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LAND DRAINAGE DEVELOPMENT PROCESS AND RUNOFF CHANGES IN LITHUANIAN RIVERS

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Abstract. There is water surplus in soils in more than half of the Lithuanian territory. As a matter of fact, to have favourable conditions for farming, too wet areas are drained by drainage (about 77% of the area to be drained has already been drained). The paper discusses the existing status of the drainage systems and analyses the effect of the drainage on river runoff. However, to calculate the effect is rather complicated, because changes in the runoff are affected by a number of factors such as physical-geographical as well as climate conditions, economy activities within the river basin, etc. As a result, only tendencies of the changes in the river runoff during different year seasons have been followed and analysed.

Keywords: subsurface drainage, river runoff, hydrological characteristics of the runoff.

1. Introduction

Climatic, physical and geographic factors determine the surplus of moisture in more than half territory of Lithuania. It is very important to drain the surplus water, because intensive and competitive agricultural production is possible only in drained and tamed soils. When economical and political conditions in Lithuania changed, then the need for a modification of reclamation works in the rural areas arose. As a matter of fact, drainage changes the physical characteristics of soil and a hydrographic network distribution in the territory. As a result, the conditions for the formation both of surface and groundwater runoff changes too. In the report, the evolution of the land drainage and the changes of the hydrologic characteristics of the runoff of rivers (spring floods and modulus of maximum yields of summer and autumn high waters and annual runoffs) in the basins of various Lithuania rivers (Nemunas, Nemunelis, Tatula and Levuo) due to the changes of the drained land area are analyzed.

2. Methods

To define how the boundaries of the areas drained by subsurface drainage were moving, the data by the State institutions has been employed. The authors used the data published by Ministries of Environment and the State Land Use Institute, which are given in view to the administrative boundaries. To analyze the changes of the river runoff, it has been employed the perennial data (1960 -2005) by the Lithuanian Hydrometeorological Service. In this paper, there are the changes of the Spring floods and Summer – Autumn showers runoff modification are analyzed.

3. Results and discussion

Current Situation

The average perennial precipitation in Lithuania varies from 500 to 900 mm, but on average only about 400–500 mm evaporate. Due to these and other physical and geographic factors there is a rather great amount of wet soils in Lithuania. These areas cover 55.8 % of the total area of the whole territory (3.4 mil. ha) or 85.9 % of the total agricultural land use area. Most of the agricultural areas are located in the basins of the Central Rivers of Lithuania, namely the basins of the Levuo river that contains 93.1 %, the Nevezis river that comprises of 78.5 %, and the Sesupe river that contains 70.0 % of the total land area. In the areas of water surplus intensive agriculture is possible only by having subsurface

drainage. The scope of land drainage works had increased greatly since 1951. In the period of 1961–1990 particularly lots of reclamation works were carried out. In 1990 after the Restoration of Independence, when Lithuania had to shift from the planned to the market economy, the new drainage systems would not be erected. Besides, due to the lack of maintenance, some of the systems would stop functioning. In accordance with the data registered during the inventory in Lithuania on 1, January 2007 [1] there were 3 003.2 thou. ha of drained lands, and of that 2 584.0 thou. ha were drained by subsurface drainage or 76.6 % of the land area to be drained.. In the drained lands, there is produced, at present, 89 % of the total Lithuania agricultural commodity production. Certain sorts of cultivated plants are grown only in these lands. The influence of the reclamation to the natural environment is versatile [2, 3]. It changes not only the mode of water in the soil, but the agricultural landscape as well, the density of the hydro graphic network in the basins of rivers; the mode of the hydrologic territory (change of the runoff of rivers and its distribution during the year as well as the quality of the river waters); the conditions of works of the applied agricultural technology [4].

