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LLI-49 Project

Optimal catch crop solutions to reduce pollution in the transboundary Venta and Lielupe river basins

Project acronym: CATCH POLLUTION

Joint concept document regarding application of catch-crop solutions to reduce agricultural pollution in the transboundary Venta and Lielupe river basins

aplinkos apsaugos politikos centras
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Abbreviations

AAPC	Centre for Environmental Policy
AREI	Institute of Agricultural Resources and Economics
AU	Animal unit
CAP	Common Agricultural Policy
CC	Catch crops
EC	European Commission
EFA	Ecologic focus area
GHG	Greenhouse gas
N	Nitrogen
P	Phosphorus
RBD	River basin district
RBMP	River Basin Management Plan
RDP	Rural Development Programme
RSS	Rural Support Service
WFD	Water Framework Directive

Introduction

Achievement of good ecological status of all water resources is one the key environmental objectives in all over EU today. Water Framework Directive (WFD) which is the main piece of water legislation anticipates that good ecological status of all water bodies has to be reached at the latest by 2027.

Since 2000, when the WFD came into force, there have been significant developments in water management sector, however agricultural pollution still remains one of the most significant sources of water pollution preventing from achievement of environmental goals. The European Court of Auditors in its special report *"Combating eutrophication of the Baltic Sea: further and more effective action needed" (2016)* states that the measures implemented so far are not sufficient to promote the recovery of good ecological status of the Baltic Sea; agriculture remains a major contributor of water pollution, and farmers have to adopt more sustainable practices.

Situation in Venta and Lielupe which are transboundary River Basin Districts (RBDs) shared by Lithuania and Latvia is not an exemption - agriculture is one of the major sources of nutrient pollution here, requiring an immediate action. Due to a very significant impact of agriculture, ecological status of rivers in the Lielupe river basin has been assessed as being the worst compared to the other river basins in Latvia and Lithuania. In the Lithuanian part of the Lielupe RBD, 70 percent of river water bodies fail to achieve good ecological status due to the impact of agricultural pollution. In Latvia, 56 % of all river water bodies and 46 % of lake water bodies in the Lielupe RBD do not meet requirements for good ecological status when classified according the concentrations of total nitrogen.

The complexity of the problem lies in the fact that this pollution from Lithuania is transported across the border to Latvia, adds to the local pollution, makes a significant impact on the river water quality and results in excessive loads into the Baltic Sea.

The increasing demand for environmental initiatives in agriculture, prompts agricultural and environmental experts to search for the best measures ensuring sustainable activities and protection of natural resources. In this context, the interest in application of catch crops as a promising option benefiting to both farmer and environment is growing in recent years. Sown in between main crops catch crops prevent losses of nutrients into water bodies by conserving them in a biomass and transferring to the subsequent crops. Catch crops also provide a range of other benefits such as reduction of erosion losses, control of pests and diseases, improvement of soil structure. However, due to missing effective support schemes, lacking information about catch crop benefits and insufficient competences of farmers catch cropping potential is still poorly utilised both in Latvia and Lithuania.

Project ***"Optimal catch crop solutions to reduce pollution in the transboundary Venta and Lielupe river basins" (LLI-49 CATCH POLLUTION)*** was initiated with the aim to investigate catch crop potentials to reduce agricultural pollution in the transboundary Venta and Lielupe RBDs, extend the existing knowledge about catch crops and quantify their potential environmental effects and benefits, support farmers in decision making, and initiate a dialog between farmers, experts and stakeholders about future developments of agri-environmental measures in Latvia and Lithuania. To facilitate a wider application of catch crops, project experts prepared recommendations for catch crop support and guidance on the required implementation actions. The decision support tool was elaborated to help farmers in finding catch crop options best suiting to the needs of their farm.

The project was supported by ***Interreg V-A Latvia-Lithuania Cross Border cooperation programme 2014-2020*** and conducted in close cooperation between environmental experts from ***the Centre of Environmental Policy (AAPC)*** (Lithuania) and agricultural experts from ***the Institute of Agricultural Resources and Economics (AREI)*** (Latvia) and ***Vytautas Magnus University Agriculture Academy (VDU ŽŪA)*** (Lithuania).

This concept document provides an overview on environmental situation and agricultural practices in Venta and Lielupe RBDs and proposes actions for implementation of the catch crop sub-measure under the RDP.

Though the document is elaborated to facilitate the necessary actions for reduction of pollution in the transboundary Venta and Lielupe RBDs, it also can be extended to other areas suffering from agricultural pollution in Lithuania and Latvia.

Detailed reports of the project and the Decision Support Tool can be found on the web-pages of the project partners: www.aapc.lt, www.arei.lv.

Environmental situation and pollution reduction objectives in Venta and Lielupe RBDs

Venta and Lielupe are transboundary river basin districts (RBDs) shared by Lithuania and Latvia (see *Figure 1*).

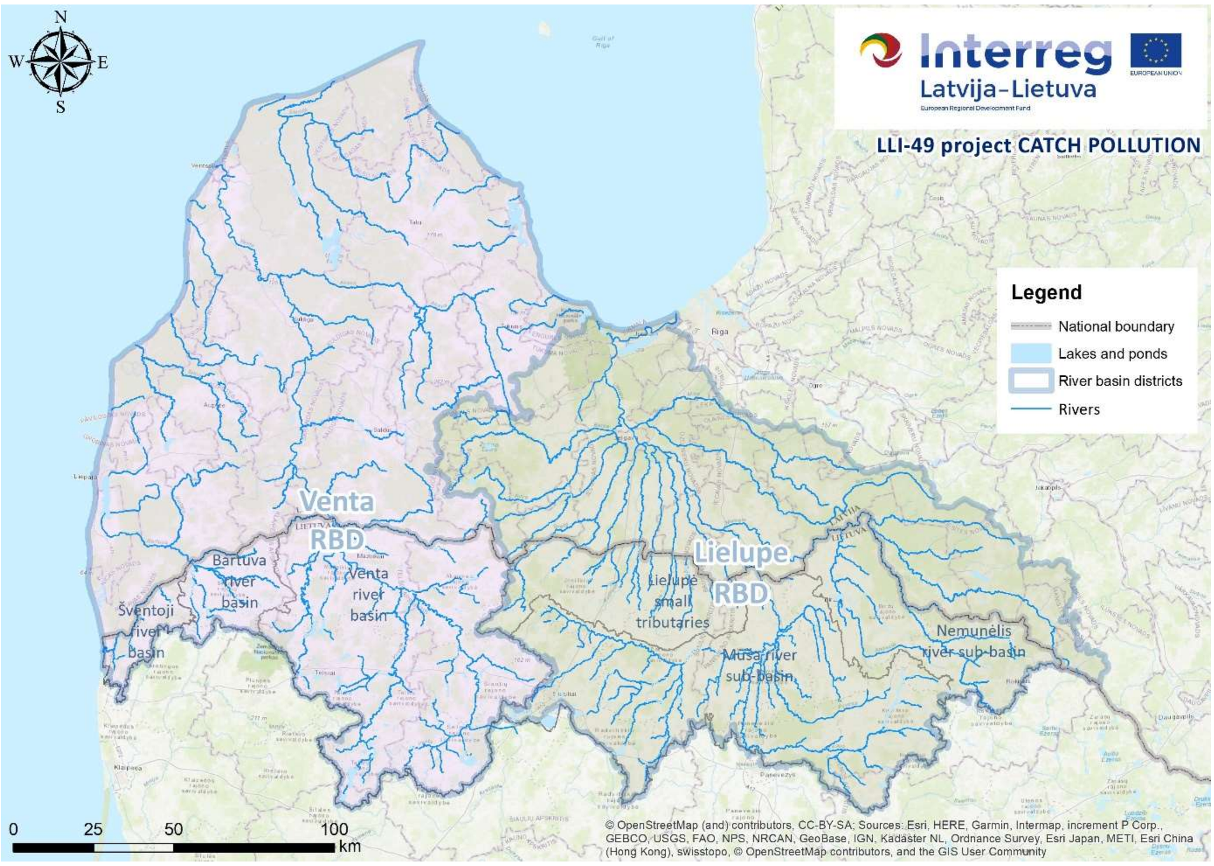


Figure 1. Venta and Lielupė River Basin Districts

The Venta river rises in Lithuania, enters Latvia in the southwest and flows north through the Kurzeme lowland to the Baltic Sea. Total area of the Venta RBD is 21 937 km^2 of which 6276 km^2 (29%) is in the territory of Lithuania and 15 630 km^2 (61%) in the territory of Latvia. In Lithuania, three river basins are distinguished in the Venta RBD: Venta river basin with the area of 5 137 km^2, Bartuva river basin with the area of 749 km^2, and Šventoji river basin with the area of 390 km^2. In Latvia, Venta RBD includes three basins: Venta river basin with the area of 6 730 km^2, coastal west basin with the total area of 5 100 km² which includes small river basins such as the Barta, Dubra, Riva and Uzava which flow to the Baltic Sea at the west coast, and coastal north basin with the area of 3 800 km² which includes small river basins within the coastal lowland on the opposite shores of the Gulf of Riga such as the Irbe, Stende, Roja etc.

The Lielupe river rises in Lithuania, enters Latvia in the south and flows north to the Gulf of Riga. Total area of the Lielupe RBD is 17 760 km^2 of which 8947 km^2 (i.e. 50%) is in the territory of Lithuania and 8843 km^2 (50%) in the territory of Latvia. It has many tributaries, the most important being the Memele, Musa, Iecava and Svete. On the Lithuanian side, Lielupė RBD consists of three sub-basins: Mūša river sub-basin with the area of 5 296 km^2, Nemunėlis river sub-basin with the area of 1 900 km^2, and sub-basin of the Lielupė small tributaries with the area of 1 751 km^2.

Agriculture is the major source of nutrient (especially nitrogen) pollution in Venta and Lielupe river basins. Due to a very significant impact of agriculture, ecological status of rivers in the Lielupe river basin has been assessed as the worst compared to the other river basins in Latvia and Lithuania.

Agricultural pollution is mainly characterised by the concentrations of nitrates nitrogen, total nitrogen and total phosphorus. In Lithuania, threshold values for good ecological status are the following:

- average annual concentration of nitrate nitrogen ≤ 2.3 mg/l
- average annual concentration of total nitrogen ≤ 3 mg/l
- average annual concentration of total phosphorus ≤ 0.14 mg/l.

Latvian system for the classification of status of river and lake water bodies does not include physico-chemical quality element NO_3-N. In the frame of development of 2nd river basin management plans for Lielupe and Venta RBD, in order to ensure coordinated setting of environmental objectives, it was agreed to use Lithuanian classification system for the slow-running river types in Lielupe and Venta RBDs.

In Lithuania, the largest impact of the agricultural activities is observed in the rivers of the Lielupė small tributaries sub-basin. The impact of agriculture results in elevated concentrations of nitrogen compounds. Total nitrogen concentrations, monitored in the rivers of the sub-basin of the Lielupe small tributaries during the period of 2010-2016, vary from 5.6 mg/l to 14 mg/l. There are no rivers in this sub-basin where concentrations of the total nitrogen would meet the requirements for good ecological status. In most of rivers threshold for good status is exceeded more than 3 times. The lowest concentration of total N (5,6 mg/l) has been measured in the Švitinys and the Švėtė rivers, while in the Beržtalis, Ašvinė and Audruvė concentrations of total N exceed 12 mg/l (bad status).

Situation in the Mūša sub-basin is a little better. In 20 % of the monitored water bodies, concentrations of total N meet requirements for good ecological status but most of rivers are of average and poor status. Mostly polluted rivers (of bad status) are Voverkis, Šiladis, Ramytė and Ežerėlė.

Unlike in the sub-basins of the Lielupė small tributaries and the Mūša river, agricultural pollution problems are not characteristic to the sub-basin of the Nemunėlis river. Here concentrations of total N vary within the threshold range for good and very good ecological status. Only two water bodies of the Agluona river are classified as water bodies at risk due to agricultural pollution (concentration of total N is not very high – 3,45 mg/l).

In the Lithuanian part of the Venta river basin, agricultural pollution problems are not dominant, however in the water bodies of Ringuva, Dabikinė, Šventupis and Ašva rivers concentrations of nitrogen are still above the allowed limit. The highest concentrations are measured in the Ringuva river - 6 mg/l (i.e. 2 times higher than allowed). The threshold for good status in the Ašva is exceeded not significantly - measured concentration of total N is 3.3 mg/l.

Agricultural activities do not have a significant impact on the rivers of the Bartuva and Šventoji sub-basins. Concentrations of the total nitrogen in all monitored rivers here meet requirements for very good ecological status.

Pressures and impacts analysis, conducted during the preparation of RBMPs, has shown that agriculture has a minor impact on the concentrations of total phosphorus in Lithuanian parts of Venta and Lielupe RBDs.

Distribution of the average annual concentrations of total N and total P, monitored during 2010-2016 in the rivers of Venta and Lielupe RBDs in Lithuania, is presented in *Figure 2*. and *Figure 3*.

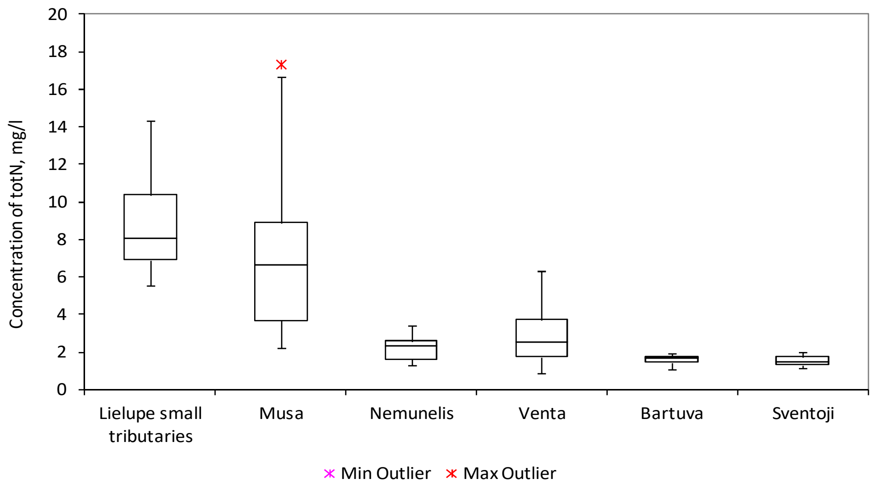


Figure 2. Distribution of concentrations of total N in the rivers of Venta and Lielupe RBD in Lithuania (based on monitoring data from 2014 – 2016)

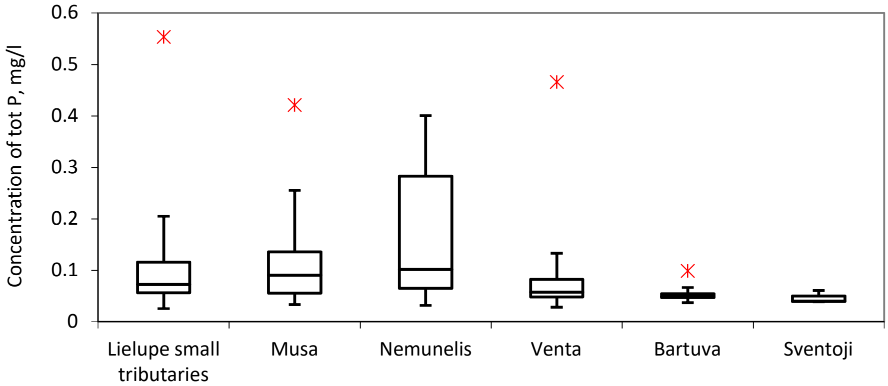


Figure 3. Distribution of concentrations of total P in the rivers of Venta and Lielupe RBD in Lithuania (based on monitoring data from 2014 – 2016)

In Latvia, 56 % of all river water bodies and 46 % of lake water bodies in the Lielupe RBD do not meet requirements for good ecological status when classified according the concentrations of total nitrogen. In the Venta RBD, percentage of water bodies not meeting requirements for good status is considerably lower - only 10% for river and 20% for lake water bodies.

