Original scientific paper
10.7251/AGRENG1901119R
UDC631.62(474.5)

EFFECTS OF CONTROLLED DRAINAGE ON SOIL WATER REGIME AND QUALITY IN LITHUANIA

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ABSTRACT

Lithuania remains one of the most extensively drained of the Baltic and Nordic countries. The overall drained area (ditches plus tile drains) totalled 87% of the agricultural land area. Many nutrients from soil are leached through drainage resulting in polluting streams (drain flow receivers) water. Drain flow is treated as a major determinant of water quality. Therefore, the reduction of nutrients entering the drains is very important. Controlled drainage conception, when the outflow height is increased at the mouth, helps reduce drainage runoff and partially purify water. The aim of the research was to establish controlled drainage influence on the soil moisture regime, nitrogen and phosphorus leaching. Investigations were carried out in sandy loam and loam soils in the Middle Lithuanian Lowland. Based on studies, several tendencies were observed: when drainage outflow began, the amount of soil moisture in subsoil (50-80 cm layer of the soil) of controlled drainage plot was higher than in the conventional drainage plot, and higher moisture supplies stayed for a longer period of time. Controlled drainage had no direct impact on phosphorus and nitrogen concentrations but they were influenced by the leaching quantities of plant usable nutrients. The reason that in many cases lower nitrate nitrogen (54% of all measurements) and phosphorus concentrations (77% of all measurements) were found in the conventional system rather than in the controlled drainage might be connected to the fact that the latter area contained predominantly lighter textured soils (sandy loam) making it easier to wash away the nutrients unused by plant.

Keywords: *drainage water, nitrogen, phosphorus, sandy loam, soil moisture.*

INTRODUCTION

The territory of Lithuania is defined as a zone of excess moisture, because precipitation amount is about 60% higher than the evapotranspiration. During some periods, the soil is too moist for growing agricultural crops. Drainage allowed to regulate rainfall effects on plant growth. A perennial drainage runoff study shows that in former years there was no drainage outflow in the winter or very rarely formed. Nowadays drainage often is functioning almost throughout the winter. An increase in drainage outflow during cold periods, when the soil is not covered with plants, it can makes easier to leaching nutrients. The concentrations of nitrate nitrogen in drainage water can vary from 3 to 20 mg/l and total phosphorus levels vary from 0.1 to 0.15 mg/l (Povilaitis *et al.*, 2015). Traditional drainage systems work one-sidedly, permanently removing moisture from the soil. In order to reduce this impact on drained areas, groundwater level should be regulated, thus reducing the leakage volume and speeding up chemical compounds transformation into the gaseous form, it should also be implemented during the growing season by adapting it for irrigation. The aim of the research was to establish controlled drainage influence on the soil moisture regime, nitrogen and phosphorus leaching in sandy loam and loam soils in the Middle Lithuanian Lowland.

MATERIAL AND METHODS

The study area was carried out in Lipliūnai village (55°19'N; 23°50'E), Kėdainiai district, in the catchment of Graisupis stream (area 16.6 km^2) which is situated in the Middle Lithuanian Lowland. The area (A=10.3 ha) was drained in 1960, tiles installed at a depth of 0.90-1.10 m with drain spacing of 20-24 m. The drain area reconstruction was carried out in 1999. Having installed a drainage manhole at the junction of two separate systems – 4.9 ha free conventional drainage (CD) and 5.4 ha controlled drainage (CWD) – were arranged. The groundwater table to rise to a maximum of 68 cm above the tiles. The area impacted by groundwater table management covered about 52% of the CWD treatment plot (Fig. 1) (Ramoška and Morkūnas, 2006; Ramoska *et al*., 2011). The research of drainage water regulation renewed in June 2014 is a continuation of study conducted during 2000-2007. The soil is non-acid Endocalcari-Endohypogleyic Cambisol (*CMg-n-w-can*) (IUSS…, 2015). In conventional drainage area, in 0-30 cm layer the soil was sandy loam and loamy sand, in 31-70 cm layer – sandy loam, in the controlled drainage area in the upper layer – loamy sand, and in subsoil – sandy loam and loamy sand.

