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Substantiation of the expediency of drainage systems renovation in Lithuania

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Abstract

Humid and boggy lands cover about 3.5 million ha in Lithuania. 3.02 million ha of humid and waterlogged lands have been drained (of which 2.58 million hectares – by drainage) till the year 1990. During the latter years, large areas of drained lands became uncultivated in agricultural industry due to the country' public-social, demographic and economic reasons. With the increase of land productivity in points the uncultivated agricultural areas decrease. The regression analysis of the increase of plant-growing production and land productivity in points (due to drainage) shows that with the increase of the addition of land productivity in points (due to drainage) plant-growing production increases as well (according to polynomial dependence). After the evaluation of the dynamics of the uncultivated areas of agricultural farming lands, the increase of the land productivity in points due to drainage, the possibility of drainage breakdowns and the plant-growing production (by typical regions), it is possible to state that the highest expediency of the renovation of drainage systems is in the region of the Middle Lithuania Lowlands, the average – in the Pajūris Lowlands and the Baltic Highlands, the lowest one is in the Žemaičiai Highlands.

Keywords: drainage; environment; productivity land; breakdown possibility; drainage renovation.

1. Introduction

Lithuania is situated in the zone of moisture surplus. The agricultural land is often too humid in our country; therefore land reclamation (draining) is of great importance for the agricultural industry infrastructure. The analysis of the land reclamation cadastre data shows that the present land reclamation fund was made before the restoration of the Independence of the Republic of Lithuania, when on the average 90 thousand ha had been drained (by drainage) per year during the period of 1961–1990. During the above-mentioned period the area of the arranged drainage systems had grown to 3.0 million ha. During the Independence period, beginning with 1991, the scale of the construction of new drainage systems and the renovation of the old ones constantly decreased. If in the year 1991 – 16 425 ha of new lands were drained and drainage systems were renovated in the area of 13 873 ha, so in 2001 these numbers were 5 and 1320 ha, correspondingly [1], in 2003 – 10 and 2310 ha, however, in the latter years the new construction of drainage systems did not occur at all. Every year renovation of drainage systems goes on in the area of 2060 ha. It is connected with the decrease of the state subsidies for the land reclamation sector. 28 million Lt allocated for the land reclamation sector in latter 2010–2013 years are not enough even for the essential drainage system repair and maintenance works.

Investigations show that the agricultural development strategy is closely connected with the market research on the European and world agricultural production; therefore the water management development strategies should take into account prognoses of agricultural market development. All actions over water management re-structuration and planning are substantiated by the calculations of ecological and economic efficiency as well as by prognoses and experience of foreign countries [2–6].

The new Land Reclamation Law (approved in 2004 and amended in 2010) regulated the transfer of land reclamation structures situated in the land of the land owner. Basically the entire subsurface drainage with all functional structures was transferred to the land owners. Following this law the owners of the drained land ought to maintain land reclamation structures arranged in their lands using their own financial sources. The subsurface drainage water collectors with the diameter of 12.5 cm and larger were left for the state. Now farmers must take care of drainage systems on their own land. They are not left alone and may ask for a help from the state if they are able to defray the expenses no less than 15%. The

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arrangement and reconstruction works of land reclamation structures are financially supported from EU structural funds. The reconstruction of drainage systems is planned to be supported according to the activity field “Agricultural water management” of the measure “Agricultural and forestry activity and its infrastructure” of the Rural Development Program for Lithuania 2007-2013. Financial support is being allocated for the business projects of the land owners of the drained land, i.e. for the investments into the modernization of agricultural holdings [7].

After the joining of the European Union, Lithuania has committed to implement the principles of water resources protection and maintenance, which are defined by the EU Water Framework Directive. In this Directive, water management questions are regulated especially circumstantially – transition to the basin management of water husbandry and the involvement of the society not forgetting ecological questions as well [8].

Having fulfilled draining works and turned scanty (bushy, boggy) areas into cultivated fields, at the same time we have destroyed the variety of perennial flora and the bogs, straightened and canalized streams, we additionally dug ditches [9]. After the destruction of protective strips in river slopes, natural ecosystems, acting as natural biogeochemical barriers producing aesthetical view for the landscape and protecting biological diversity as well as decreasing the pollution of surface waters, are being damaged [10]. Barvidienė and Šaulys [11] states that the average strip width of protective shores near cultivated lands makes up only 31–52% of the strip width required by legal acts. Having done this we have increased the danger for water to be polluted and have uniformed and impoverished the landscape. It should be noted that the areas of drained lands have no impact upon the characteristics of river run-off [12]. The impact of the negative land reclamation factors can be limited or even entirely liquidated.