In the rivers of the Lielupe RBD in Latvia, total N concentrations vary in the range from 1.0 to 10.5 mg/l. Highest concentrations are observed in water bodies L153 Īslīce and L149 Svitene. In the Venta RBD rivers, total N values vary from 0.73 to 2.96 mg/l, with highest values measured in water bodies V062 Vadakste and V082 Roja.

In Lielupe RBD rivers, total P concentrations vary from 0.028 to 0.123 mg/l, with the highest values in water bodies L147 Vircava and L117SP Auce. In Venta RBD rivers, total P values are 0.031 – 0.126 mg/l, with 6 maximum outlier values in V014 Tebra and V043 Venta (both belong to slow-running rivers), V004 Ālande (slow-running type); V049 Venta (slow-running type); V082 Roja (assumption); V058 Lētīža (fast-flowing type).

While higher total P concentrations in Venta RBD are mostly observed in slow-running river types, *classification results* by total P are worse for fast-flowing river WBs, for which more stringent criteria apply.

Distribution of concentrations of total N and total P in the rivers of Venta and Lielupe RBDs in Latvia is presented in *Figure 5* and *Figure 6*.

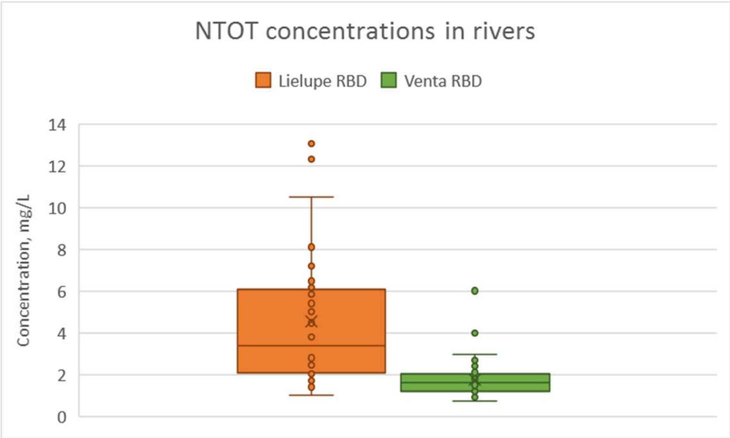


Figure 4. Concentrations of total N in the rivers of Venta and Lielupe RBDs in Latvia (based on monitoring data for the period 2006-2016)

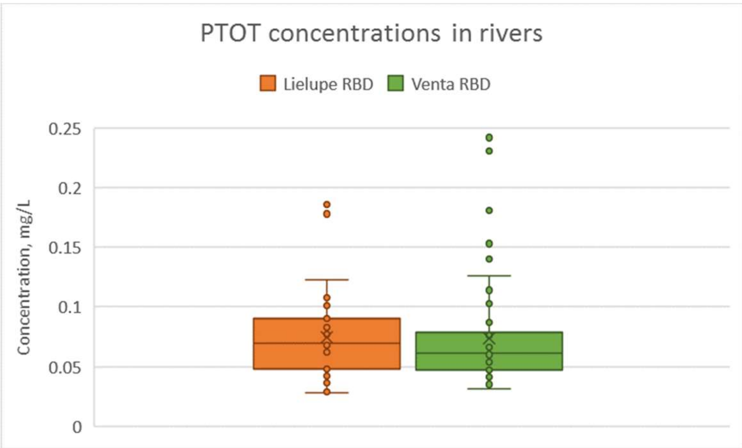


Figure 5. Concentrations of total P in the rivers of Venta and Lielupe RBDs in Latvia (based on monitoring data for the period 2006-2016)

The analysis of impacts shows that nitrogen concentrations in water is the main indicator of agricultural pollution – elevated concentrations above thresholds signal about significant impacts from agricultural activities.

Results of the river ecological status classification according to concentrations of total nitrogen are presented in *Figure 6*. Distribution of water bodies in different classes of ecological status is presented in *Figure 7* and *Figure 8*.

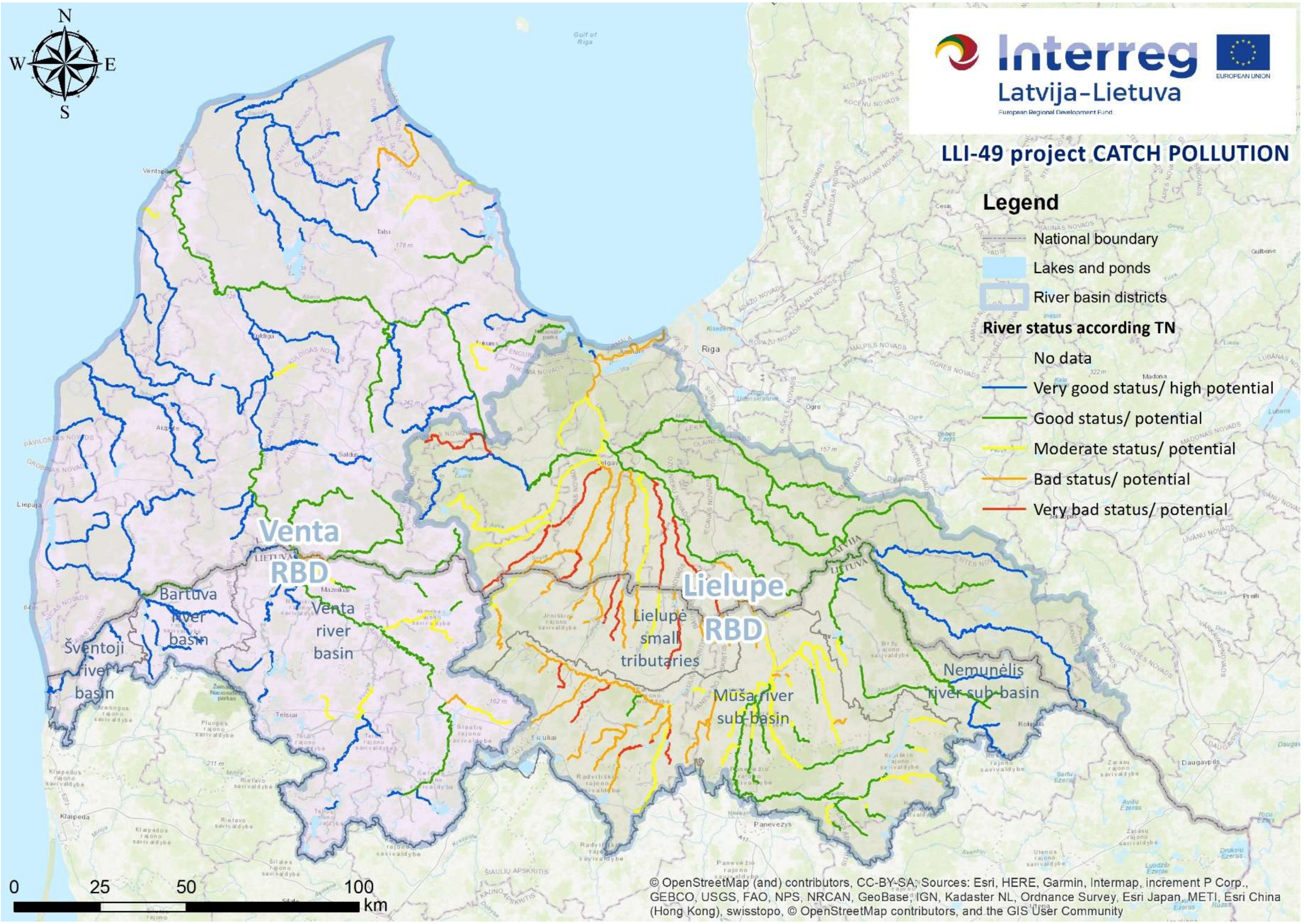


Figure 6. Classification of river ecological status according to concentrations of total nitrogen (based on monitoring data from 2014 – 2016 for Lithuanian rivers and data from 2006 – 2016 for Latvian rivers)

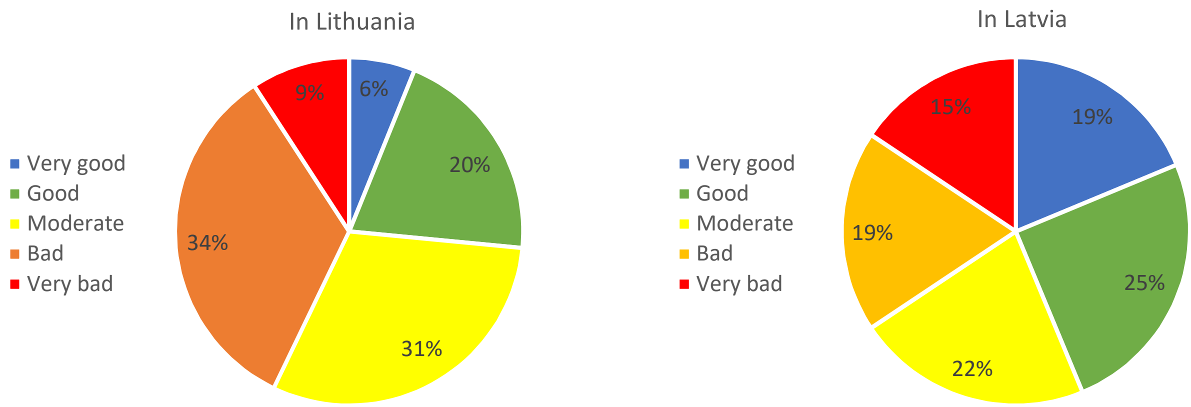


Figure 7. Classification of river ecological status according to concentrations of total nitrogen in the Lielupe RBD

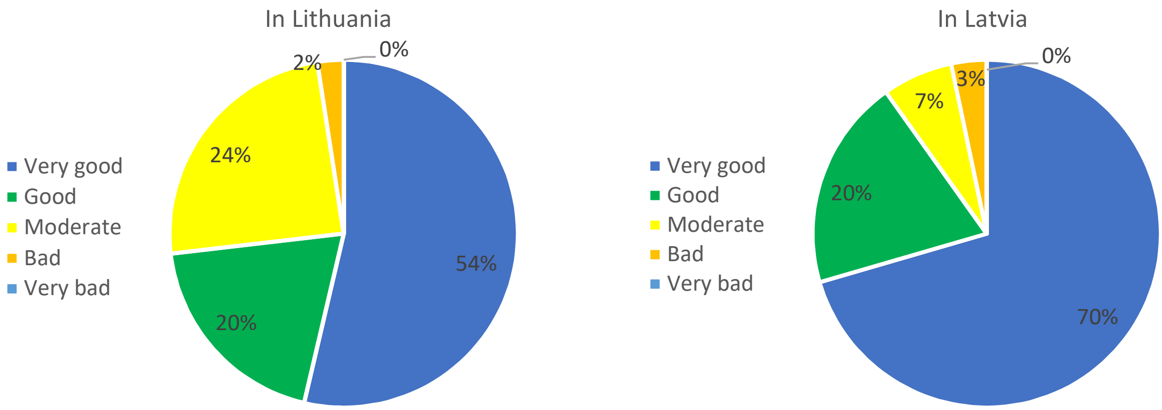


Figure 8. Classification of river ecological status according to concentrations of total nitrogen in the Venta RBD

In order to select the most effective pollution reduction measures leading to the achievement of the environmental objectives, pollution reduction objectives were estimated for each water body at risk.

For Lithuanian parts of Venta and Lielupe RBDs pollution reduction objectives have been estimated based on the water quality monitoring data from 2014 – 2016, for Latvian parts – based on the results of the Swedish Mass Balance model for three years - 2006, 2013 and 2015.

Estimated pollution reduction objectives for total nitrogen are presented in *Figure 9*.

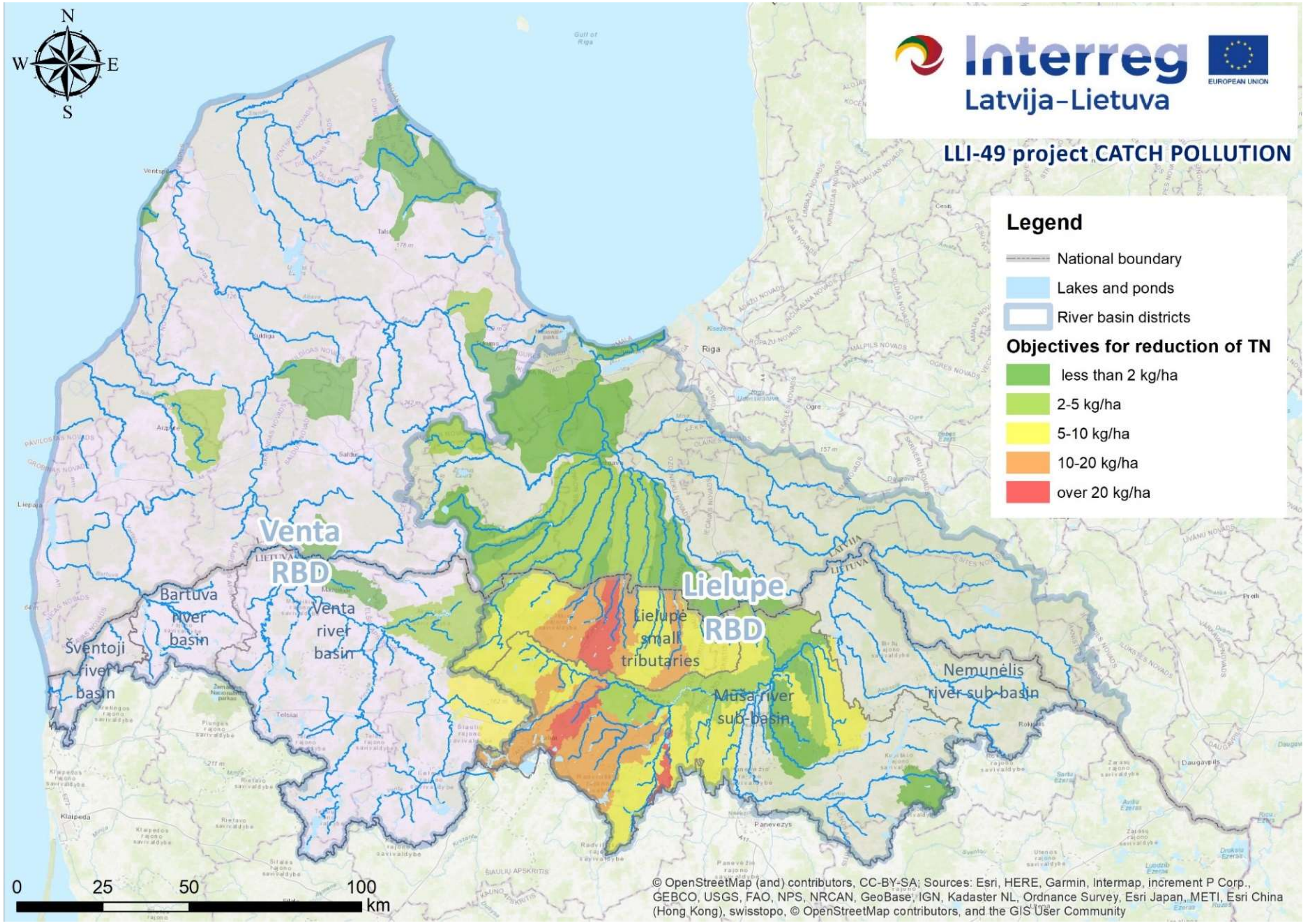


Figure 9. Objectives for reduction of nitrogen loads in Venta and Lielupe RBDs

Assessment reveals that current pollution reduction objectives for the Lithuanian part of the Lielupe RBD are even stricter than those estimated in the 2nd River Basin Management Plan. This can be explained by the fact that pollution loads during the period of 2014 – 2016 have increased in many rivers.