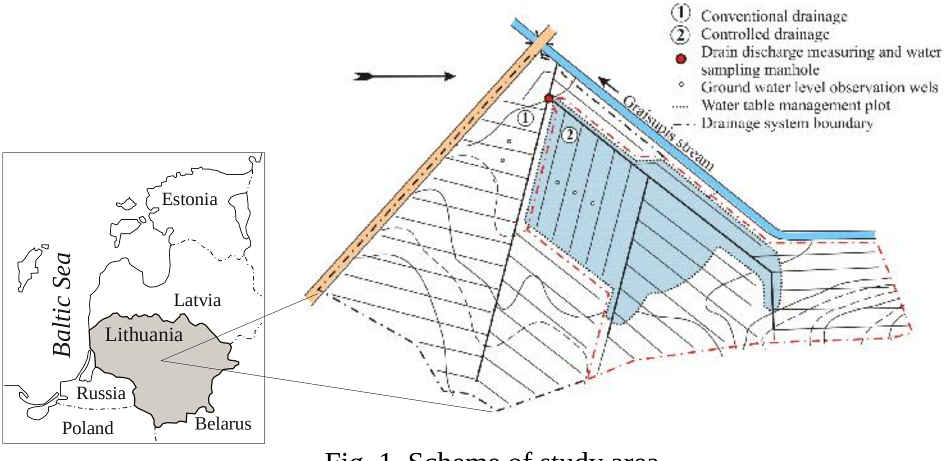

Fig. 1. Scheme of study area

Drainage water quality (NO_3-N (nitrate nitrogen) and TP (total phosphorus)) were determined by spectrometric method according to Lithuanian Standards (LAND 58:2003; LAND 65:2005). The water samples analysis was done at Chemical Analysis Laboratory of the Institute of Water Resource Engineering, Faculty of Water and Land Management of Aleksandras Stulginskis University.

The samples of soil moisture were taken at every 10 cm to 80 cm depth. Soil moisture was determined in all samples by drying at 105^{o}C and reweighing to constant weight. Meteorological condition (precipitation and average air temperature) was described using the data of the nearest Dotnuva Meteorological Station (Kėdainiai district), which is 8 km away from the study area. The mean annual precipitation is 566 mm (using 1981-2010 data) and the annual mean air temperature is 7.0 ˚C. Student's test was used to determine the reliability of differences between the studied data (Čekanavičius and Murauskas, 2001).

RESULTS AND DISCUSSION

The annual precipitation was 560 mm for 2014, 485 mm for 2015 and 721 mm for 2016, thus was approximate to the mean annual precipitation, 14% below the mean annual precipitation, and 27% above the mean annual precipitation, respectively.

During the research period the highest monthly precipitation variations from the perennial average was observed in February 2016 (262% perennial average), in January 2015 (191%), in August 2015 (9%), in October 2015 (14%), in February 2015 (15%), and in September 2016 (19%) (Fig. 2).

