ) becomes higher than the depth of the regulated little river ( $h_c$ ) and the water overflows. Increasing the coefficient of the hydraulic roughness up to the 0.160, the water in the bed overflowed in all the regulated sectors of the Tatula river so the level of the water in the bed was higher than the depth of the regulated river.

From the result of research we see that with the existing area of the Tatula river covered with the wooded flora and the maximum 10 % probability debit in spring, the

water does not overflow out of the bed. The conclusion is that the intensive naturalisation processes in the Tatula river do not destroy the functionality of its systems (is conductive considering spring flood 10 % probability debits) and makes the natural environment ecologically more diverse.

#### 4. Conclusions

Areas of the wet land in the basin of the Tatula river form 90 % of all the area. Analysis of the interchanges of excessively wet lands and drained area in 1960–2009 shows that until 1961, such drained areas reached only 12 % of all the area of wet land, and in 2000 such area reached 94 %. In the recent years the new drainage systems nearly have not been prepared so the area of the drained land changed very little.

The essential differences of the river runoff changes in the Tatula river are not defined. The analysis of interchanges of the runoff depth in spring and summer seasons and the drained land area; and what part of the water in comparison to the annual runoff forms that water which is flown in the river during the spring flood and summer overflow; and interdependency of the changes of these values in the relation to the drained land area showed that in spring as well as in the summer seasons, the growth of the drained areas has no impact (the correlation coefficients change from 0.25 to 0.26).

Evaluating the changes of coefficients of the river runoff unevenness which with the growth of the drained land area decreased in 16 %, it is possible to state that such changes do not show essential differences of the runoff distribution during the year as the least even runoff of the river during the year still remains.

The natural research of the Tatula river showed that it is the place of intensive naturalisation processes which make the natural environment ecologically more diverse, and in the current situation do not make harm concerning the functionality of the drainage systems.

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