In Lithuania, having decreased the traditional maintenance of regulated streams the spontaneous channel winding and other processes are going on more intensely. The slopes and shores of regulated streams overgrow with grass and woody vegetation and the stream channel starts to deform. Many investigators, such as [11], [13], [14] wrote articles on the resistance of trees and bushes to water flow, the impact of their shading on the vegetation development as well as on the influence on the hydraulic throughput of ditches. Of course, every additional obstacle (trees, bushes and grass vegetation) increases the resistance to flow and decreases the hydraulic throughput of ditches. The process of the overgrowth of the derivation network of drainage systems was evaluated sensitively: it decreases hydraulic throughput and have positive impact on the structure of the landscape, decreases deflation possibility, accumulation of sediments and pollution of water reservoirs [15].

After the restoration of the ownership rights to people, the land use started to change intensity. In less favourable for agricultural development places of Lithuania the reclaimed land is used not intensely. There are places, where drainage systems are old and their state is bad. There are 45 percent of drainage systems, which serve more than 40 years [1].

The aim of these investigations – contextualize environmental and economic issues, to substantiate the expediency of the drainage systems renovation according to the carried out analysis of agricultural production, the changes of the farming lands area and the technical state of drainage systems.

2. Investigation methods

Investigations were carried out following the land reclamation infrastructure analysis and evaluation. The data from the Lithuanian Department of Statistics, the State Land Management Institute and the Ministries of Environment and Agriculture of the Republic of Lithuania were used for the analysis.

We evaluated the intensity of agricultural production when analysing the plant-growing production received from municipalities. Animal breeding production was not evaluated, because it reflects insufficiently the intensity of the production received in local areas. Fodder is usually brought from other places, even from other countries.

The technical state of drainage systems was evaluated using the database of the Lithuanian Land Melioration Situation and Soaking Mel_DB10LT, where information on the drained areas is gathered in digital form. Graphical and attributive data on the drained lands, the state of land reclamation structures as well as the reasons for their bad state are accumulated in this database.

The data were computed by statistical analysis, relative rate calculation and comparison methods.

3. Investigation results and discussion

In Lithuania humid and boggy lands make up 3.5 million ha or 86% of the total agricultural land area. 3023 thousand ha of humid and waterlogged lands were drained in Lithuania till 1990, of which 2 582 thousand ha were drained by drainage. With the land reform going on in the country the ownership forms of the land and land reclamation structures have been changing. In order to thoroughly evaluate the drained land one should take into account natural, technical and economic criteria. The significance of every evaluation criterion of the drained land can be modified considering particular conditions and evaluation demands. In order to evaluate the changes of the use of the drained land and land reclamation structures as well as to fix their state and specify drained lands, the technical evaluation of the state of drained lands and land reclamation structures was carried out in 2006.

Agricultural production in drained lands depend on the potential productivity of these lands (conditioned by the mechanical composition of soils, nutrition materials of soils and the structure of field crops) as well as on the additional conditions for plant growing created by human efforts (arrangement of drainage systems), however, due to the heterogeneousity of the soil layer, the efficiency in various territorial areas differs significantly.

3.1. The changes of the agricultural farming land area in the country's territory

In Lithuania dominate soils of different granulometric composition. Sandy soils cover 13%, sandy loam soils – more than 37%, clay loam soils – more than 39%, clay soils – about 3%, turf and humous turf soils – about 8% of the agricultural farming land area (Lithuanian soils, 2001). Due to the heterogeneousity of the soil layer, the draining efficiency in various territories differs significantly. For example, the point addition in Šalčininkai district is only 7.2, in Vilnius, Molėtai, Zarasai districts – 9.1–9.3, and in Pakruojis, Joniškis and Šakiai districts – even 21.4-20.4 points, see Fig. 1a.