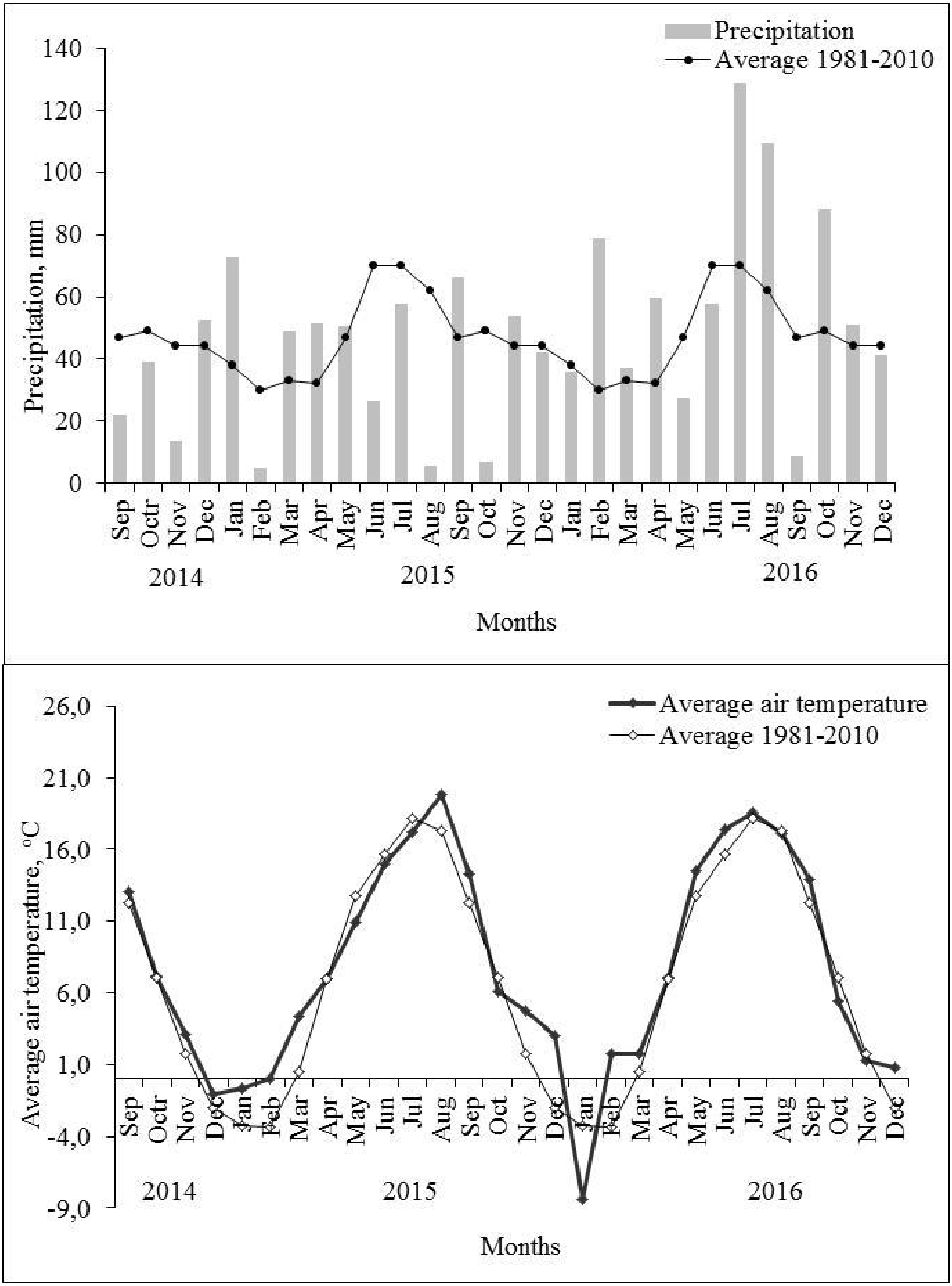

Fig. 2. Monthly precipitation (mm) and monthly air temperature (˚C)

Average annual air temperature 14% (2014), 22% (2015), and 9% (2016) was higher than the perennial average. Average monthly air temperature was 5 ^{o}C higher than the perennial average in December 2015 and February 2016, 3.9 ^{o}C higher in March 2015, 3.3 ^{o}C higher in February 2016, but 5 ^{o}C lower in January 2016.

During the study period, the average soil moisture of 0-80 cm layer was higher in conventional drainage area (12.2-25.6%) than in controlled drainage area (10.4-25.0%), but this difference was insignificant (Fig. 3). The moisture of the soil depended on meteorological conditions and soil texture. Studies (Morkūnas and Ramoška, 2001) shown, that the affluent drainage has impact on soil moisture. It is estimated linear correlation between soil moisture and groundwater table above the collector. In most cases this correlation (correlation coefficient r = 0.41-0.77) varied from weak to strong every 10 cm in 20-70 cm soil layer

In the study area, the moisture in 50-80 cm layer (55 of all measurements) was greater in controlled drainage area. In this drainage area, the moisture supplies obtained in subsoil for a longer period compared to conventional one. Ramoška (2001) states that the controlling of drainage outflow has increased the soil moisture supply in the subsoil and it did not has a greater impact on their changes in the upper soil layers.

In both study plots the highest variation of moisture was in 0-30 cm layer (in the conventional drainage plot standard deviation (SD) was 5.3-6.0, in the controlled drainage plot – 5.2-5.8). Black (1973) maintains that the moisture is more rapidly changing in the upper soil layer compared to the deeper layers. In sandy soil fluctuation of moisture at the top layer depended on meteorological conditions, at the lower layer equalled to the highest capillary moisture (Ivanauskienė, 1976).