Total catchment area of water bodies at risk where pollution reduction objectives for total N are established is 90 thou ha in the Venta river basin (17% of the basin area), 383 thou ha in the Mūša sub-basin (72% of the sub-basin area) and 175 thou ha (all territory) in the sub-basin of the Lielupė small tributaries. In order to achieve good status, ***leaching of the total N*** from the catchments of water bodies at risk ***in the Venta RBD has to be reduced by approx. 400 t/year;*** leaching from the catchments of water bodies at risk ***in the Lielupė RBD*** has to be reduced ***by 4800 t/year (1800 t/year reduction is needed in the sub-basin of the Lielupė small tributaries and 3000 t/year in the sub-basin of Mūša).***

For ***the Latvian part of the Lielupe RBD*** pollution reduction objectives with respect to nitrogen are considerably lower than for Lithuanian. This is mainly because of larger pollution accumulation potential because rivers in Latvia are larger and, if there were no significant pollution from Lithuania, they could assimilate larger loads of agricultural pollution. Pollution reduction goals for the Latvian part of the Lielupe RBD were established for sub-catchments of 18 river water bodies at ***600 t/year in total***. In the ***Venta RBD***, pollution reduction for 8 sub-catchments is needed, ***120 t/year in total***.

Agricultural activities in Venta and Lielupe RBDs

Intensity and structure of agricultural activities largely influence environmental situation in Venta and Lielupe RBDs. Intensive agricultural activities result in high nutrient losses from the fields and hence the basins dominated by intensive agriculture often suffer from nutrient pollution and fail to achieve their environmental objectives.

There are a number of factors such as climate, geomorphology, product costs and demand on the market, etc. that make an impact on agricultural practices in Venta and Lielupe RBDs.

Soil fertility

Venta and Lielupe RBDs are rather different in their geomorphological properties what consequently determine different patterns of soil productivity in both RBDs.

Most fertile soils are found in the Lielupe RBD though soil productivity in different parts of the basin varies in a quite wide range. The highest soil fertility score is characteristic to the sub-basin of the Lielupė small tributaries in Lithuania where it reaches 49 on average and even up to 55 – 57 in some counties (it has to be noted, that soils with the score exceeding 42.1 are considered fertile and highly fertile). The average soil fertility score in the Mūša sub-basin is about 45 and in the Nemunėlis river sub-basin - only about 38. Soil fertility score in the Latvian part of the Lielupe RBD varies from 27 to 67 with an average of 41. Most fertile soils are found on the southwestern part of the Latvian part of the Lielupe RBD.

Soils in the Venta RBD are less productive than in the Lielupe RBD. In Lithuania, average soil fertility score in the Venta basin is 38, in the Bartuva and Šventoji – 37. In the Latvian part of the Venta RBD soil fertility varies from 16 to 49 with an average of 34 (*Figure 10*).

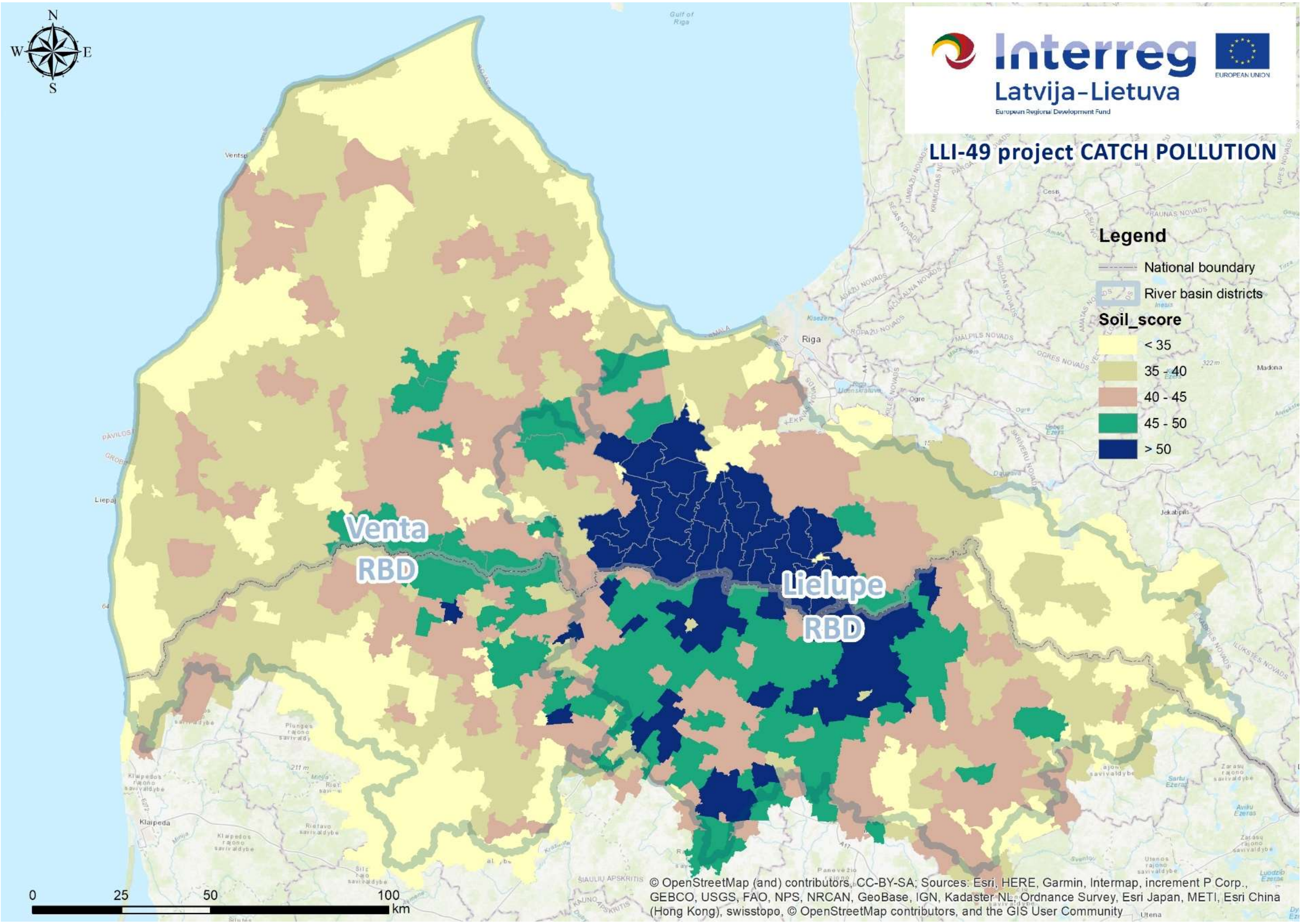


Figure 10. Soil fertility score in Venta and Lielupe RBDs (adopted from www.geoportalas.lt and www.geolatvija.lv data bases)

Agricultural land and its structure

Soil fertility is one of the key factors determining intensity and structure of agricultural activities. Territories dominated with high-fertility soils are intensively used for agriculture. On both Lithuanian and Latvian sides, most fertile soils are located in the Lielupe RBD (in particular, in the sub-basin of the Lielupe small tributaries in Lithuania and southwestern part of the Lielupe RBD in Latvia). These territories are intensively used for agriculture. Utilised agricultural land makes around 60 % of the total land area in the Lithuanian part of the Lielupe RBD and around 40 % in the Latvian part. In the Venta RBD, agricultural activities are much less developed. Here, on the Lithuanian side, agricultural land makes about 50 % of the RBD area while on the Latvian side - only 25 %. The share of agricultural land in the counties of Venta and Lielupe RBDs is illustrated in *Figure 11*.

Arable land dominates in the structure of agricultural land in both RBDs. The largest share of arable land is in the territories with fertile soils. In the Lielupe RBD, on both sides of the border, in the territories dominated by very productive soils, arable land makes over 80% of all utilized agricultural land. In counties with less fertile soils, intensity of agriculture and percentage of arable land is lower. E.g. in the eastern part of the Lielupė RBD in Latvia arable land makes only less than 60% of the total agricultural land area. In the Venta RBD, soil fertility is lower than in the Lielupe RBD and, consequently, intensity of agriculture and share of arable land is lower there as well. In the Lithuanian part of the Venta RBD, arable land, on average, makes 64% of the total agricultural land area, and on the Latvian part – 67%. For more detailed information on the percentage of arable land in counties of Venta and Lielupe RBDs see *Figure 12*.

Territories with most productive soils are used for crop production. Meadows and pastures are mainly distributed in non-productive soils or even in dense relief areas where annual crop production cannot be expanded. Hence, larger areas of meadows and pastures are naturally characteristic to the Venta RBD.

Crop production

Crop structure analysis reveals that annual winter crops dominate in both RBDs in both Lithuania and Latvia. In the Lithuanian part of the Lielupe RBD winter crops take near 60 % of the total arable land area; the share of winter crops in the Venta RBD is about 50 %. In Latvia, winter crops take up to 69% of the arable land in the Lielupe RBD, and 60% in the Venta RBD.

Of winter crops, winter wheat covers the largest areas in all river basins; winter rape is a second important winter crop. Winter wheat and winter rape are cash crops ensuring good and constant income for farmers. For growing these crops intensive cropping technologies are usually used.

Summer crops dominate in the areas with less productive soils. Summer wheat and summer barley are the most popular summer crops. Except for the summer wheat and summer rape, growing technologies of summer crops are less intensive because abundant use of fertilizers and pesticides does not pay off in less productive soils.

Introduced greening requirements resulted in increased areas of legumes. Legumes positively contribute to the achievement of environmental goals, reduce the demand for the application of mineral fertilizers. In the current crop structure, the share of legumes in the Lithuanian part of Venta and Lielupe RBDs makes 15 and 16 % respectively; in Latvia, accordingly, 4 and 6%.

Crop structure in Venta and Lielupe RBDs is presented in *Figure 13*.

In the farms of intensive crop production crop rotation usually consists of 3 fields: one field of leguminous crop/ rape / or other crops, and two fields of winter wheat and other cereals. At the end of the rotation, leguminous crops are replaced by rape and vice versa. When the share of leguminous crops and rape is larger, rotation is composed of 4 fields: rape is cultivated as a second or third crop in a sequence after cereals (usually winter wheat).

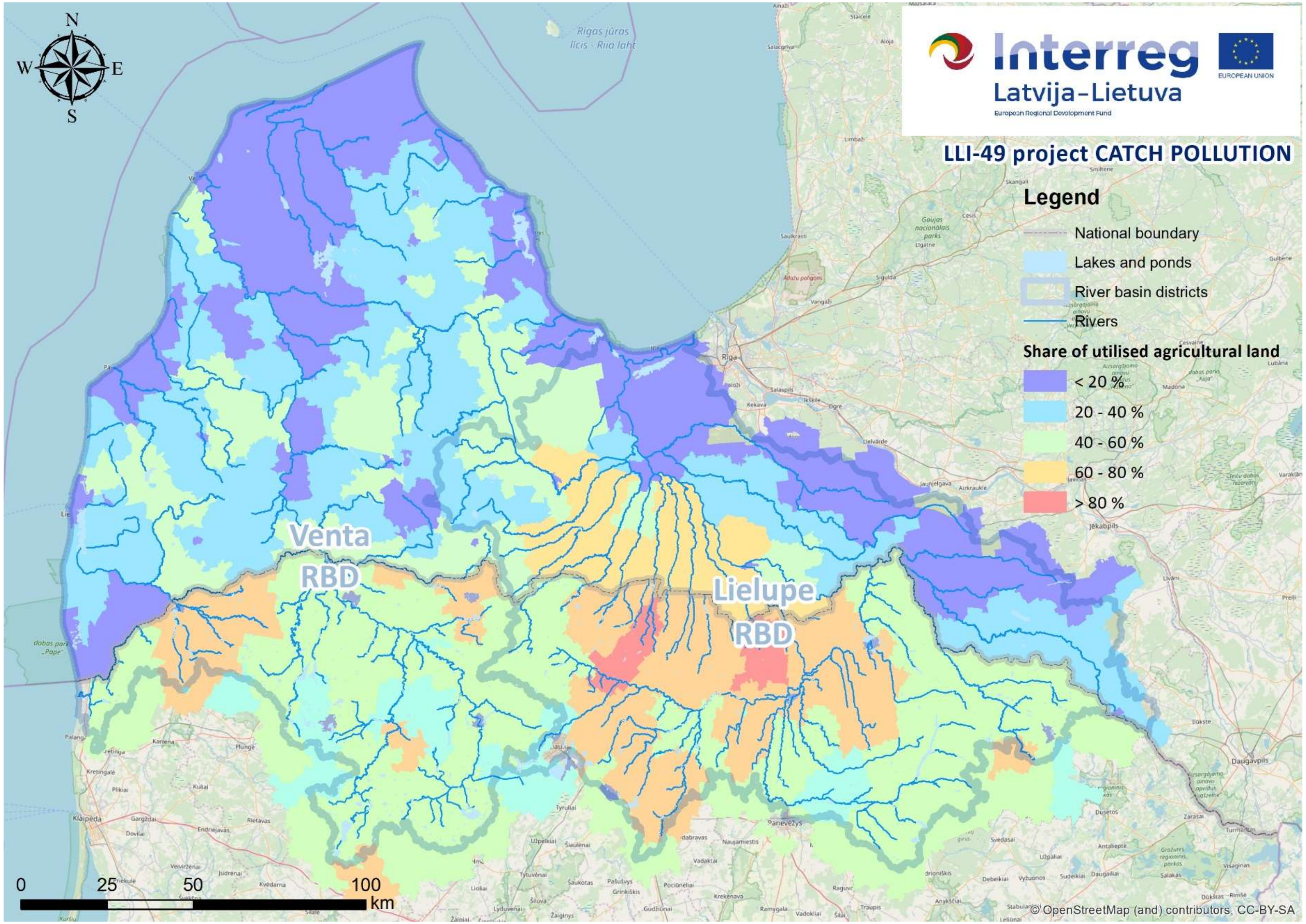


Figure 11. Percentage of the utilised agricultural land in Venta and Lielupe RBDs (data source: data for 2017 from the Centre of Agricultural Information and Rural Business (for the Lithuanian part) and data for 2016 from the Rural Support Service (for the Latvian part))