Today's most acute problem of reclamation is considered to be the maintenance of the current systems and their renovation. Due to the shortage of funds to keep adequate maintenance of the installations of reclamation and the drainage systems, the equipment and systems are mostly out of order, the majority of systems operate inefficiently. The individuals concerned with the production of agriculture commodities tend to experience many losses due to the faulty operating systems of reclamation. A lot of systems used in the plots of land returned to the former owners, are considered to be the systems of joint usage. The maintenance of such systems on a single farmer's land, who acquired the systems in accordance with the right of ownership, became practically impossible due to the shortage of the owner's funds. In accordance with the law on Land Reclamation, a certain part of the structures of reclamation became the ownership of the land proprietors. That fact caused the maintenance of the installations to be a rather complicated one and it was hard to carry out the repair works, as well as the application of inspection in order to determine the functionality of the reclamation systems, which could assist in determining the resources for the financing of the works. Thus, the strategy for the efficient usage of the reclamation installations as well as the management and financing of the systems became a very significant problem. The financial assistance allocated from the state budget funds of the Republic of Lithuania to the owners of the drained non-governmental land to keep up the maintenance and repair works of the structures of the reclamation systems which are owned by the right of ownership by these owners is not enough and the economical support is inadequate.

Due to the insufficient maintenance of the systems, the state of the main channels tends to worsen, namely the deformations of the beds and slopes of the trenches are appearing, the open channels have not been cleaned and repaired for a long time as well. The functionality of the dewatering systems has deteriorated; the mouths of the drains are banked up, and the operation of the drains has degenerated.

Moreover, any kind of repair and renovation works of the drainage at the expense of the state's budget have not been carried out in Lithuania since 2005 on lands owned by private owners. That is why the state budget funds were increased and allocated for the repair works to be carried out on the open channels. In 2006 there were allocated 19.7 mil Euros from the state budget just for the reclamation needs alone and 20.3 mil Euros in 2007, but the allocated sum comprised only about 65 % of the required funds.

The Ministry of Agriculture together with the French Palace of Agriculture of the Department of Lioret worked out and started to implement an international project dealing with the research on the possibilities for further establishment of the Association of Land Users, so as to be able to keep the maintenance of the structures of reclamation in future. The project is aimed at assisting land owners and users to acquire theoretical knowledge and practical experience concerning the maintenance and surveillance of reclamation systems when the systems are located on the plots of several owners, and by co-operating the funds of various resources and in more efficiently applying the financial assistance from the EU support funds. The projects of water treatment are being implemented and part of the costs concerned with the implementation will be financed from the EU funds. It is obvious that one can expect the situation to be improved but the funds possessed do not fully assist the solution of the problem as such.

The renewable value of the whole infrastructure comprises about 6.4 billion Euros. The depreciation of the structures of reclamation is 2% annually or, in other words, their value is annually decreased by 29 mil Euros. At present the annual investments allocated to the reclamation systems are unable to ensure the regular functioning of the systems. The systems are considered to be of great value for farmers and it is very important to safeguard them to be able to function for many years. After Lithuania joined and gained the membership in the EU, there were able to survive only competitive farms. The amount of the output of the agricultural commodities is directly related to the productivity of the land use and the latter depends on the state of the reclamation systems. It is necessary to have an effective functioning system in order to determine the lands requiring reclamation and to be able to assess the state of the structures for reclamation as well. Moreover, the economic efficiency is not the same on the all soils. Drainage systems installed on the fertile land increase the productivity of the land use by 3 times if compared with the productivity on the non- fertile lands. At present the owners are changing from the traditional agriculture to other businesses regarding the lands that are not very productive, e.g. a very wide development of rural tourism is being developed. In future, the production in low productivity lands has a

tendency to be not perspective and that is why the specialists have very reasonably to assess whether the reclamation systems have to be preserved or not or whether it is possible to liquidate the systems. The data collected concerning the state of the dewatered lands are significant from the point of view of environmental protection. When analyzing the quality of the water in a river it is very important to evaluate the economical activity of a person operating in the river basins because the process of lands drainage is one of the major fields of economical activities significantly influencing the environment. That is why the analysis of the problem of accounting of drained lands in the basins of rivers is very significant too. Up till now all the information was accumulated in accordance with the administrative regions of the country. As prescribed by the General Water Policy of the EU, water quality management has to be solved when based on the principal of river basins.