The nitrate nitrogen concentration (54% of all measurements) and the total phosphorus concentration (77% of all measurements) were greater in the controlled drainage water (Fig. 4). However, significant differences (Student's test t_{act} = 2.28, p = 0.027) only in TP concentration between the studied drainage systems were confirmed. The TP concentration had the largest difference between the two systems in August 2014. In this month, the precipitation was 111 mm (66% higher than the CN), therefore more soil particles could enter in the water level control device.In the CWD system area prevailing lighter textured soils (sandy loam) which the nutrients can be easier leaching. This could be reason why in many cases lower NO_3-N and TP concentrations were found in the CD system. The literature (Wesström and Messing, 2007; Ramoska et al., 2011; Povilaitis et al. 2018) states that the controlled drainage reduced nutrients load while reducing drainage outflow. Controlled drainage outflow was 21-24% lower than the normally functioning drainage.

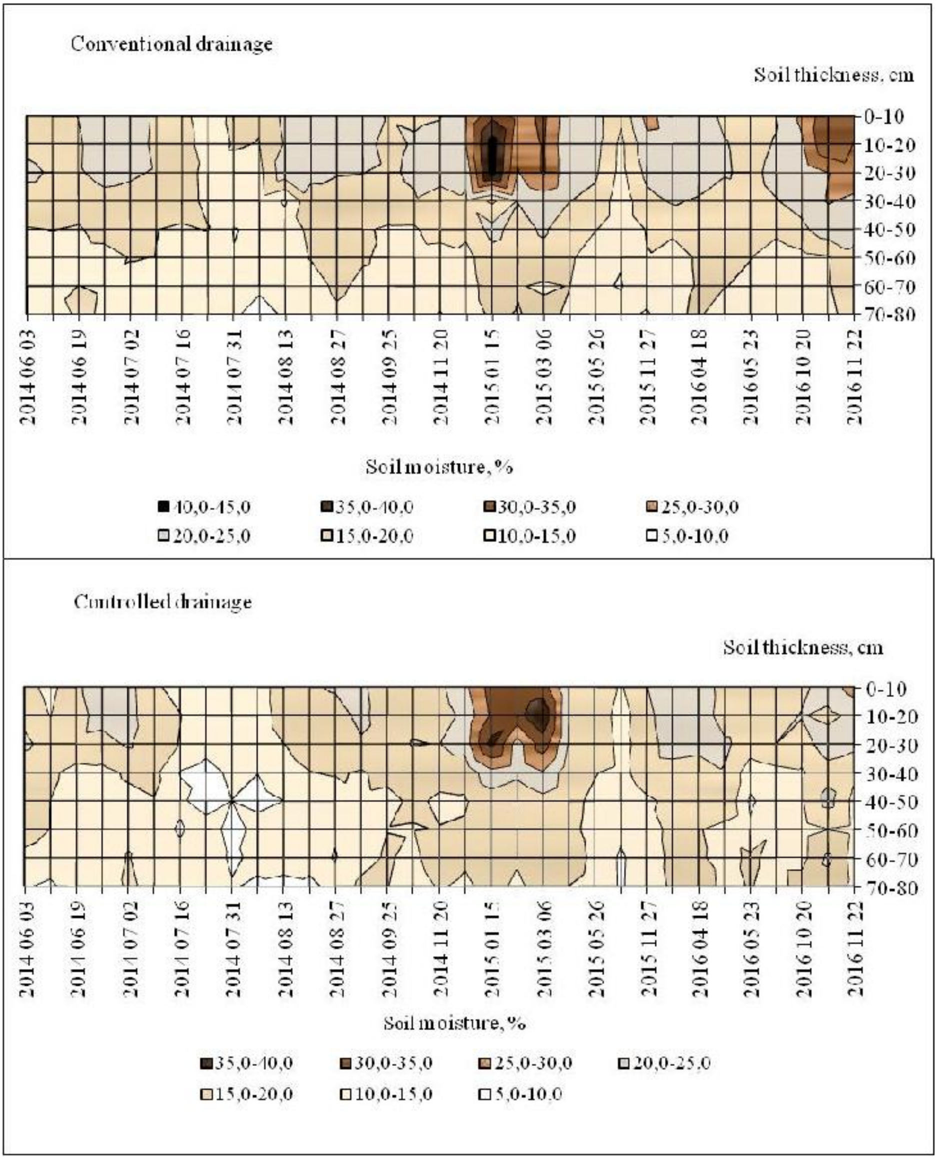

Fig. 3. Dynamics of soil moisture in the conventional drainage and controlled drainage area