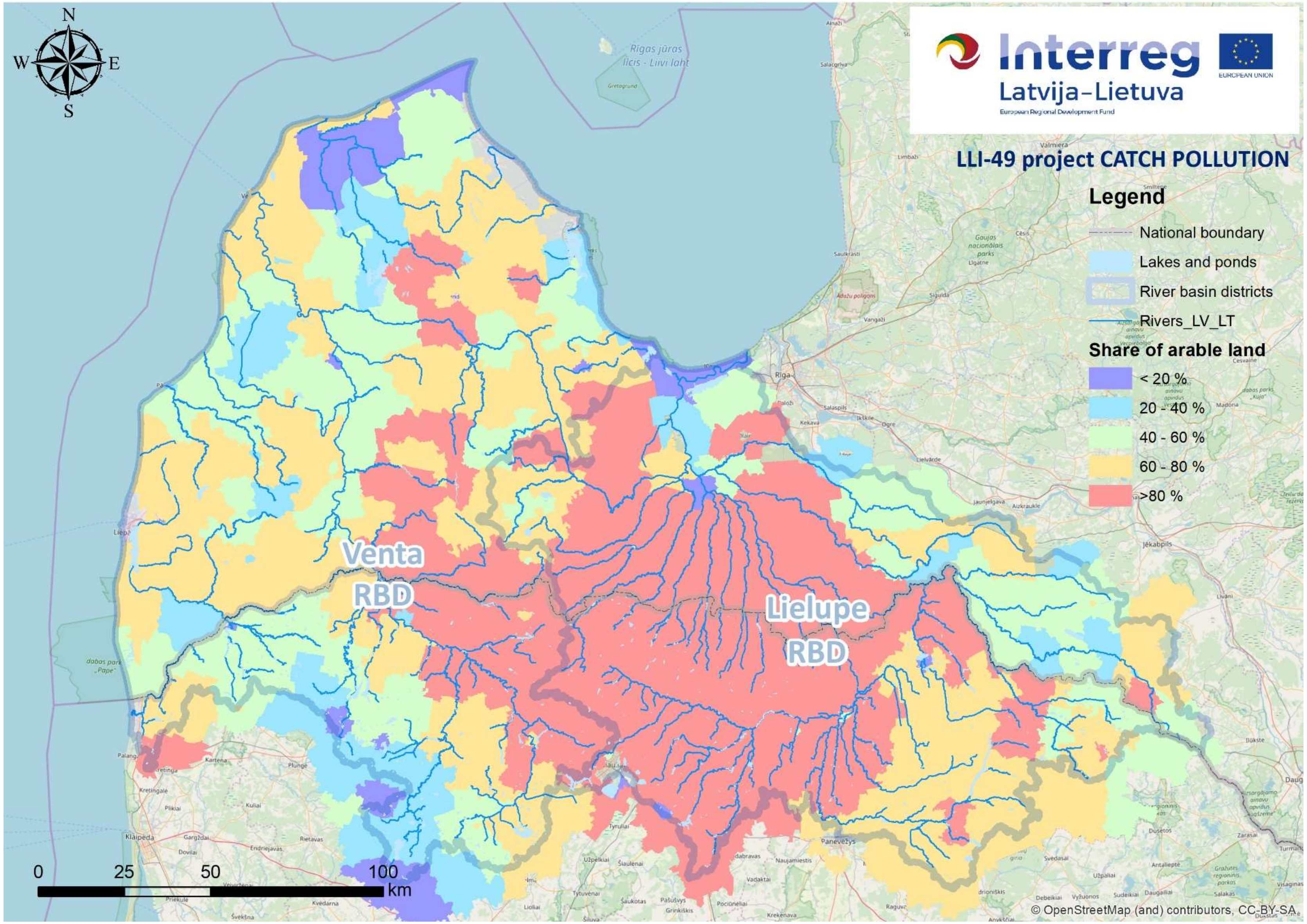


Figure 12. Percentage of arable land (of the total utilized agricultural land area) in Venta and Lielupe RBDs (data source: field declaration data for 2017 from the Centre of Agricultural Information and Rural Business (for the Lithuanian part) and data for 2016 from the Rural Support Service (for the Latvian part))

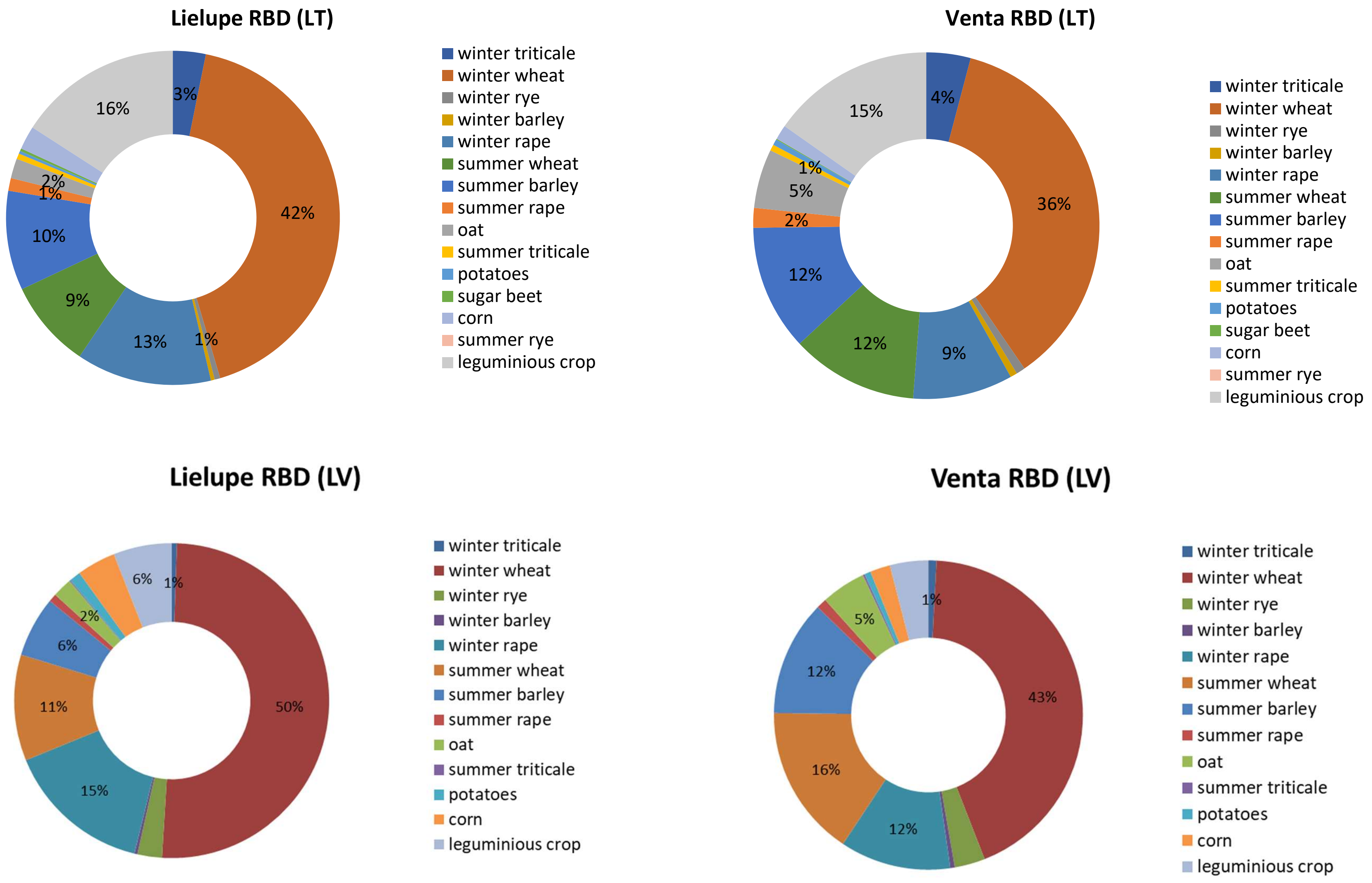


Figure 13. Crop structure in Lithuanian and Latvian parts of the Lielupe and Venta RBDs (source: 2017 declaration data from the Centre of Agricultural Information and Rural Business (LT) and RSS data for 2016 (LV))

Crop productivity mainly depends on soil fertility and intensity of agricultural technologies. In Lithuania, the highest yields are obtained in the sub-basins of the Lielupe small tributaries and the Mūša river having the most favourable conditions for crop production. The largest yields are obtained from the fields of winter cereals. In the period of 2014-2018, an average yield of winter cereals in the sub-basin of the Lielupė small tributaries was 5.4 t/ha. For comparison, in the basins of Nemunelis, Šventoji and Bartuva yields of winter cereals were about 30 % lower (3.7 t/ha). In Latvia, the yield of cereals from the fields in the Lielupe RBD during the last 5 years varied from 4.1 to 5.3 t ha^{-1}, while in the Venta RBD – from 3.3 to 4.5 t ha^{-1}.

During the last 5 years, yields of winter cereals in Lithuania have been gradually increasing. The increase in winter cereal yields in the Lielupė RBD was more pronounced than in the Venta RBD and that, most probably, indicates improvement of agro-technologies and intensification of crop production activities. Yields of summer cereals are on average by 20 % lower than those of winter cereals. Spring cereals are mainly cultivated in soils with low fertility thus, farmers pay less attention to their agro technologies (pre- crops, fertilizers and pesticides).

Actual data on the use of fertilizers at the regional or local level is not yet available either in Lithuania or in Latvia. Interviews with Lithuanian farmers reveal that striving for larger yields they continually increase rates of mineral fertilizers that consequently often exceed the crop demand. Nitrogen fertilizers are relatively cheap if to compare with the profit which can potentially be earned from the crop production. Application of mineral P and K fertilizers is rather limited, they are mainly used by large farms or companies. Farms (especially small) are not interested in performing soil agrochemical analyses and considering thereof results when planning fertilization. Farms that own less than 50 ha of land, which are not the main source of income for the farmer, usually use only mineral fertilizers (200-300 kg/ha). Family farms owing more than 100 ha of land usually use 200 kg/ha of complex (NPK and PK) fertilizers and 400-500 kg/ha of nitrogen fertilizers. Those farms are focusing on long term vitality of the farm and protection of soil productivity. Largest amounts of fertilisers are used in large farms and companies – 800 – 900 kg/ha (of that 600 kg/ha of nitrogen fertilizers). These farms have better potential to create a higher value-added by attracting external financial support, better management of such financial resources and increasing labour efficiency. In the areas which are less favourable for crop production, intensive farms usually owned by young and active farmers, use 100 – 200 kg/ha of complex fertilizers (NPK or PK) and 300 kg/ha of nitrogen fertilizers. Older farmers use little mineral fertilizers. National statistics in Latvia shows that use of mineral fertilizers per one hectare of sown area has increased as well – from 84 kg in 2010 to 110 kg in 2017, or by about 30%.

Livestock production

In the Lithuanian part of the Lielupe RBD livestock density currently averages to 0.15 LU per hectare of agricultural land. If to compare with 2014, it decreased by 9 %. In Latvia, a decreasing trend in livestock numbers is observed as well, however the total livestock number and livestock density in the Latvian part of the Lielupe RBD remains considerably higher than in Lithuanian - 0.26 LU/ha. Since 2013, livestock number in the Latvian part of the Lielupe RBD has decreased by almost 8%.

Livestock density in the Latvian part of the Venta RBD equals to approx. 0.25 LU/ha and is rather similar to that in the Lielupe RBD. Since 2013, livestock numbers in the Latvian part of the Venta RBD even slightly increased though in the Lithuanian part of the Venta RBD livestock numbers are decreasing. In comparison to 2014, the decrease is 8 % but the livestock density still remains close to that in the Latvian part – 0.24 LU/ha.

Farm structure

Farm structure analysis reveals that current farming patterns in Venta and Lielupe RBDs considerably differ. Farming in the Lielupe RBD with large intensive crop farms dominating in its structure is not favourable to the environment while more diverse farming activities in the Venta RBD are more sustainable.

The most intensive crop production is concentrating in the Lithuanian part of the Lielupe RBD (in particular in the sub-basin of the Lielupe small tributaries). Based on the field declaration data of 2017, in the Lithuanian part of the Lielupe RBD nearly 60 % of all agricultural land is at the disposal of farms specializing exceptionally in the crop production. 60 % of all agricultural land is owned by farms larger than 150 ha. In each county of the Lielupe RBD there are at least 2-3 farms larger than 500 ha. In the counties with the most productive soils there can be 5 or more farms larger than 500 ha.

Most of agricultural companies and large farms in the Lithuanian part of the Lielupe RBD are fully equipped with modern machinery, achieve high productivity and work efficiency. They constantly improve their results, generate good income, implement innovations, and invest in purchasing new lands. Well-developed infrastructure of those farms reduces dependency on weather conditions and customers. However, large and modern farms are more specialised in growing only few crops, use more fertilisers and pesticides.

In Latvia, field crop farms also dominate in the farm structure of the Lielupe RBD but the percentage of those comprising 48% of all farms is lower than on the Lithuanian side. As well as in Lithuania, the largest share of agricultural land in the Latvian part of the Lielupe RBD is managed by big farms. Based on the data of Rural Support Service, even 74% of the land is managed by farms larger than 100 ha with the largest share (44 %) being in the farms larger than 500 ha.

Farm structure in the Venta RBD in both countries is more diverse, with a larger share of mixed and livestock farms and lower percentage of land managed by large and intensive farms. In the Lithuanian part of the Venta RBD crop production farms cultivate 40 % of all agricultural land and the remaining part is managed by mixed and livestock farms which can combine fertilization with organic and mineral fertilizers and ensure more sustainable farming practices. The share of crop farms on the Latvian side of the Venta RBD is 46%.

In Latvia, a larger share of the agricultural land in the Venta RBD is managed by big farms. Rural support service data demonstrates that 65 % of the land is at the disposal of farms larger than 100 ha with even 32 % being in the largest farms with over 500 ha. In Lithuania field declaration data shows that 40 % of the agricultural land in the Venta RBD is owned by the farms larger than 150 ha.