Analysis of Changes in Rivers Runoff

In Lithuania there are stored long-term data (period of 40–50 years) concerning the runoff of the rivers basins of which the drained lands by means of drainage comprise more than 70 %. There appeared the possibility to analyze the change of the runoff of rivers when changing the area of drained lands. The report presents the data concerning the change of the runoff in the basin of the river Nemunas which comprises of 75 % of the territory of Lithuania as well as the data that were analyzed concerning the regions located in the Lielupe river basin (in the basins of Nemunelis, Tatula and Levuo basins). The above mentioned region is specific because it is considered to be an international region (it borders with Latvija), but also because it is considered as the area of sinkholes. The very peculiar feature of this sinkhole area is a very high sensitivity to pollution of the underground waters. The vast agricultural areas meant for farming and located in the basin (occupy about 72 % of the area of the Lielupe river basin) are considered to be the major reasons causing the intensive overspread pollution (especially by nitrogen). The farming of organic agricultural commodities in this area, which is favourable from the point of view of the protection of water reservoirs against pollution, is developed. One of the first scientists who analyzed the influence of dewatering on the runoff of the Lithuanian rivers was V. Marcenas [5]. He stated that the activities concerned with drainage tend to reduce the runoff during separate seasons and later [6] when the investigation of the problem was carried out by means of simulation models he derived the conclusion that the activities of land reclamation and intensive farming insignificantly reduced the annual runoff. Other authors [7, 8, 9] stated that drainage had no significant effect on the maximum modulus of the runoff neither of the Year nor the Spring. It is proclaimed that when the area of drained lands in the river basins was increased up to 30 %, the modulus of the runoffs of Summer and Autumn maximum high waters tends to increase by 30–40 %, where the coefficients of the runoffs were 30 %, and the duration of high waters was reduced by 7 %. Research carried out by other authors [10] indicated that by increasing the per cent of land under drainage in the basin registered a reduction of the coefficients of the runoffs during Spring floods, but the coefficients of the runoffs of Summer and Autumn periods and through the whole year tend to be increased. However, these dependencies were specific because of their low correlation. When carrying out the processes of research on the runoffs of rivers and processes of drainage in the river basins, a significant assessment of the change of the cycle of the water regime fluctuation was required. There was analyzed the long-term change (1910–2001) of the river Nemunas at Smalininkai of the minimum runoff during the summer period (it was pointed out that change of minimum and annual runoff in this river is identical) and the scope of the change of dewatering of the wet soils [11]. It was determined that when increasing the scope of drained lands, the minimum runoff of the rivers is reduced, but when the scope of the activities of drainage is reduced the runoff has a tendency to be increased. From the point of view of the investigators to state that it is a lawful process it is not possible because the period from 1963–1977 was especially dry, but the period from 1977– 1990 was very wet. In the dry season, the annual runoff of rivers located in the Central part of Lithuania was about 20–30 % lower than the average received values, but during the wet season the values were 20–50 % higher.

In Fig. 1 the compiled data represented by the integral curve of the deviations from the average of the modulus coefficients of Spring maximum yield on the river Nemunas at Smalininkai and the integral curve of the drained areas are submitted. The curve presents the fact that until 1960 there was observed an increase of the maximum yields, but since 1961 there was observed a decrease.

The area of dewatered lands till 1960 was not great and comprised only up to 10 %, later on the amount had a tendency to be increased and starting from 1990 it became stabilized. When comparing these integral curves it is not possible to state that the maximum yields tend to be reduced due to the increase of drained areas of land. The change is possibly explained only by the total tendency of reduction of precipitation. Fig. 2 presents the integral curves of deviations from the average on the amount of annual precipitation (a) and deviation from the average of the level of the annual runoffs of two rivers, namely the Nemunelis River at Tabokine (b) and the Tatula River at Trecionys (c).