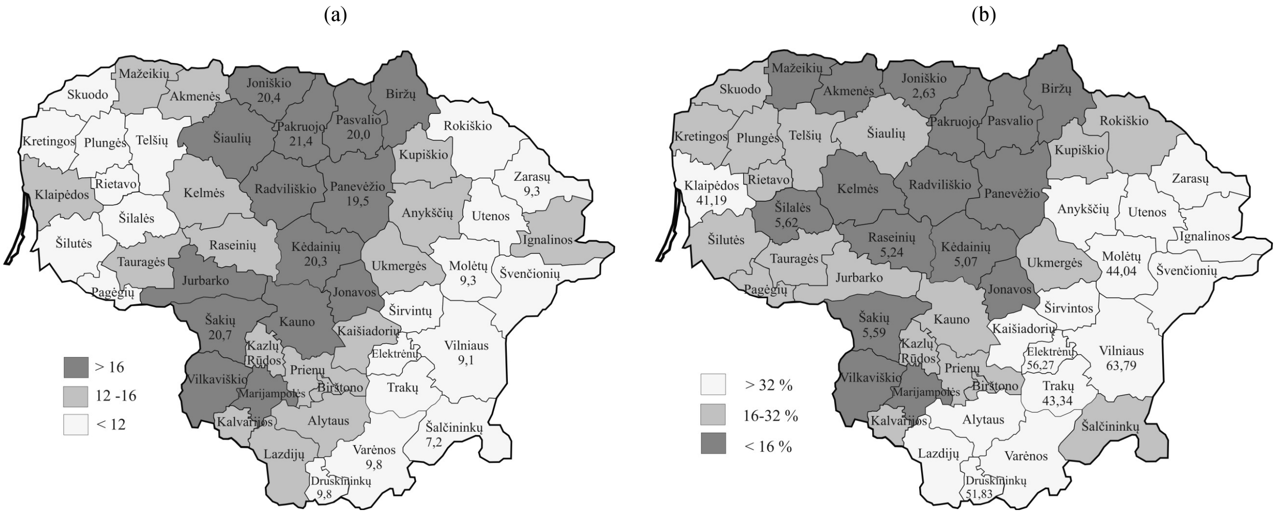

Fig. 1. Increase of the land efficiency points due to land draining in the municipalities of Lithuanian districts (a), areas of uncultivated agricultural farming lands in the municipalities of Lithuanian districts (b)

Especially fertile are brown soils predominating in the Middle Lithuania, the productivity of which reaches about 50 points (it also includes the increase of productivity due to drainage). Consequently, the advantage of the Middle Lithuanian regions in respect of other regions is obvious [16]. Productivity points of the soils with light granulometric composition (sands and sandy loams) increase less and the soils with heavy granulometric composition (clay and clay loams) – more due land draining.

The evaluation scale of the impact of agricultural farming lands upon the soil productivity can be made by grouping the increase of productivity points due to the drainage (B) into three categories: $B > 16.0$ – the impact of draining is large, when B fluctuates from 12.0 up to 16.0 – the average and when $B < 12.0$ – the impact of draining is small. The strength of the impact of draining can be evaluated by coefficients, the values of which can fluctuate from 0 up to 1. With the decrease of the impact of draining the value of the coefficient approximates to 0 or vice versa.

Having surveyed rural development tendencies of the latter years as well as the regional specialization of agriculture it should be noted that due to the small yield in the productive lands of farms as well as due to the unprofitable agricultural activity in the regions of less favourable for farming lands, the areas of the uncultivated agricultural farming lands increase, see Fig. 1b.

It can be obviously seen when comparing the municipalities of Joniškis, Kėdainiai, Šakiai, in which the part of the abandoned agricultural farming lands make up only 2.6–5.6% and the municipalities of Trakai, Molėtai and Vilnius districts, where this index reaches 43.3–63.8%.

In the regions, where the increase of land productivity points (due to the land draining) is higher than the country's average, the draining service has significantly higher value. It shows the dependence of the uncultivated agricultural farming land areas in municipalities on the increase of land productivity points due to the land draining (1).

The correlation coefficient of the relationship $r = 0.60$ says that the relationship between variables is of the average strength.

$$A_{AP} = 1107\, B_S^{-1.558}, \tag{1}$$

where: A_{AP} – abandoned, uncultivated agricultural farming land areas, %; B_S – increase of the productivity points of land due to land draining.