Implementation of environmental measures: meeting the greening requirements and participation in agri-environmental schemes under the Rural Development Programme

Greening requirements. Greening payment (GP) for climate and environment favourable agricultural practices was introduced in 2015 as result of the CAP reform with a view to deal with the present impact of agriculture on the environment.

Farmers receiving an area-based payment have to make use of various straightforward, non-contractual practices that benefit the environment and the climate. These require action each year. They include:

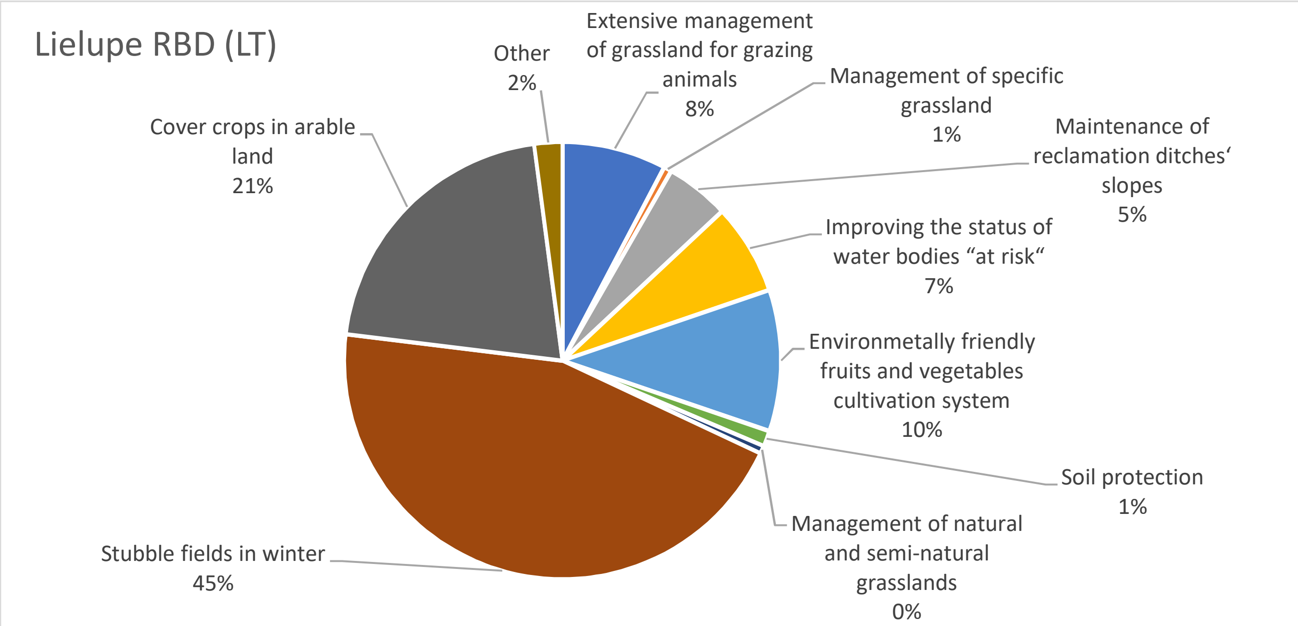
- diversification of crops ((rotations of at least 2 or 3 crops depending on the farm size),
- maintaining permanent grasslands,
- dedicating 5% of arable land to 'ecologically beneficial elements' ('ecological focus areas').

Both in Latvia and Lithuania, greening with at least 3 different crops included in crop rotation turned out to be the most popular. In the Latvian part of the Venta RBD crop rotations included up to 5 field crops, while in the Lielupe RBD crop rotations were shorter consisting from cereal, rape, pea/faba bean.

Declaration data shows that growing of nitrogen fixing plants was the most popular option for ecological focus areas in both RBDs in Lithuania in 2017. Areas of nitrogen fixing plants comprised 84%

of the entire area declared for EFA in the Lielupe RBD and 78 % - in the Venta RBD. With the introduction of greening requirements areas of legumes have increased significantly and dominate in EFA in the Latvian part of Venta and Lielupe river basins too. However, it is expected that in the nearest perspective ecologic focus areas with nitrogen fixing plants will considerably decrease because of the ban of plant protection products in ecologic focus areas from 2018. As growing of peas and beans without use of pesticides is very complicated, farmers are now considering other alternatives for ecologic focus areas.

Agri-environmental measures of RDP 2014-2020. Based on the field declaration data, there have been 13 agri-environmental measures being implemented in Venta and Lielupe RBDs in 2018 in Lithuania, the most popular of which were two: stubble fields in winter and cover crops in the arable land. In the Lielupe RBD, areas of stubble fields comprised 45 % of the entire area of agri-environmental measures, and the areas of cover crops – 21 %. In the Venta RBD areas of stubble fields and cover crops were respectively 41 % and 16 % of the total area of agri-environmental measures.



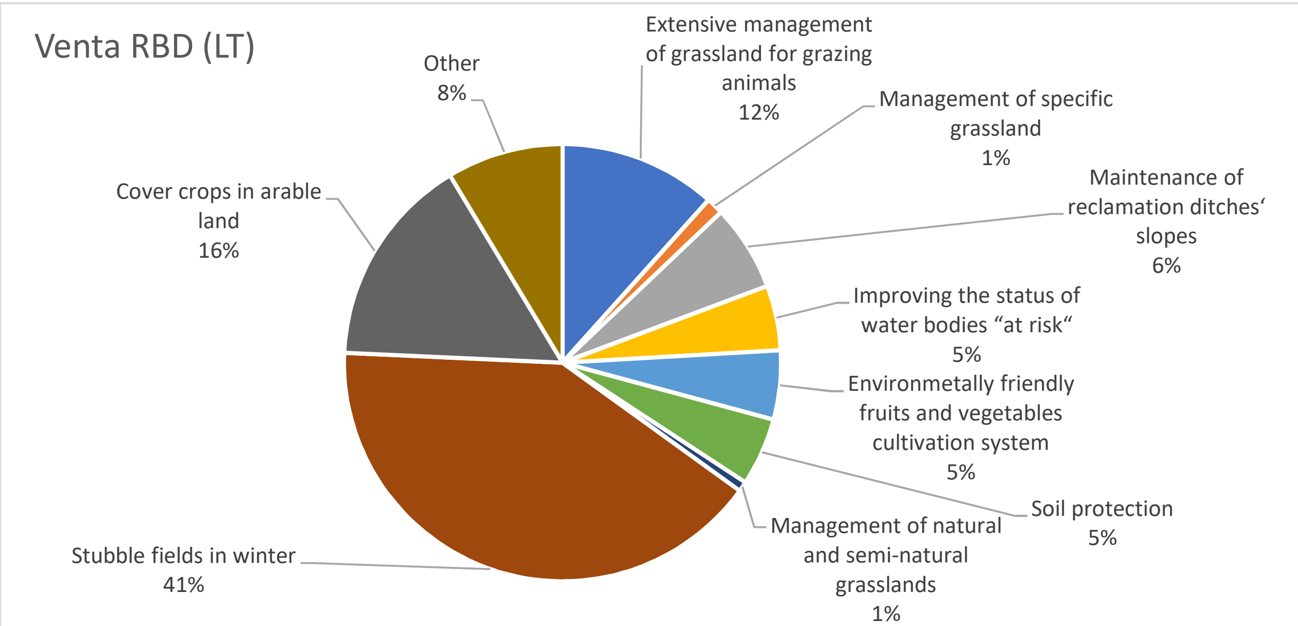


Figure 14. Agri-environmental measures in Venta and Lielupe RBD in Lithuania in 2018 (data source: the Centre of Agricultural Information and Rural Business)

The coverage of agri-environmental measures in relation to the total area of agricultural land is, however, very little. In 2018, only about 3 % of the agricultural land in the Lielupe RBD and 2 % in the Venta RBD in Lithuania were under the contracts for agri-environmental measures. Cover crops, one of the most popular measure, was implemented on only 1% of the arable land in both RBDs. The measure for improving the status of water bodies at risk, which is intended at converting the arable land to perennial grasslands, was implemented on only 0.2% of the arable land in both Venta and Lielupe RBDs. This suggest that from the current implementation of agri-environmental measures only very little environmental effect can be expected because with such little coverage any environmental initiatives cannot overweigh or significantly decrease effects of intensive farming.

In Latvia, as well as in Lithuania, in the Lielupe and Venta RBDs agri-environmental measures are implemented in relatively small areas (see *Table 1*). *Rye field in the winter period* is the most important RDP 2014-2020 agri-environmental sub-measure in Latvia. Supported area under this sub-measure in 2016 was 4% in the Venta river basin and 3% of agricultural land in the Lielupe river basin. In general, conventional agriculture is predominant in both basins and agri-environmental measures are implemented in small areas.

Table 1. Implementation of agri environmental measures of RDP 2014-2020 in the Venta and Lielupe river basins in Latvia (source: author's calculation according to the RSS data 2016).

	Venta RBD	**Lielupe RBD**
Measures under Agri-environment and climate scheme:		
Rye field in the winter period, ha	16859	9168
Rye field in the winter period, beneficeries	351	176
Environmentally friendly horticulture, ha	824	2460
Environmentally friendly horticulture, beneficeries	102	82

Organic farming. In the Lithuanian part of the Lielupe RBD, 6 % of the agricultural land is certified according the rules of organic farming. In the Venta RBD for organic farming 7 % of the agricultural land is used.

In Lithuania, organic farming is usually chosen by the farmers working in less fertile lands. In the districts with fertile soils organic farming is less popular. Due to reduced payments, organic farming is losing its popularity lately. The number of farmers engaged in organic farming decreases, and those who remain in business enlarge their farms.

In Latvia, the area supported by RDP 2014-2020 measure M11 Organic farming take up to 11% of the utilised agricultural land in the Venta river basin and 5% in the Lielupe river basin. Two thirds of the organic farm areas are grasslands and only one third is arable land.

Analysis shows that today very little environmental effect can be expected from implementation of agri-environmental measures in Venta and, especially, in the Lielupe RBD, because environmental initiatives with such little coverage cannot overweigh or significantly decrease effects of intensive farming. It is expected that the intensity of agriculture will increase in future, so in order to prevent the natural balance from damaging and allow responsible and sustainable use of resources the demand for agri-environmental measures such as catch crops will grow.

Catch crops and their growing potentials in Venta and Lielupe RBDs

Intensification of agricultural activities and unsustainable use of natural resources result in degradation of soil and pollution of waters and that increase the pressure on application of more environmentally friendly farming practices. Application of agri-environmental measures is often associated with additional costs and production losses what makes them not attractive to the farmers. The newest studies and increasing interest in catch crops demonstrate that they can be a good compromise because they provide benefits to both the environment and the farmer.

Catch crops do not occupy a separate field in the crop rotation. They are grown in the same field before or after the main crops, so agricultural (cash) crops, needed by a farmer, grow in the soil during the entire vegetation period.

The three major categories of commonly grown catch crops are grasses, legumes, and brassicas. Lithuanian and Latvian agricultural experts identify the following catch crops that can be grown in Venta and Lielupe RBDs:

Brassicas:

- White mustard
- Brown mustard
- Spring rape
- Winter rape
- Oil (forage) radish
- Root (tillage) radish
- Turnip;

Grasses/cereals:

- Winter rye
- Italian ryegrass
- Perennial ryegrass
- Oat and black oat

Legumes:

- White clover
- Red clover
- White melilot
- Winter vetch
- Pea
- Blue bitter lupine
- Bean

Other:

- Buckwheat
- Phacelia

When choosing which catch crops to grow, farmer has to take into account the crop rotation, soil properties, climatic conditions, and expected effects of different catch crops.

Catch crop growing potentials in Venta and Lielupe RBDs

Catch crops can fit well into many different crop rotations during periods between two main crops when the soil would otherwise be bare for a long time (for instance, after wheat harvest and before sowing spring crops such as corn, sugar beet or potato). Often the main limiting factor for establishing catch crops is too short vegetation period left after the late harvested main crops. To grow sufficient biomass, even the latest seeding time having brassica species must by sown till 10-15th of August when the most of main crops are still on the field. Niches between the main cash crops generally determine catch crop growing potentials in Venta and Lielupe RBDs.

In Lithuania and Latvia winter wheat is usually succeeded by winter rapeseed. After good preceding crop, winter wheat is used to be reseeded for one year[1]. For wheat stubble with perennial weeds chemical or mechanical weed control should be used. In some cases, perennial grasses can be undersown in winter wheat in spring. However, after the harvest, if winter wheat is followed by winter crops or perennial grasses, there is no possibility for catch cropping. Only in case when winter wheat is succeeded by spring crops (cereals, rape, row crops, etc.) there is good possibility for post-harvest or undersown catch crops in between. Considering the current crop structure, today only up to 30 percent of the area covered with winter wheat can be used for catch crop establishment.

Winter rye can be grown in less productive, poor, sandy soil, even with low pH ≤ 5.5. Such soil conditions usually are not favourable for catch cropping. In more productive soils winter rye is preferred as preceding crop for winter rapeseed as well as other winter cereals. In such cases, there is no sufficient niche for catch crops in between the main crops. Only if winter rye is followed by spring cereals or other spring crops there is an opportunity for catch crops. Hence, only about 10 percent of area after winter rye can usually be used for catch crops.

Harvest time for winter triticale is about 7–10 days later than for winter wheat or winter rye. In comparison with other winter cereals, winter triticale is more susceptible for weed spreading and laying of crop stand. These are the main limiting factors for undersown catch crops. Post-harvest catch cropping is possible if winter triticale is succeeded by spring crops. Considering the above, only about 20 percent of area with winter triticale is potentially suitable for catch crop establishment.

In Lithuania winter barley is usually used as preceding crop for winter rapeseed. As there is no niche for catch cropping between these two crops, it is assumed that there is no potential for catch cropping after winter barley in Lithuania. In Latvia, winter barley is sometimes succeeded by spring crops, so experts estimate that some 10% of the area can be used for catch crops.

Spring barley in the farms with livestock can be under-sown with perennial grasses and in such a case there is no possibility for catch cropping. Only minor part of spring barley area can be harvested before 10-15th of August, but some catch crops can be under-sown in spring. Also catch crops (especially white mustard and spring rape) can be seeded before crop harvest, usually by broadcasting. Thus, approx. 30 percent of spring barley area can potentially be covered with catch crops.

Spring wheat is a late harvest crop, with a high stand. Therefore, this crop is not suitable for either undersown or post-harvest catch cropping. Catch crop (especially brassica) seeds can only be broadcasted before the harvest of spring wheat. Potential area for catch cropping is approx. 20 percent.

Early potatoes can be harvested even at end of June or beginning of July. Therefore, after early potatoes there are very good opportunities for growing long vegetation period legume and nonlegume catch crops. On the contrary, there are no possibilities for catch cropping after the late harvest potatoes. Depending on the potato's variety, potential area for catch crops is approx. 30 percent.