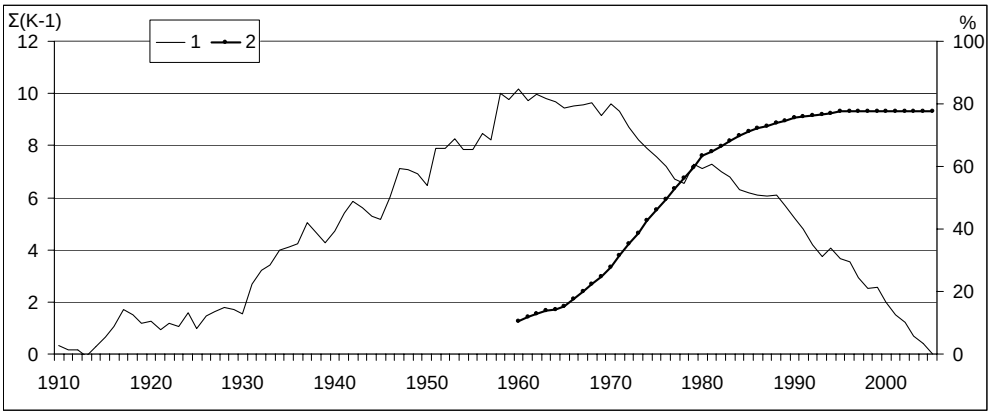

Fig. 1. The integral curves of deviations from the average concerning modulus coefficients of maximum yields of Spring floods of river Nemunas at Smalininkai (1) and dynamics of drained areas of land in percentage from the area of lands to be dewatered (2)