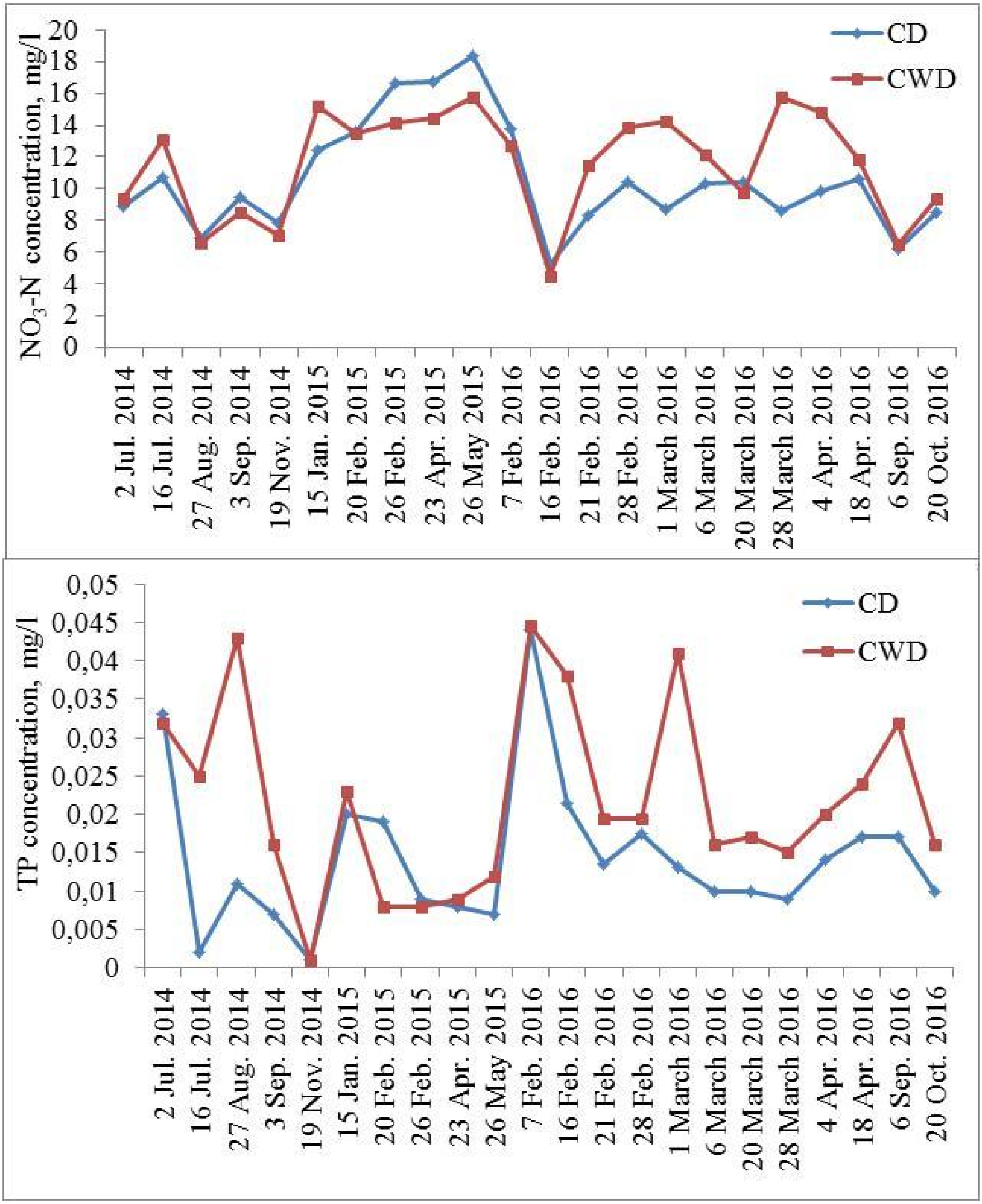

Fig. 4. Nitrate nitrogen (NO_3-N) and total phosphorus (TP) concentration in conventional (CD) and controlled drainage (CWD) water

In both study area, the NO_3-N concentrations was lower in period when average air temperature was about 10°C and precipitation amount was close to the CN (Table 1).