[1] In Latvia (especially in the Lielupe RBD) dominating crop rotation practice still is 2 or 3 years of winter wheat and after that winter rapeseed or legumes.

Depending on weather conditions, harvest time for pea is first and second decade of August. Pea is good preceding crop for winter rapeseed or winter wheat. Such circumstances define that about 50 percent of the area after pea can be used for catch crop.

Winter rape is the main preceding crop for winter wheat in Lithuania, while Latvian farmers sometimes use it a preceding crop for spring crops. There is only very short niche of about 50 days between winter rape and winter wheat which is not sufficient for catch cropping, so experts assume that there are no possibilities for catch crops after winter rape in Lithuania. In Latvia, 10 % of the winter rape area is considered to be available for catch crops.

Harvest time of spring rape is too late for establishment of catch crops. It is considered as good preceding crop for winter wheat, so there is no sufficient niche for catch cropping after spring rape.

Establishment of catch crops after perennial grasses, bare land or fallow is not reasonable.

Sugar beet, corn, soya, fava bean, oat, spring triticale are harvested too late to leave a niche for establishment of catch crops.

Main crops after the harvest of which establishment of catch crops is possible and available niches for catch crops are summarised in *Table 2*.

Considering the current crop structure, project experts estimated catch crop growing potentials in Venta and Lielupe RBDs. For the assessment field declaration data for 2016 was used.

Calculation results demonstrate that on average 20 percent of arable land can be used for catch cropping. The potential is higher in counties where prevailing crop rotations include more crops with early harvest time leaving sufficient time for catch crops. Under current crop rotations, the potential is mainly determined by the areas of winter wheat and summer barley. Additionally, there are counties having significant areas with peas which are also favourable for establishment of catch crops.

Calculated catch crop growing potentials are presented in *Figure 15*. The potential is expressed as a percentage of arable land in each county which potentially can be used for the establishment of catch crops. The estimated potential represents the maximum area available for successful establishment of catch crops under the current crop rotations.

Table 2. Catch cropping potentials after the main crops

Main crops after the harvest of which establishment of catch crops is possible	Main crops after the harvest of which establishment of catch crops is not possible
Winter wheat – 30 % of the area	Winter rape (in LT)
Winter rye (depending on soil conditions) – 10 % of the area	Spring rape
Winter triticale – 20 % of the area	Winter barley (in LT)
Spring barley – 30 % of the area	Perennial grasses (red clover, timothy, …)
Spring wheat – 20 % of the area	Bare land or fallow
Potatoes – 30 % of the area	Sugar beet
Pea and mixtures with pea– 50 % of the area	Corn
Winter barley – 10 % of the area (in LV)	Soya
Winter rape – 10 % of the area (in LV)	Faba bean
	Oat
	Spring triticale

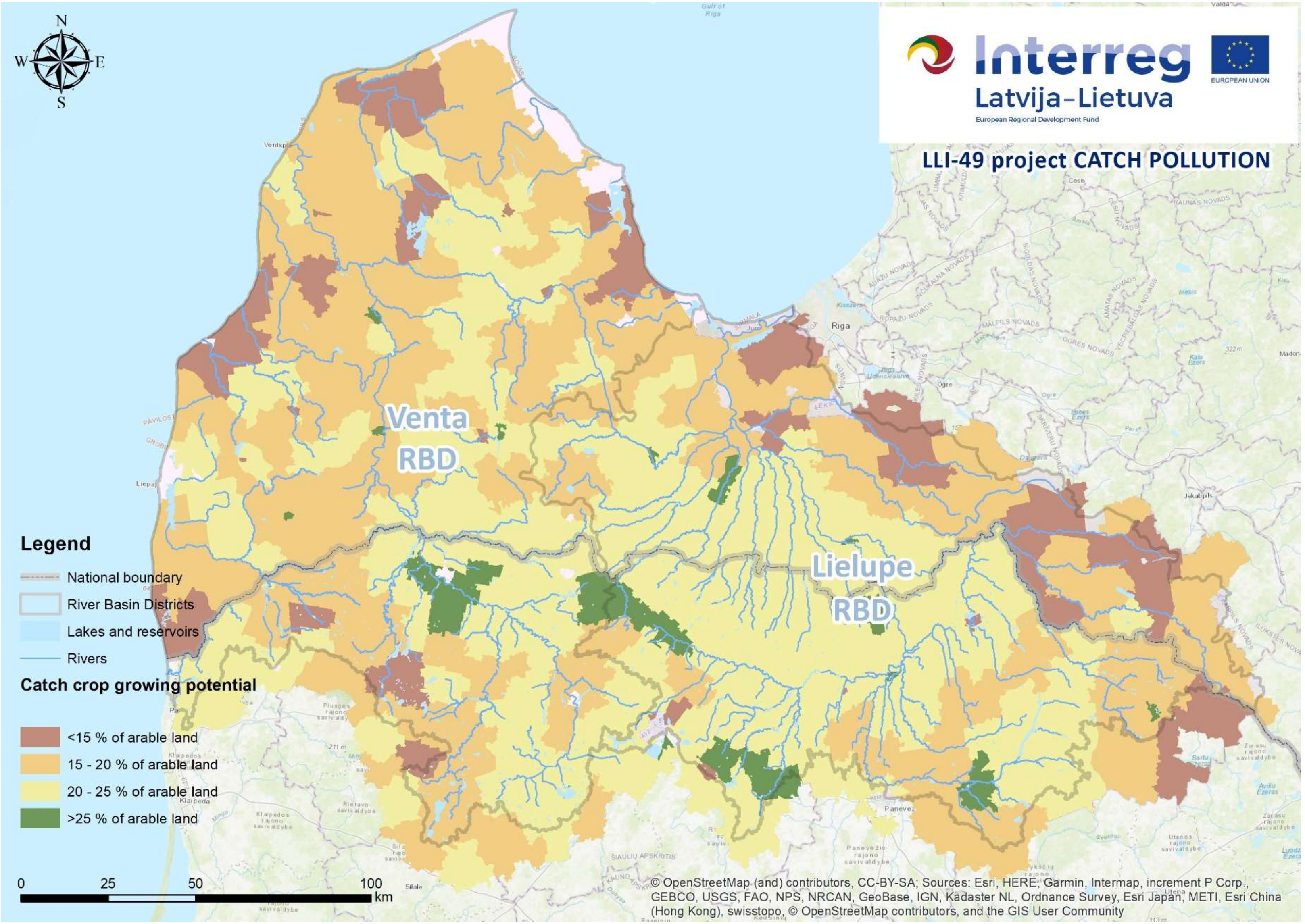


Figure 15. Catch crop growing potential in Venta and Lielupe RBDs (estimated by the project experts)

The role and potential effects of catch crops

By playing different roles, catch crops provide a range of different benefits. To get the best of them, it is important to know and understand their potential role and performance.

Usually the following main benefits of catch crops are considered:

- Retention of nutrients and reduction of nutrient leaching
- Transferring of nutrients to the next main crop
- Reduction of greenhouse gas (GHG) emissions
- Increasing soil organic carbon content
- Reduction of weeds and control of pests and diseases
- Reduction of soil erosion.

Retention of nutrients and reduction of nutrient leaching

While growing, catch crops utilize considerable amounts of nitrogen from the soil for the formation of the above-ground and below-ground biomass (biological accumulation of nitrates), consequently nitrate leaching is decreased. Where nitrate leaching is a serious problem, catch crops can beneficially fill any “fallow” periods in a rotation.

Results of experimental research conducted in Lithuania, Latvia and other European (in particular Scandinavian) countries demonstrate that in most cases catch crops reduce nitrogen leaching by over 50%.

Different species of catch crops depending on their root depth have different potentials to scavenge nitrogen from soil. Broadleaf cover crops (radish, winter rape, phacelia) grow deeper roots faster than cereals (rye, oats) or annual ryegrass. Therefore, they have larger nitrogen leaching reduction capacities. In some cases, leaching reduction effect of fast-growing brassicas (e.g. oil radish) may even exceed 80%.

Legumes usually have significantly lower nitrogen retention rate and leaching reduction potential than grasses and brassica. Performance of legumes with respect to reduction N leaching is poor because instead of scavenging from the soil their fix nitrogen from the atmosphere.

Catch crop effectiveness is highly determined by the root depth. Timely establishment of catch crop is critical to ensure sufficient depth of roots. Therefore, planting catch crops as soon as possible in late summer or early autumn is important for maximizing their environmental effects.

It has been estimated that application of catch crops may protect **approx. 12 kg/ha** of nitrogen from being lost into water bodies by leaching. If full catch crop growing potential is utilized, nitrogen losses to water bodies could be reduced by approx. **1800 t/year in the Lielupe RBD** and by approx. **1100 t/year in the Venta RBD**.

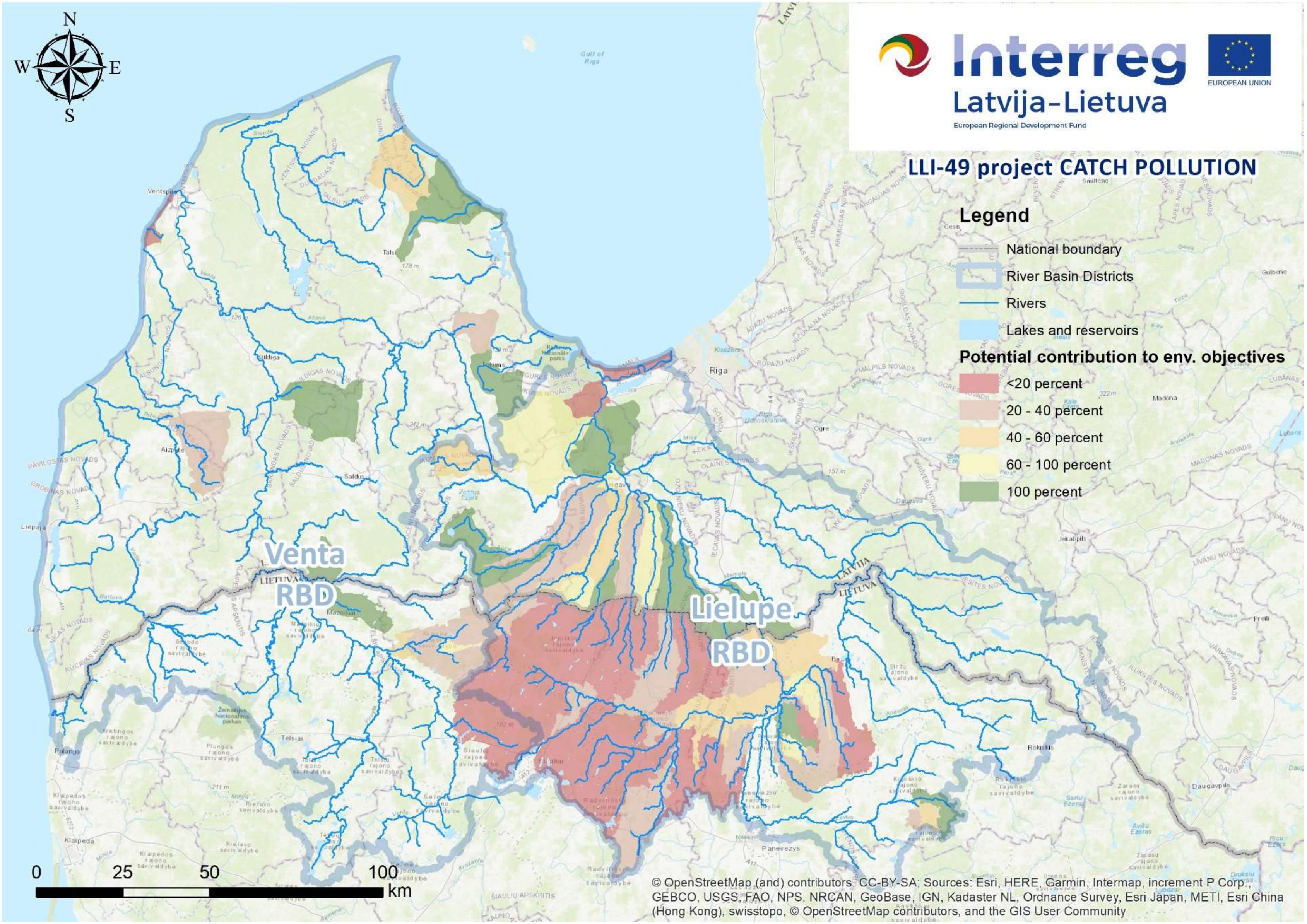


Figure 16. Potential contribution of catch crops to achievement of environmental goals in Venta and Lielupe RBDs

Transferring of nutrients for the next main crop (nitrogen crediting)

Included in crop rotations catch crops scavenge nitrogen from the soil and thereby reduce nitrogen losses by leaching or volatilisation. As the cover crop residue decomposes, the organic nitrogen in its tissue is mineralised to ammonium (NH_4) and then to nitrate (NO_3), which can be latter utilized by the succeeding crops, and thereby reduce the demand for fertilizer nitrogen input.

It has to be considered that only a portion of the nitrogen contained in the catch crop residues will be released as NH_4 and NO_3 during the life cycle of the following cash crop. Scientists conclude that only plant residues with C:N ratios less than 24 increase concentration of the mineral N. Materials added to the soil with a C:N ratio greater than 24 will result in a temporary nitrogen deficit (immobilization).

Along with the composition and quality of the residue, climatic factors such as temperature and moisture have a huge influence on the mineralisation process. The soil organisms responsible for decomposition work best at warm temperatures and are less energetic during cool spring months.

Tillage also affects decomposition of plant residues in a number of ways. Residues incorporated into the soil tend to decompose and release nutrients much faster than those left on the surface, as in a no-till system.

Research demonstrates that the nitrogen mineralization can be expected to be high in the first year, but what is not mineralized this year will mineralize very slowly over the succeeding years.

Assessment shows that legumes have the largest potential for nitrogen crediting. Under the typical production of biomass, they can be expected to leave approx. 30-40 kg of mineral nitrogen for the next cash crop. The similar amount (i.e. about 40 kg/ha) can also be credited by mustards and oil radishes. While 2/3 of the legume nitrogen is fixed from the atmosphere, mustards and oil radishes retain nitrogen from soil providing a dual benefit: they prevent excessive nitrogen from leaching and transfer to the subsequent crop.

Grasses and cereals usually have lower potential for release of PAN than that of legumes or mustards, however they all positively contribute to mineral nitrogen pool (e.g. grasses and cereals can provide around 10 kg/ha of mineral N). Hence, all catch crops can be considered as potential sources of nitrogen facilitating reduced application of mineral fertilisers.

It has been estimated that if full catch crop growing potential was utilised, each year **approx. 5 200 t of nitrogen** could be credited for the succeeding cash crops **in the Lielupe RBD** and **approx. 3 300 t - in the Venta RBD**.