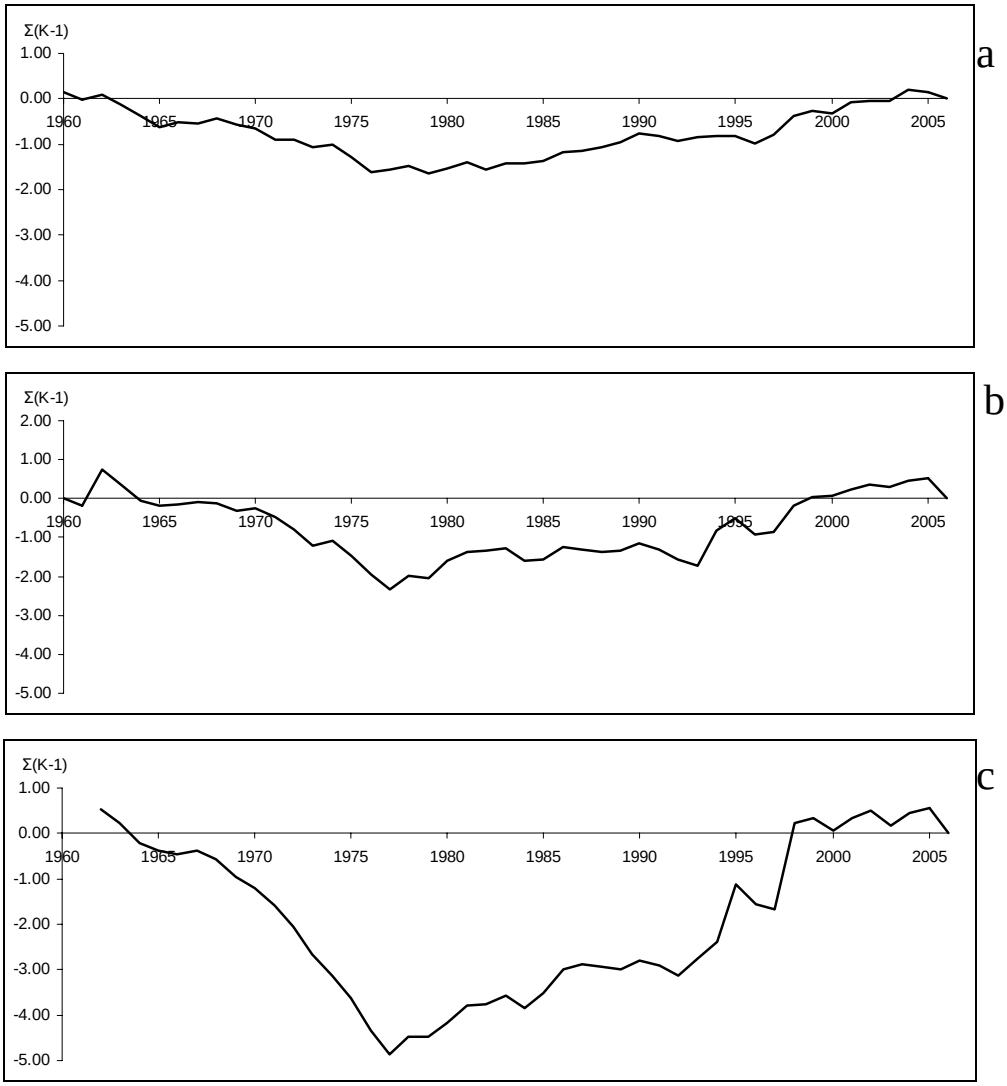

Fig. 2. The integral curves of deviations from the average of the annual precipitation (a) and deviations from the average of annual runoff height in rivers of Nemunelis (b) and Tatula (c)

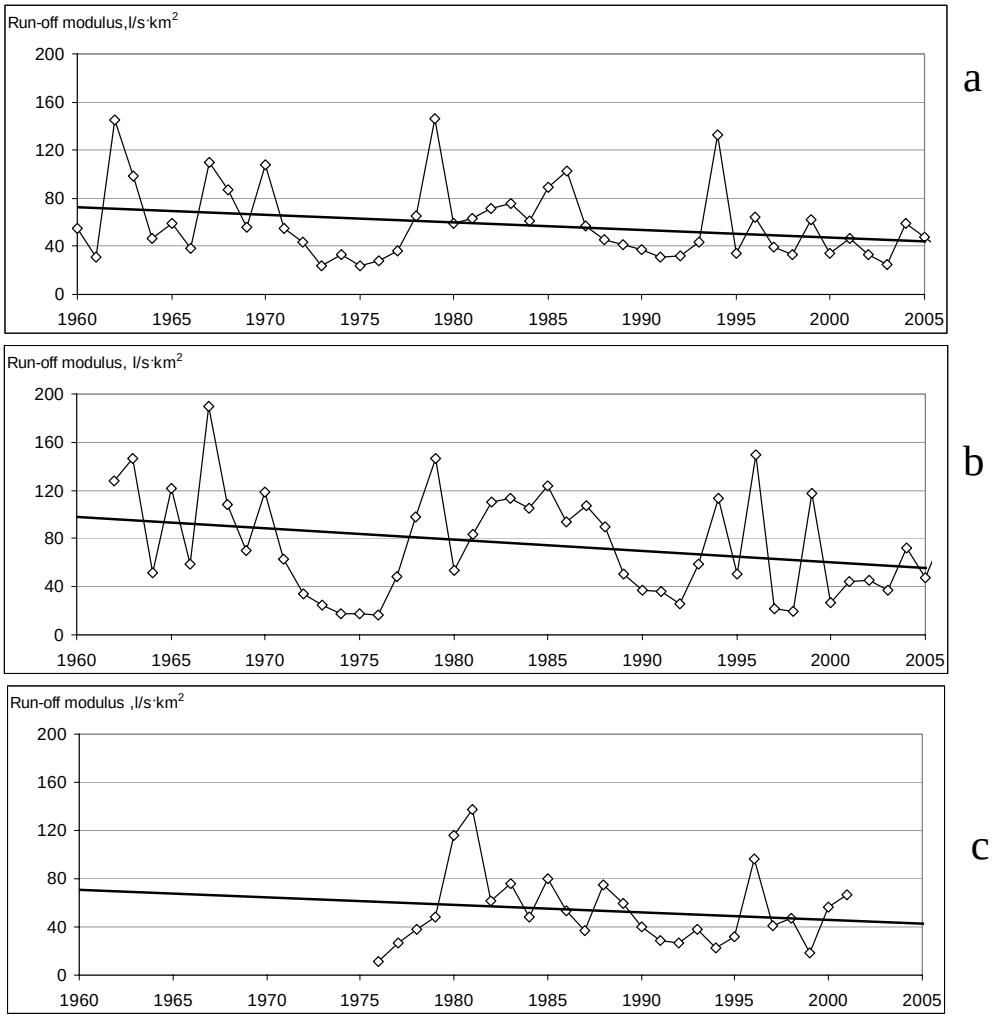

Fig. 3. The change of modulus of maximum yields of Spring floods in the rivers Nemunelis (a), Tatula (b) and Levuo (c)

The curves vividly represent the similar tendencies of precipitation and the change of the height of annual runoff. There exists a strong correlation connection between the runoff and precipitation, the coefficient of correlation is 0.65.