Table 1. Precipitation, average air temperature, NO_3-N and TP concentrations in drainage water estimated in seasons

		2014 Jun-Dec	2015 Jan-May	2016 Jan-May	2016 Sep - Oct
Precipitation	mm	372	228	238	97
	% CN	96	127	132	101
Average air temperature	°C	10.6	4.3	3.3	9.7
	% CN	106	158	122	100
	Conventional drainage				
NO_3- N, mg/l	AVG	8.7	15.4	10.5	7.3
	SD	2.6	2.4	3.5	1.6
TP, mg/l	AVG	0.028	0.013	0.019	0.014
	SD	0.06	0.006	0.011	0.005
	Controlled drainage				
NO_3- N	AVG	9.6	14.8	13.4	7.9
	SD	4.8	0.9	5.2	2.03
TP	AVG	0.03	0.013	0.026	0.024
	SD	0.02	0.006	0.011	0.011

CN – climate normal; AVG – average; SD –standard deviation.

The efficiency of pollutant retention depended on the climatic conditions. In dry years, the difference between controlled and conventional drainage was higher and it was lower in moderate years (Ramoska et al., 2011). Woli *et al.* (2010) reported that soil denitrification was rarely observed during the early period of spring, because of the minimal activities of denitrifying bacteria owing to the cold temperature. Denitrification rate may reflect the amount of nitrate in the water.

CONCLUSIONS

Investigations were carried out in sandy loam and loam soils in the Middle Lithuanian Lowland showed several tendencies: higher moisture supplies stayed for a longer period in the deeper layers of controlled drainage area; controlled drainage had no direct impact on nitrate nitrogen and total phosphorus concentrations.

When the drainage mouth was affluent (retained leakage), at the time chemical compounds with the runoff did not drain into the water receiver, and this had a positive impact on the environment.

REFERENCES

Black, K. A. (1973). Soil-plant. Kolos, Moskva, Russia

Čekanavičius V., Murauskas G. (2001). Statiska ir jos taikymai. TEV, Vilnus, Lithuania.

IUSS Working Group WRB. (2015). World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Ivanauskienė, K. (1976). Drainage in sand soil. Lietuvos hidrotechnikos ir melioracijos mokslinio tyrimo instituto darbai, Vol. 10, pp. 53–62.

LAND 58:2003. Vandens kokybė. Fosforo nustatymas. https://www.e-tar.lt/portal/lt/legalAct/TAR.1E2EC01703E3/PpTblTelOr Accessed on 2/08/2018

LAND 65:2005. Vandens kokybė. Nitratų kiekio nustatymas. https://www.e-tar.lt/portal/lt/legalAct/TAR.54C30958336D Accessed on 24/08/2018

Morkūnas V., Ramoška E. (2001). Investigation on drainage runoff regulation. Vandens ūkio inžinerija, Vol. 16, pp. 53-60.

Povilaitis A., Rudzianskaitė A., Misevičienė S., Gasiūnas V., Miseckaitė O., Živatkauskienė I. (2018). Efficiency of drainage practices for improving water quality in Lithuania. Transaction of the ASABE, Vol. 61(1), pp.179-196.

Povilaitis A., Lamsodis R., Bastienė N., Rudzianskaitė A., Misevičienė S. Miseckaitė O., Gužys S., Baigys G., Grybauskienė V., Balevičius G. 2015. Agricultural drainage in Lithuania: a Review of practices and environmental effects. Acta Agriculturae Scandinavica, Section B –Soil and plant Science, Vol. 65, Suppl. 1, pp.14-29.

Ramoška E. (2001). Drenažo tvenkimo poveikis dirvožemio drėgmės režimui. Abstract of the Scientific Conference Development of Rural Water Management Based on EU Example, October 18, 2001, Lithuanian University of Agriculture, Water and Land Management Faculty.

Ramoska, E., Bastiene, N., Saulys, V. (2011). Evaluation of Controlled Drainage Efficiency in Lithuania. Irrigation and Drainage, Vol. 60, pp.196-206.

Ramoška, E, Morkūnas, V. (2006). Drenažo nuotėkio reguliavimo įtaka dirvožemio vandens režimui. Vandens ūkio inžinerija, Vol. 30 (50), pp. 5-14.

Woli K. P., David M. B. Cooke R. A., Mclsaac, G. F., Mitchell C. A. (2010). Nitrogen balance in and export from agricultural fields associated with controlled drainage systems and denitrififying bioreactors. Ecological Engineering, Vol. 36, pp.1558-1566.

Wesström I., Messing I. (2007). Effects of controlled drainage on N and P losses and N dynamics in a loamy sand with spring crops. Agricultural Water Management, Vol. 87, pp. 229-240.