Mrs. Gurskienė [17] has determined using the mathematical analysis and the statistical grouping methods that there are relatively more economic subjects in the lands of Middle Lithuania. With the increase of the productivity point (B) of agricultural farming lands, the number of the owners not cultivating their lands ($P_{\%}$) decreases according to the linear equation $P_{\%} = 14.47 - 0.24\ B$. The natural investigations over the number of abandoned lands in the municipalities of the Middle Lithuanian districts were carried out by Mrs. Brusokaitė-Stravinskienė [18].

It was defined that with the decrease of the land productivity points the number of abandoned lands (A_{AP}) increases according to the exponential dependence (r = 0.95). There are two main reasons why the land is unexploited: 1 – low agricultural value of land, bad farming structure and bad situation of land plots; 2 – defects in subsurface drainage network. In first case it takes 92.2, in second – 7.8%.

It should be noted that the number of unexploited lands basically depends on the productivity of lands as well as on the entire complex of factors having economic character. Analysing the changes of agricultural farming lands and the reasons of land use intensity, the authors [19] name the following factors: natural factors, such as relief, segmentation of farming lands, soil diversity, economic factors – a complex of measures, which helped create and maintain land to farms more efficiently using land and social factors, such as the density of rural inhabitants and the changes of the numbers of inhabitants.

3.2. Intensity of agricultural production

We evaluate the intensity of agricultural production in different soil habitats as well as the intensity of agriculture in different soils (from the point of view of draining) when analysing the received plant-growing production. We refused the evaluation of the animal-breeding production because of the reason that fodder is usually being brought to the large animal-breeding complex even from other countries. Land productivity points and their part influence the plant-growing production on a large scale (due to land draining). Analysing amounts of the plant-growing production in the municipalities of Lithuanian districts during 2005–2009, one can notice the increase of production in 2007. For the evaluation of the efficiency of agricultural production the financial means of the plant-growing production for 2007–2009 were chosen and calculated for one ha of agricultural farming lands. The data are presented in Fig. 2a.

The analysis of agricultural production shows that the largest part of plant-growing production is achieved in Kėdainiai, Joniškis and Šakiai districts – 2.48, 2.38 and 2.13 thou. Lt/ha, correspondingly. At the same time, these are the municipalities of the district with the largest addition of land productivity points. On the other hand, in Zarasai, Molėtai, Utena and Trakai municipalities plant-growing production reaches 0.32, 0.37, 0.40, 0.46 points, correspondingly and it is by 5-7 times less of the production falling on one ha of agricultural farming lands. Here the increase of the land productivity points is less than twice.

The regression analysis (Fig. 2b) carried out on the increase of the land productivity points and plant-growing production (due to land draining) apparently shows that with the increase of the addition of the land productivity points the plant-growing production increases (due to land draining) too by means of polynomial dependence (2). The coefficient of correlation r = 0.88 shows that the relationship is strong.

$$P_A = 0.0024 B_S^2 - 0.0286 B_S + 0.0387, \tag{2}$$

where: P_A – plant-growing production by thou. Lt/ha; B_S – increase of the land productivity points due to land draining.