When analyzing the change of the modulus of the maximum yields of the Spring floods (Fig. 3) as well as the modulus of the maximum yields of Summer and Autumn high water seasons (Fig. 4) during the long-lasting period of observation from 1960–2006, it is possible to state that in the rivers under research and together with the increase of the areas of land cultivated by drainage in the basin, there were observed the following tendencies of the changes of these hydrological characteristics: namely the modulus of the yields of the maximum Spring floods tend to decrease and the modulus of the maximum yields of the autumn season high waters tend to increase.

The exception is the river Levuo change of the maximum yields modulus of the high waters of summer and autumn seasons because the data were received during the shorter period of observation of the runoff only in 1974–1999. To quantitatively assess the dependence of the change on the amount of the dewatered land areas in the river basins is a complicated task because the correlation connection between these data is a weak one. Many physical and geographic factors, which act together, influence the change of the characteristics of the runoff.

The influence of the drainage is both a complicated one and a versatile one. First, drainage improves the physical characteristics of the soil, because the porosity of the soils cultivated by drainage is increased as well as the structure of the soil, the filtration characteristics, and the mode of heat are improved.

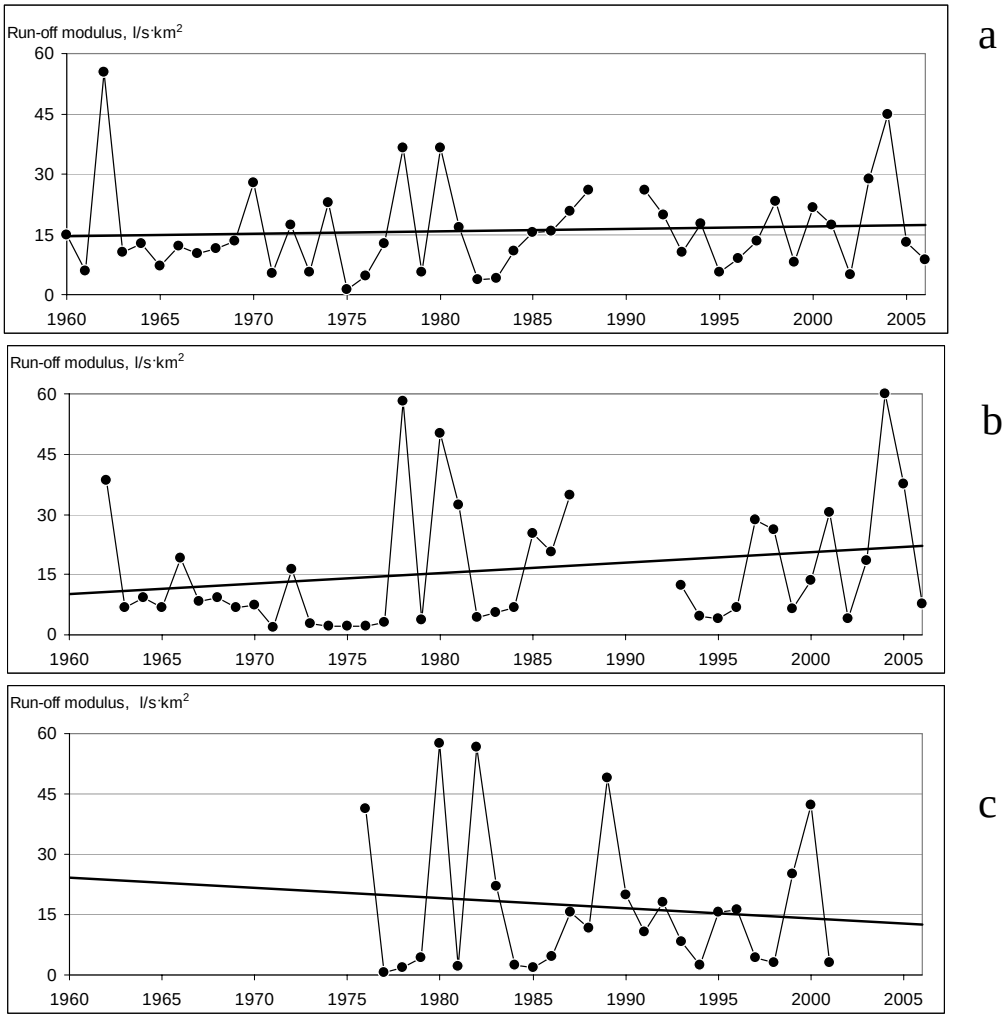

Fig. 4. The change of modulus of maximum yields of high waters in Summer and Autumn in rivers Nemunelis (a), Tatula (b) and Levuo (c)

After the soil is drained the aeration is improved, the anaerobic processes are reduced, but the aerobic processes are increased, and plants obtain the possibility to penetrate into the deeper layers. The positive change of physical characteristics perfects the water mode of the soil and at the same time improves the efficiency of the influence of the drainage. In areas cultivated by drainage the surface runoff is reduced, and there is an increase of the ground water runoff.

The second factor is that after the lands are dewatered there is the transformation of the agriculture land use. Instead of the natural and of little productivity meadows there are arranged high productivity cultivated lands and pastures. The fertility is increased of cultural plants. Due to such changes the evaporation is changed which is a significant element of the water balance.

The third factor is that when working out the systems of drainage, there are straightened the watercourses of the rivers, and new open channels are prepared. Because of that the hydro graphic network density is changed as well as the morph-metric characteristics of the small rivers (length of the rivers, area of the basin, inclination and other morph–metric parameters). The total above-mentioned factors – especially the size of the river basin area – influence the hydraulic conditions of the water supply. Due to the enumerated changes it becomes rather complicated to evaluate the influence of the drainage on the runoff of the rivers the basins of which occupy different areas or parts of dewatered lands.