Reduction of greenhouse gas emissions

Catch crops have revealed to have a positive effect on GHG balance through the soil C sequestration (storage) in which CO_2 is removed from the atmosphere and stored in the soil carbon pool. Our analysis indicate that catch crops can potentially sequester approx. 1.2 – 1.3 t CO_2/ha/year.

GHG mitigation effect is also related to changes in nitrous oxide (N_2O) emissions. Existing research with respect to catch crop impacts on emissions of N_2O is rather limited but it demonstrates that effect is usually minor. When cover crops do alter N_2O emissions, the effect may be an increase or decrease of about 0.01 g N/m^2/year, which equals to roughly 4.7 g CO_2 e/m^2 /year.

Establishment and termination of catch crops require extra operations which can result in increase of CO_2 emissions by approx. 2.8 g CO_2 e/m^2 /year.

In our study, we estimated catch crop GHG mitigation effect as the sum effect related to changes in CO_2 and N_2O emissions. Performed assessment suggest that catch crop GHG mitigation effect can be around 1.1 CO_2e/ha/year. If full catch crop growing potential is utilised, application of catch crops might facilitate decrease of annual GHG emissions by almost 170 thou t CO_2-e in the Lielupe RBD and by 107 thou t CO_2-e in the Venta RBD.

Increase in soil organic carbon (SOC) content

Catch crop potentials to increase SOC content are highly determined by the chemical composition of the residue. There is a close relation between humification intensity and biomass content of cellulose and lignin. C:N ratio of the residue also plays an important role. The largest contribution to SOC pool can be expected from the catch crop residues which are high in lignin (i.e. >15%) and have C:N ratio in the interval between 15 and 25. Respectively, residues which are low in lignin and have C:N ratio below 15 are expected to have little effect on SOC stocks.

Analysis has revealed that grasses have the largest potential to contribute to SOC pool because in comparison with other catch crops, they usually contain more lignin which is stable and resistant to mineralization. Results of our assessment suggest that under the typical production of the biomass as predicted for Venta and Lielupe RBDs, grasses (e.g. Italian ryegrass) may contribute to SOC stocks by approx. 200 - 220 kg C/ha/year. The contribution of brassicas (e.g. mustard or oil radish) can be rather similar (in the range of 150 – 200 kg C/ha), while expected SOC inputs from leguminous catch crops are under 150 kg C/ha/year. Taking into account the predicted structure of catch crops in Venta and Lielupe RBD we estimate that the average catch crop SOC inputs may amount to approx. 200 kg C/ha/year.

Taking into consideration current potential for catch cropping in Venta and Lielupe RBDs and predicted structure of catch crops we estimate that catch crops may contribute to SOC stock by approx. 30 thou t C/year in the Lielupe RBD and by 19 thou t C/year in the Venta RBD.

Control of pests and diseases

One of the important effects of a catch crop is its ability to suppress and reduce harmful organisms: weeds, diseases and pests. Catch crops occupy the space and utilize the resources that would otherwise be available to weeds. Incorporated or soil surface-placed cover crop residues can inhibit or retard germination and establishment of weeds; phenolics from legume may contribute to weed control through allelopathy. Incorporated residues of allelopathic catch crops can also inhibit or retard germination, emergence and growth of weeds.

The analysis performed by the project experts demonstrates that catch crops can play an important role in the weed control strategy and can bring economic and environmental benefits both to conventional and organic farming systems. Of all proposed catch crops, white mustard, rape, radish, winter rye, oats and buckwheat have revealed to have the largest weed reduction capacities. They can reduce weed density by over 70%. In comparison, weed reduction potential of pea, white clover, winter vetch, phacelia and Italian and perennial ryegrasses does not exceed 30%.

The analysis shows that the role of catch crops on pest and disease control is uncertain. On one hand catch crops improve biodiversity in such a way providing habitat for beneficial insects which help in suppressing the pests but on the other hand, they can also harbour crop pests and pathogens if the catch crop is from the same family as the main crop is grown. Thus, in order to avoid the risk of crop diseases proper catch crop choices are very important. When choosing catch crops, it is important to avoid growing biologically similar species together too often, to prevent transferring common pests and diseases.

Reduction of soil erosion

Catch crops can play a major role in controlling soil erosion. Quick-growing crops hold soil in place, reduce crusting and protect against erosion due to wind and rain. Grasses are often selected for erosion control as they rapidly establish, protecting the soil from the direct impact of raindrops, have a fibrous root system that contributes to decreased soil erodibility, and have a high stem density which reduce runoff velocity. Other crops that contribute to erosion control are tap-rooted crops (e.g. forage radish, *Raphanus sativus,* and rapeseed*, Brassica napus*), which increase water infiltration and decrease soil compaction, thereby reducing runoff.

Soil erosion usually takes place in the fields with slope larger than 2^0. Both in Lithuania and Latvia majority of fields that could potentially be used for catch crops are in flat areas and thus are not at the risk of erosion. Only about 13% of fields in the Lielupe RBD and 24% - in the Venta RBD can be negatively affected by erosion (most of these fields have slopes in the interval of 2-5^0).

Study results indicate that application of catch crops (if their potential is fully utilised) can protect approx. 44 thou. tonnes of soil from being lost by water erosion in the Lielupe RBD and approx. 58 thou. tonnes – in the Venta RBD annually. This corresponds to 1.4 thou. tonnes of SOM and 80 tonnes of N protected from being lost in the Lielupe RBD and 1.8 thou. tonnes of SOM and 102 tonnes of N – in the Lielupe RBD.

All expected catch crop effects in Venta and Lielupe RBDs are summarised in *Table 3*.

In *Table 4*, potential catch crop role and significance of various effects is presented as estimated from the project performed assessment of catch crop environmental effects.

Table 3. Potential effects of catch crops in basins and sub-basins of Venta and Lielupe RBDS

River basin/sub-basin	River basin area, km^2	Potential effects of catch crops							
		Reduction of nitrogen leaching, t/year		Transferring of nitrogen to the subsequent crop, t/year	GHG mitigation effect, thou t CO_2-e/year	Production of SOC, thou t C/year	Amount of soil protected from being lost by water erosion, thou t/year	SOM protected from being lost by water erosion, t/year	Nitrogen protected from being lost by water erosion, t/year
		total reduction in river basin/sub-basin, t/year	of that reduction in sub-catchments of water bodies at risk, t/year						
Lielupe RBD:	***17789***	***1750***	***1230***	***5204***	***168.9***	***29.6***	***43.9***	***1365***	***79***
Mūša sub-basin (LT)	5296	680	530	2040	65.7	11.6	16.7	521	30
Nemunėlis sub-basin (LT)	1900	140	-	422	14.1	2.4	7.4	231	13
Lielupė small tributaries sub-basin (LT)	1750	300	300	931	30.1	5.3	3.2	80	5
Latvian part of the Lielupe basin (LV)	8843	630	400	1811	59	10.3	16.6	533	31
Venta RBD:	***21906***	***1130***	***190***	***3301***	***106.8***	***18.9***	***58.0***	***1750***	***102***
Bartuva basin (LT)	749	50	-	141	4.7	0.8	4.2	159	9
Venta basin (LT)	5137	420	100	1258	40.3	7.2	25.2	567	33
Šventoji basin (LT)	390	30	-	83	2.8	0.5	1.0	23	1.5
Latvian part of the Venta basin (LV)	15630	630	90	1819	59	10.4	27.5	1002	58

Table 4. Catch crop roles and significance of various environmental effects (based on the results of the project preformed assessment of catch crop environmental effects): green colour in the table marks the largest, orange – medium, yellow – the lowest effect.

Catch crops	Reduction of nitrogen leaching	Nitrogen crediting	Reduction of GHG emissions	Increasing soil organic carbon content	Reduction of soil erosion	Weed control
White mustard						
Brown mustard						
Spring rape						
Winter rape						
Oil radish						
Forage radish						
Winter turnip						
Italian ryegrass						
Perennial ryegrass						
Oat and black oat						
Winter rye						
White clover						
Red clover						
White melilot						
Vetch						
Pea						
Blue bitter lupine						
Bean						
Phacelia						
Buckwheat						

Results of the farmers' survey regarding the most valued catch crop effects

In order to raise a discussion and investigate farmers and agricultural experts' perception towards catch crop roles and effects, an interactive survey was held during the project's field days.

Within the project, four field days were organised in the autumn of 2018, out which two took place in Latvia (Stende and Vītiņi) and two – in Lithuania (Viekšniai and Vaškai). During the field days, participants were asked to express their personal opinion and evaluation on the environmental benefits of catch crops.

Each participant received three voting chips and could choose between one or more effects of catch crops which in his/her opinion are the most important in building environmental quality:

- catch crops reduce greenhouse gas (GHG) emissions in crop production
- catch crops reduce nutrient leaching from the soil
- catch crops increase soil organic carbon content
- catch crops control weeds, pests and diseases
- catch crops reduce soil erosion
- catch crops transfer nutrients to the next crop.

In total 268 answers were received to the survey, out of which 145 votes were casted during the field days in Lithuania and 123 votes were obtained during the field days in Latvia. The survey results are summarised in the figures below.

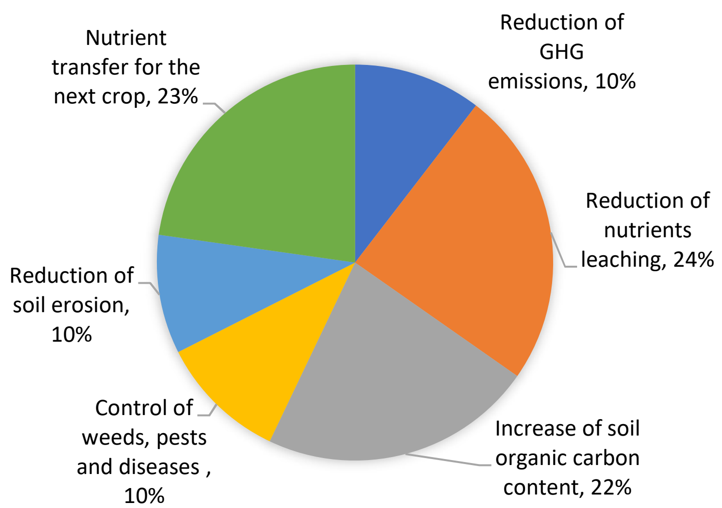


Figure 17. Results of the survey (% as of total votes)

Summary of the survey results reveals that participants of the field days consider that the main environmental effect of catch crops is related to their ability to catch nitrogen, thus reducing its leaching (24% of the votes) and retaining it in the soil to be further used by the following crops (23%). The role of catch crops in improving soil fertility has also received high evaluation (22%). The effects of catch crops to reduce GHG emissions, soil erosion and control of weeds, pests and diseases have each received 10% of votes.

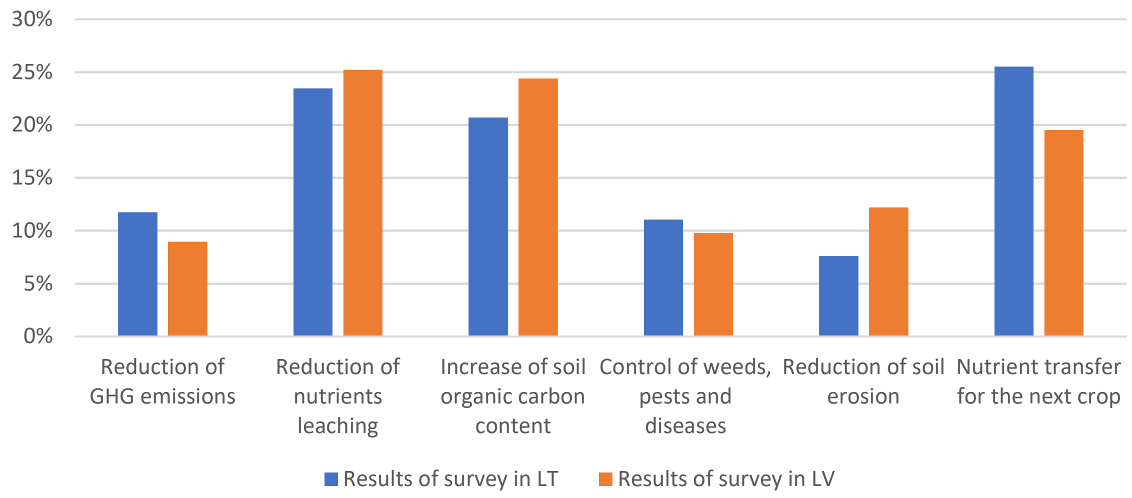


Figure 18. Results of the survey by countries (% as of total votes)

The results show that participants of the field days in Latvia evaluate the role of catch crop in the increase of soil organic carbon and reduction of soil erosion higher than Lithuanian voters, while Latvians less believe in the catch crop ability to transfer nutrients to the next crop and their role in the reduction of GHG emissions in crop production as compared to Lithuanian voters.

Comparison of the votes between Latvia and Lithuania does not reveal significant differences, which is quite understandable as most of the participants in all field days were farmers. Also, the voting indicates that higher priority is given to those catch crop effects that can be assumed as benefit not only for a society as a whole but also at a farm level.

Catch crop support in the Baltic Sea region countries

Due to notable environmental benefits, growing of catch crops is being increasingly supported in the EU countries – mainly as a greening measure and by different measures under agri-environment and climate action of the RDPs 2014-2020.

Greening refers to the mandatory greening requirements introduced in 2015, the observation of which allows receiving direct payments - basic payment alongside greening payment. One of the general requirements is that farms with more than 15 ha of arable land ensure that at least 5% of their arable land is EFA, for which catch crops or green cover was one of the options for countries to be chosen. The overview of the support for catch crops as EFA in the Baltic Sea region countries is summarized in *Table 5*. The Baltic Sea region countries refer to the EU countries having a shoreline along the Baltic Sea – Latvia, Lithuania, Estonia, Poland, Finland, Denmark and Germany. For Germany the case of Bavaria has been studied as it is the State with the largest arable land area.

The possibility to fulfil the greening requirement of direct payments for the EFA by establishing catch crops is used in most Baltic Sea region countries (except Estonia and Finland), with quite similar approach. Overall, under-sowings should consist of grasses and/or legumes, while intercrops should be a mixture of at least two crops. The largest flexibility for intercrop species is provided in Poland as the eligible crops are defined quite broadly (cereals, oilseeds, fodder, legumes and melliferous plants), followed by Denmark (in general case). Generally, intercrops have to be maintained for about 60 days and it is forbidden to apply plant protection products during the period of the maintenance of intercrops.