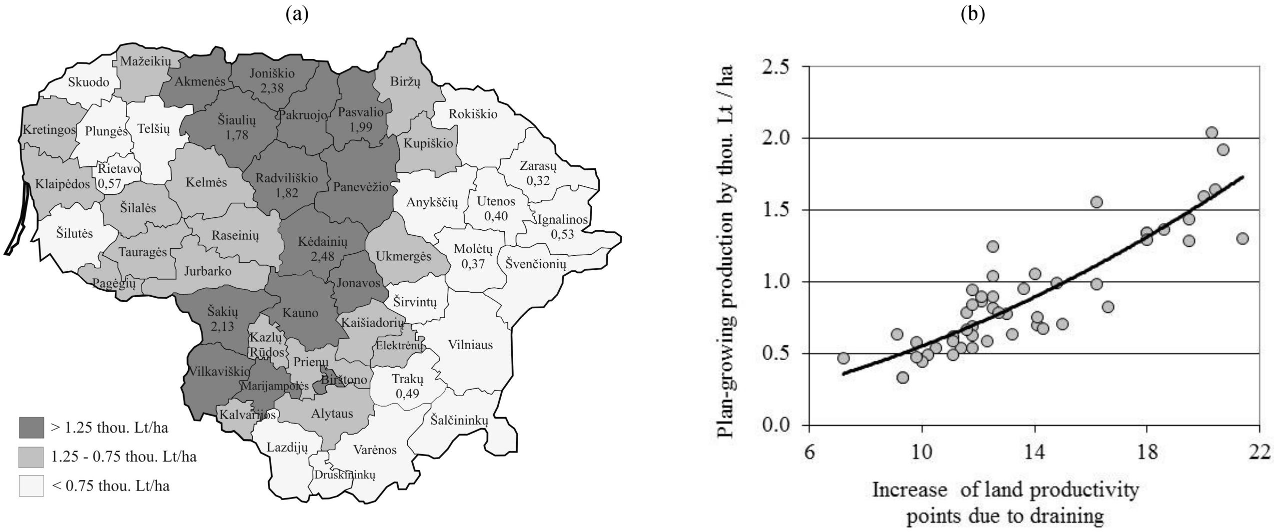

Fig. 2. Plant-growing production in the municipalities of Lithuanian districts in 2007–2009 (a), the change of plant-growing production subject to the increase of land productivity points due to land draining (b)

The analogical dependence is received when evaluating the change of the plant-growing production in municipalities subject to the general land productivity points. The coefficient of correlation is equal to r = 0.88.

The intensity of agricultural production has apparent advantages in more fertile Lithuanian soils. Therefore, we cannot defer to the authors' opinion [20] that the main factors on the increase of the agricultural efficiency in Lithuania are considered the use of productive machinery and the cheap manpower. On the other hand, uncultivated lands are gradually loosing economic characteristics and strong financing would be necessary for the cultivation of these lands (land reclamation works).

3.3. The technical state of drainage systems

The average age of the land reclamation systems is approximating to the limit of 40 years and it allows to predict that the number of breakdowns in the future will only increase. The financing of the drainage systems maintenance decreases every year. Necessary maintenance works are not carried out in time and, thus, the possibility for various damages and breakdowns only increases. After the carried out investigations [21] it was defined that there is a reliable relationship between the decrease of the efficiency of drainage systems and the duration of their exploitation. During the primary period of the exploitation of drainage systems (from 2 up to 11 years) the drainage efficiency decrease curve rises up because of the drainage designing and arrangement defects due to which inefficient draining areas appear. During the second duration period of exploitation (from 1 up to 21 years) the number of inefficient draining areas decreases and during the third duration period of the exploitation (from 21 up to 31 years) the size of the inefficiently drained areas is the smallest and is relatively constant. The forth duration period (it is called the drainage aging period) starts beginning with 31 years, when the inefficiently drained area starts to increase intensely.

It was defined that one of the constantly changing indices characterizing the state of land reclamation is the age of drainage [22], [23]. The carried out investigations show that the strong relationship of correlation exists between the durability of drainage exploitation and the possibility of its breakdowns. However, after the generalization of the data it was defined that the distribution of the drainage exploitation before the breakdown was different in various territories of Lithuania. Having grouped (into three groups) the integral curves of the drainage breakdown distribution functions it is clear that the drainage breakdown possibility (*BP*) in the districts of Middle Lithuania is smaller than in other part of the territory, see Fig. 3. It is the group of the districts of the best conditions for the drainage system exploitation. In the hilly districts of Žemaitija and Southeast Lithuania the possibility for the drainage breakdown is the largest one. The Šakiai district, situated in the southwestern part of Lithuania, falls into the largest risk group of the districts due to the soil sufosity. The drainage system of the second group occupies transitional situation between the already discussed district groups. The differences of the duration of drainage functioning before the breakdown of the above-mentioned district groups (singled out according to the similarity of the drainage exploitation conditions) were statistically evaluated. The dispersion analysis showed that all three groups of municipalities have essential differences even at the 0.01 level of significance (reliability according to the Fisher's criterion).