The research made on the change of the meteorological factors (precipitation, air temperature) by Bukantis A. and Macevicius J. [12, 13] indicate that the tendencies of global climate change are observed in Lithuania as well. The tendency of the increase of air temperature in winter seasons and the tendency of the decrease of water resources on snow cover as well as the greater frequency of showers during summer and autumn seasons and the tendency of the increase of the scope of precipitation were observed. Such changes are significant and are able to influence the tendencies of changes of the distribution of the run-of of rivers during the whole year and the amount of the runoff during the separate seasons.

In summarizing the total information presented here, it is possible to understand why the scientists evaluating the influence of dewatering on various characteristics of

the runoff of rivers have different opinions, because the field investigations on the influence of drainage was carried out in various seasons and possessing different amounts of areas of dewatered lands as well as under different meteorological conditions, and they were handling other different physical and geographic conditions of the analyzed basins of the rivers.

4. Conclusions

In Lithuania, there were cultivated by means of drainage about 77% of the area from the total land area which had to be purposefully dewatered. Dewatering made real conditions for the establishment of the farms which were able to compete, as well as gave a new development for the intensive farming. However, because of the shortage of the funds allocated for the adequate maintenance of the systems, the systems are not regularly repaired, that is why a certain part of the systems operate inefficiently enough. The systems of drainage together with the equipment installed became the property of land owners and that is why it is important to start the establishment of the Associations of Land Users so as to be able to keep the maintenance of the installations of the systems of reclamation and to be able to cooperate the funds received from various sources.

The cultivation of land by drainage caused the change of the conditions for the formation of the runoff of rivers. There were transformed the following: the greatest part of the basins which occupy dewatered lands, the physical characteristics of the soils as well as the use of the agricultural land, the morph-metric characteristics of the watercourses of the small rivers and basins. It is rather complicated to quantitatively assess the changes of the hydrologic characteristics of the runoff because the runoff is influenced by a number of factors such as the annual rainfall, the physical-geographical conditions of the basins and the morph-metric parameters.

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