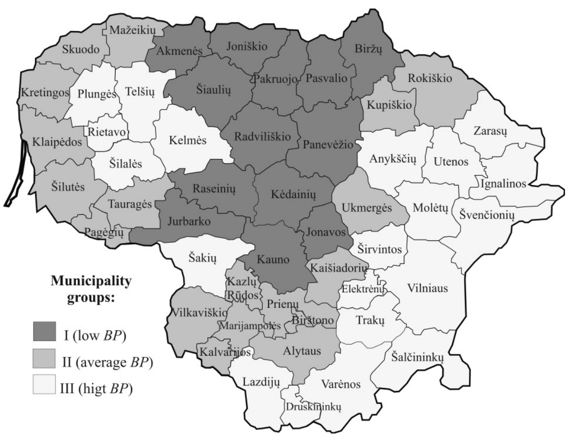

Fig. 3. Distribution of the drainage breakdown possibilities in the municipalities of Lithuanian districts

In 1999 the annual average price of canal maintenance and repairing (applying optimal canal maintenance scenery) fluctuated between 50 Lt/ha in the plane up to 55 Lt/ha in hilly districts (Čiulėnai subdistrict of Molėtai district and Dotnuva subdistrict of Kėdainiai district). 26–32 Lt/ha were necessary for the elimination of the defects of drainage network [24], [25]. We have not in mind such drained areas, where drainage systems should be reconstructed, because the cost of the reconstruction works of drainage systems is much more higher than the comparative exploitation maintenance and repair costs of canals and drainage network. Talking about the maintenance expenses of drained areas (the annual average cost of the canal maintenance works is 50–55 Lt/ha), it was stated that the annual average cost of the elimination of the defects of the drainage network (26–32 Lt/ha) fluctuates. They decrease when using new technologies and equipment, but they increase on absolute quantity, because with the older drainage systems get the greater possibility of their damages.

Having carried out the recalculation of the costs of these works (for the costs of 2009) it emerged that the annual average cost of canal maintenance and repairing has increased up to 106–116 Lt/ha, and for the elimination of the breakdowns of the drainage network we need already 83–102 Lt/ha every year. As it happens, the annual average cost of canal maintenance and repairing has increased up to 2.1 times, whereas the cost of the elimination of the breakdowns of the drainage systems has increased by 3.2 times, basically because of the increase of the cost of fuel and materials.

According to the evaluation data over the state of the reclaimed land and land reclamation structures, 222.4 thousand ha or 8.61 percent of the drained area (out of 2.58 million ha drained by drainage) are ranked as the area of bad state from the technical and agro technical point of view. Of these – 157.1 thousand ha are suggested to be reconstructed, 35.4 thousand ha – to be repaired, and 29.9 thousand ha – to be discarded. More than half (53.6%) of 50 817.5 km of canals (belonging to the state on ownership rights) are considered as bad quality ones. 20.9% of these canals are suggested to be reconstructed, 32.6% – to be repaired and 0.12% – to be discarded. According to the data of 2010, these numbers and works almost did not change – predominating failures of main canals (due to which they considered as bad ones), – canals chocked with sediments (67.2%) and canals overgrown with trees and bushes (91.5%). The presented numbers show that the approach towards the use of drainage systems should change.

3.4. Substantiation of the renovation of drainage systems

Typical regions (planning the substantiation of the renovation of drainage systems) can be singled out considering the Lithuanian hydrological regime, natural and economic conditions. Best of all they are coordinated with the hydrological regions singled out in the Lithuanian territory (Table 1). In this instance, main criteria, such as relief, precipitation, soils could be evaluated in a complex way [26]. Though the territory of Lithuania is relatively small, the character of the supply of surface water reservoirs and their hydrological regime are different due to the diversity of factors forming and redistributing the runoff.

The country's hydrographical network includes various waterways (rivers, streams and rivulets, canals and ditches), lakes and reservoirs, other water bodies. There are 22.2 thousand rivers and streams in Lithuania. Their total channel length is about 76.8 thousand km. The density of the hydrographical network in Lithuania makes up 1.18 km/km^2 [27]. 4 hydrological regions are singled out in the Lithuanian territory:

- the Baltic coast hydrological region; the narrow strip of the Pajūris sandy plain with expressive marine climate;
- the hydrological region of Žemaičiai plain with comparatively large land surface slopes and predominating sediments with heavy mechanical composition condition that 44% of the precipitation flow down into the rivers – mostly as the surface runoff;
- the Middle Lithuanian hydrological region. It is the largest hydrological region in Lithuania. Relief is smooth, surface slopes are small, basins are covered by the sediments with heavy mechanical composition, filtration characteristics of which are small, therefore, the subsurface only marginally supplements the runoff of rivers;
- the South-eastern hydrological region. Here prevail sediments with light mechanical characteristics, rivers are supplied with water in mixed way, parts of snow, rain and groundwater are almost equal in their runoff.

The criteria and substantiation of drainage systems renovation are presented in Table 2.

Evaluating the increase of land productivity in points (due to land draining) the Middle Lithuanian Lowlands (III) with the largest point additions (>20) and the Baltic Uplands (IV) single out, where the draining of lands gives the smallest addition of land productivity points (<10). The districts situated in the Pajūris Lowlands (I) and the Žemaičiai Uplands (II) are considered as average ones. Therefore, if we should evaluate only the drainage efficiency criterion (the increase of land productivity in points due to land draining), the highest expediency of the renovation of drainage systems would be in the Middle Lithuanian Lowlands (III), and the lowest one – in the Baltic Uplands (IV).

The areas of uncultivated agricultural farming lands in the municipalities of Lithuanian districts are distributed unevenly as well. If a part of abandoned agricultural farming lands situated in Vilnius, Kaunas and Klaipėda municipalities can be attributed to the impact of large towns, so other districts reflect the real situation while developing efficient agriculture. Evaluating the dynamics of the uncultivated farming lands area from the expediency of drainage systems renovation viewpoint it is necessary to rebuilt drainage systems in the Middle Lithuanian Lowlands (III), because the number of unused agricultural farming lands is the smallest in this region. Other regions are average (I, II) or more than average (IV) from this point of view.

The smallest possibility of drainage breakdowns is in the drainage systems arranged in the Middle Lithuanian Lowlands (III). Expenses for drainage systems repair works are relatively the smallest there. The possibility of the drainage systems breakdowns is in the districts situated in the Žemaičiai Uplands (II), the average possibility is in the Pajūris Lowlands (I) and more than average is in the Baltic Uplands (IV). According to this evaluation the region of the Middle Lithuanian Lowlands is the most expedient for the drainage systems renovation and the region of the Žemaičiai Uplands (II) is less expedient for the drainage systems renovation.

After the evaluation of the dynamics of the increase of the land productivity in points (due to land draining), the abandoned agricultural farming lands, the drainage breakdown possibility and the plant-growing production for typical regions, it is possible to state that the highest expediency of the drainage systems renovation is in the habitat of the Middle Lithuanian Lowlands (III). The average – in the Pajūris Lowlands (I) and the Baltic Uplands (IV), whereas the lowest expediency is in the habitat of the Žemaičiai Uplands (II).

Table 1. Characteristics of typical regions when planning drainage systems renovation

Habitat	Typical regions	Relief	Soil cover variegation	Supply characteristics of rivers	Mechanical composition of soils
The Pajūris Lowlands	I	smooth	cover is even and very even	minimum of rain makes up 40–70% of the annual runoff	sandy and sandy loam
The Žemaičiai Uplands	II	large (>5°) slopes	very variegated and variegated	mixed rain and snow supply, about 44% of precipitation flows down into the rivers as the surface runoff	sandy loam and clay loam
The Middle Lithuanian Lowlands	III	slopes are small	cover is even and variegated	mixed rain (36–54%) and snow (35–50%) supply, ground supply is light	clay loam and clay
The Baltic Uplands	IV	large (>5 °) slopes	very variegated and variegated	predominate ground supply from snow and rain, water parts are almost equal	sandy and sandy loam

Table 2. Expediency and criteria of drainage systems renovation

Habitat	Typical regions	Increase of productivity in points due to land draining	Abandoned agricultural farming lands	Possibility of the drainage breakdown	Plant-growing production	Expediency of the drainage systems renovation
The Pajūris Lowlands	I	average or smaller	averagely	average	average and low	average
The Žemaičiai Uplands	II	smaller than average	averagely	large	low	the lowest
The Middle Lithuanian Lowlands	III	the largest	not much	small	high	the highest
The Baltic Uplands	IV	the smallest	more than averagely	average and large	low and average	average

4. Conclusions

The analysis of the technical state of drainage systems as well as the change of the possibilities of drainage breakdowns in the regions allows to predict that the number of various drainage systems breakdowns will only increase in future, therefore, drainage systems inefficiently used in agricultural production should be naturalized. 4 regions of typical conditions, significantly differing when planning the expediency of the drainage systems renovation, were singled out.

After the evaluation of the dynamics of the increase of the land productivity points (due to land draining), the abandoned agricultural farming lands, the drainage breakdown possibility and the plant-growing production for typical regions, it is possible to state that the highest or lowest expediency of the drainage systems renovation.

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