Table 5. Catch crops as EFA in the Baltic Sea region countries (source: based on the support requirements available from the national agricultural support paying agencies for 2018)

Country	Types	Variety of species	Sowing date	Termination date
Latvia	under-sowings, intercrops	under-sowing of grasses and legumes; mixture of a minimum of 2 intercrops[1]	by September 1 (intercrops)	after October 31 (intercrops)
Lithuania	under-sowings, intercrops	under-sowing of grasses or legumes; mixtures of a minimum of 2 intercrops[2]	from April 1 to June 30 (under-sowings); from June 30 to August 15 (intercrops)	after October 15 (or until sowing of winter crops (under-sowings); or 8 weeks after sowing of a mixture)
Estonia	-	-	-	-
Poland	under-sowings, intercrops	under-sowing of grasses or small-seed legumes; mixtures of at least 2 intercrops[3]	from July 1 to August 20 (stubble intercrops); from July 1 to October 1 (winter intercrops)	after October 15 (or 8 weeks after sowing of a mixture) (stubble intercrops); after February 15 (winter intercrops)
Finland	-	-	-	-
Sweden	under-sowings, intercrops	under-sowing of grasses and/or legumes; mixture of at least 2 intercrops[4]	before September 1 (intercrops)	from November 1

Country	Types	Variety of species	Sowing date	Termination date
Denmark	under-sowings, intercrops	under-sowing of grasses and/or legumes; mixture of at least 2 intercrops[5]	by June 30 (under-sowings); from June 30 to August 1 or August 20 (intercrops)	from October 20 (or 8 weeks after the harvesting of maize (under-sowings))
Germany (Bavaria)	under-sowings, intercrops	under-sowing of grasses and/or legumes; mixture of at least 2 intercrops[6](max 60% for one crop; grasses max 60%)	by October 1 (intercrops)	after January 15; after February 15

[1] summer rape, Italian ryegrass, white mustard, oil radish, oats, phacelia, buckwheat, summer vetch, winter vetch, rye, beans, peas or fodder radish
[2] listed in Regulation on direct payments (December 4, 2015 No. 3D-897)
[3] cereals, oilseeds, fodder, legumes and melliferous plants (mixtures cannot consist of cereals only)
[4] beet, red clover, buckwheat, oats (spring), phacelia, barley (spring), oil radish, Persian clover, bristle oat, ryegrass, rape (spring), turnip rape (spring), rye (spring), triticale (spring), radish, sunflower, subterranean clover, Sudan grass, tagetes, wheat (spring), vetch, white mustard, pea. The mixture must not contain any other than these crops
[5] cereals, grasses, cruciferous plants, chicory and honeycomb (by August 1); spring barley, common rye, perennial rye, hybrid rye or oats, cruciferous plants, honeycomb (by August 20)
[6] listed in Appendix 3 of DirektZahlDurchfV (Regulation on the implementation of direct payments)

While greening is a compulsory requirement set by the CAP, agri-environment measures go beyond mandatory standards and provide additional environmental benefit. The overview of the support for catch crops under agri-environment and climate measures of the RDPs 2014-2020 in the Baltic Sea region countries is provided in *Table 6*.

Latvia and Denmark are the countries with no agri-environment support provided for the growing of catch crops in their RDPs. However, Danish farmers have experience of growing of catch crops because catch crops are a mandatory part of the implementation of the Nitrate Directive in Denmark since the late 1980-ties. And, the case of Denmark implies that there is a confidence about the environmental and farm-level benefits of catch crops. There is no directly targeted agri-environment support for catch crops also in Estonia, though catch crops are supported as one of the environmentally friendly practices along other agricultural crops on arable land serving as a plant cover. A single targeted agri-environment measure for catch crops per country is available in Lithuania and Sweden. In Lithuania, the support for catch crops has been introduced only in 2018. In Poland and Finland, support for catch crops is provided in a directly targeted and in an indirect way. In Bavaria, along a targeted measure, growers of catch crops can benefit also in some specific cases.

To summarize, on the contrary to the EFA, catch crops under the agri-environment and climate action have to be maintained till spring in all analysed countries, with the exception of Finland and Sweden, and it is generally common that the use of plant protection products and also fertilisers is prohibited on catch crops. Different approaches are used at the national level for listing catch crops eligible for agri-environmental support. In some countries (e.g, Lithuania, Sweden and Poland) the list of crops is rather closed, while in Finland the choice is left to farmers for picking the most suitable crops to the local conditions. This could depend on the objectives set in each country for the specific agri-environment measure. The more directly the support is targeted at catch crop benefits, the more precise list of supported crops and higher support rate is applied.

Table 6. Catch crops within agri-environment and climate measures of RDPs 2014-2020 in the Baltic Sea region countries (source: based on the information from national RDPs 2014-2020 and the support requirements available from the national agricultural support paying agencies)

Country	Name of the measure	Crops	Support rate	Supported area	Min area	Sowing - termination date
Latvia	-	-	-	-	-	-
Lithuania	*Growing of catch crops on arable lands*	oil radish, white mustard, clover, vetch and their mixtures	134 EUR/ha	arable land	-	by September 15 - after March 1
Estonia	*Support for environmentally friendly management (10.1.1)* - main activity (package of management requirements); - additional activity of water protection (one-year)	agricultural crops providing plant cover	- 50 EUR/ha; - 5 EUR/ha	arable land	- 30%; - 50%	by November 1 - after March 31
	Regional water protection support (10.1.2), 1) keeping land under winter vegetation (+ Support for environmentally friendly management (main activity))	agricultural crops providing plant cover	7 EUR/ha (+ 50 EUR/ha)	arable land in Nitrate Vulnerable Zones	60%	by November 1 - after March 31
Poland	*Sustainable agriculture (Package 1)*, one of the requirements for land use	intercrops	400 PLN/ha (93 EUR/ha)	arable land	-	by October 1 - from February 15
	Protection of soils and waters (Package 2), Intercrops (Variant 2.1)	mixture of a minimum of 3 plant species (max 70% for dominant plant or cereals)	650 PLN/ha (151 EUR/ha)	arable land in target area[1]	-	by September 15 - from March 1
Finland	*Plant cover on arable land in winter (07)* (+ Balanced use of nutrients (01))	agricultural crops providing plant cover (including catch crops)	from 4 EUR/ha to 54 EUR/ha[2] (+ 54 EUR/ha)	arable land in target region and other regions	20%[3]	-
	Biodiversity in arable land environments (09), catch crops (+ Balanced use of nutrients (01))	catch crops (under-sowings, intercrops)	100 EUR/ha (+ 54 EUR/ha)	arable land	-	by August 15 - from October 1
Sweden	*Reduced nitrogen leakage*, activity - cultivation of catch crops	forage grass or forage grass in mixture with forage legumes (max 15%); white mustard; oilseed radish or radish; rye (autumn) or Italian ryegrass	1,100 SEK/ha (107 EUR/ha)	arable land in Nitrate Vulnerable Zones	-	no specific dates[4] - from October 10 (forage grass, white mustard and radish); from January 1 (rye and Italian ryegrass)
Denmark	-	-	-	-	-	-
Germany (Bavaria)	*Winter greening with catch crops/wild crops (B35/B36)*	catch crops (under-sowing, intercrops); wild crops (approved seed mixtures - wildlife-friendly catch crops)	70 EUR/ha; 120 EUR/ha	arable land	at least 5%; max 10 ha for wild crops	by October 1 - after February 15

[1] areas particularly at risk of water erosion, problem areas with low humus content and areas particularly exposed to nitrates from agricultural sources
[2] 4 EUR/ha, if plant cover is 20%; 18 EUR/ha in the target region and 9 EUR/ha in other regions, if plant cover is 40%; 36 EUR/ha in the target region and 11 EUR/ha in other regions, if plant cover is 60 %; 54 EUR/ha in the target region, if plant cover is 80%
[3] may be implemented also by reduced tillage; in other areas, plant cover may be implemented in full with reduced tillage
[4] catch crops should be able to develop well and pick up nitrogen after harvesting the main crop

Cost-benefit assessment of catch crop application in Venta and Lielupe RBDs

Cost-benefit assessment of catch crop application covered assessment of the following effects, brought not only to a farmer, but to a whole society:

- Reduction of nutrient leaching
- Nutrient transfer to the next crop
- Increase soil organic carbon content
- Reduction of soil erosion
- Reduction of GHG emissions
- Control of weeds.

It is important to note that effects of catch cropping and thus costs and benefits thereof depend on the specifics of the farm, farmer's preferences, attitudes, the field, catch crop types, main crop species, soil, weather, climatic conditions, management, pest pressure and other things.

Most costs and benefits of catch cropping are "off-site". It means that the greatest part of costs/benefits are paid/received by a society.

Some of effects (such as improvement of soil health, soil organic matter) the catch crops provide are slow processes and hard to observe in a short time period, they take some time to be measurable. The benefits in these cases are also slow and hard to see; they vary year to year, depending on the weather. Ideal cost/benefit analysis should take these processes into account as well, however, cost and benefit assessment made for the Venta and Lielupe river basins could not take specificity of a farm and the time aspect into account. The monetary results represent averaged values and can vary, depending on various conditions, considerably. The main objective of this analysis is to demonstrate what are the catch cropping merits to a farmer and a society in general and provide order of magnitude of potential annual costs and benefits.

Cost assessment

Cost assessment of catch cropping is based on prices of seeds of the catch crops, seeding rates and costs of machinery and equipment of catch crop establishment and termination. Unit costs of catch crop application in Lithuania and Latvia vary from 34 to 210 Eur/ha. Average annual unit cost makes around 120 Eur/ha in Lithuania (2019) and around 100 Eur/ha in Latvia (2017).

Two types of areas were used for the catch cropping cost (and benefit) assessment for sub-basins and basins of Lielupe and Venta:

1) potential for catch cropping and
2) areas at risk (where, according to the requirements of the Water Framework Directive, nitrogen concentration limit is exceeded).

Annual costs of catch crop application in potential areas, as well as in the areas at risk, of each Lielupė and Venta basin/sub-basin were calculated multiplying number of hectares of potential for catch cropping areas or areas at risk in each basin/sub-basin by unit cost of catch crop application. In many cases minimal and maximal costs of certain catch crop application were calculated, though comparison with benefit figures was made using average cost figures.

If catch cropping was to apply only in potential areas at risk, the annual costs, depending on cost of its components, would amount to approx. MEUR 5.8 - 9.7 in Lielupe river basin and approx. MEUR 0.8 - 1.3 in Venta river basin. These costs are about 1.7 times less than costs of catch cropping in all potential areas in Lielupe river basin and even 8 times less than costs of catch cropping in all potential areas in

Venta river basin. The latter is explained by the fact that in Venta basin only 12% of potential for catch cropping area is area at risk.

Benefit assessment

Benefits which catch cropping provides can be distinguished as:

- Direct financial benefits to farmers
- Economic (environmental / social) benefits to a whole society.

Catch crops can positively affect yields by storing nutrients in the soil, helping to supress weeds, reducing soil erosion, i.e., mainly decreasing the need to apply fertilisers and herbicides. Such financial benefits to farmers are calculated in monetary terms mainly via savings due to smaller amount of fertilisers and herbicides needed.

Environmental (social) benefits are calculated using values from assessments of ecosystem services and, in the case of GHG emissions reduction, using CO_2 price from the European Emission Allowances system. In Lithuania and Latvia, there are only a few studies / surveys carried out, which assessed ecosystem services (mostly water resources quality related). Some valuations of ecosystem services, relevant to catch cropping, are available in European countries. These estimates were applied, using simplified benefit transfer.

Potential to reduce nutrient leaching; Nutrient transfer to the next crop

Direct financial benefits of these catch cropping effects are calculated via reduced purchase of fertilisers. Environmental (social) benefits are calculated via reduction of eutrophication.

Potential to increase soil organic carbon content

Direct financial benefits are calculated via reduced purchase of fertilisers. Environmental (social) benefits the SOC contributes to a society is correlated with changes in soil biodiversity and the generation of supporting ecosystem services. Potential average benefit is assessed using multiple literature sources.

It should also be stressed that economic (social, environmental) benefits of reduction of soil degradation, i.e. increasing soil organic carbon and organic matter, are much more substantial than financial ones (i.e. to a farmer). Moreover, it is very important that the benefits will be stronger over time, as the impacts are cumulative. The latter aspect, however, is not reflected in our assessment.

Catch crop potential to reduce soil erosion

Direct financial benefits are calculated via reduced purchase of fertilisers. Environmental (social) benefits are assessed using averages from multiple literature sources on the values of ecosystem services provided by soil. Moreover, two types of calculations are presented – based on value per ha and based on value per tonne of soil saved.

Reduction of GHG emissions

Direct financial benefit of climate change mitigation to a farmer is practically non-existent. Catch crops play an important role in mitigating the effects of climate change and this is benefit to a whole society (including a farmer). Two methods of environmental (social) benefit assessment are applied: using a CO_2 European Emission Allowances related price of CO_2 and monetary assessment of ecosystem services of soil, which covers broader spectrum of services, but includes the climate change mitigation service.

Control of weeds

Direct financial benefit to a farmer is calculated via reduced purchase of herbicides and environmental (social) benefits are assumed to be reflected under the benefits which soil organic carbon delivers to a society. Moreover, financial benefit is are calculated using two strategies: 1) assuming the catch cropping allows a farmer to use reduced dose of herbicides and 2) assuming the catch cropping replaces herbicides. Total financial benefits to all farmers of Lielupe and Venta RBDs are not assessed, as exist too many variables affecting the potential of catch crop control of weeds.

Summary monetary assessment

In benefit/cost analysis the assumption is made that costs of catch cropping are the same (average) when considering different effects of catch crops. Benefits, however, differ, and in our assessment are calculated per each effect catch cropping brings.

Comparison of annual costs and benefits allows to see what effects the catch crops bring mean the highest benefits to farmers and to a society, taking into consideration assumptions taken. As noted, these are averages and results, depending on concrete conditions, can vary considerably, thus one needs to tread them cautiously.

Table 7. Costs of catch cropping and financial benefits to farmers, MEUR/year

River basin / sub-basin	Annual costs	Savings of farmers
	In potential for catch cropping areas	Reduced amount of fertilizers (savings of nutrients)
Lielupe RBD	**13.6**	**2.8**
- Lielupe LT	8.6	1.8
- Lielupe LV	5.0	1.0
Venta RBD	**8.5**	**1.8**
- Venta LT	3.7	0.8
- Venta LV	4.8	1.0
Total for LT	**12.3**	**2.6**
Total for LV	**9.8**	**2.0**
Total	**22.1**	**4.6**

**-note that no payments according to agricultural support programmes to farmers are considered in these calculations*

Table 8. Costs of catch cropping and environmental (social) benefits in potential for catch cropping areas, MEUR/year

River basin / sub-basin	Annual costs in potential for catch cropping areas	Environmental (social) benefits due to			
		Increase of soil organic carbon, weed control	Soil erosion reduction (based on value per ha)	GHG emission reduction (based on value per ha)	GHG emission reduction (based on value per tonne of CO_2)
Lielupe RBD	**13.6**	**322.9**	**24.4**	**422.3**	**4.6**
- Lielupe LT	8.6	209.0	15.8	273.4	3.0
- Lielupe LV	5.0	113.9	8.6	149.0	1.6
Venta RBD	**8.5**	**205.2**	**15.5**	**268.4**	**2.9**
- Venta LT	3.7	91.7	6.9	119.9	1.3
- Venta LV	4.8	113.5	8.6	148.5	1.6
Total for LT	***12.3***	***300.6***	***22.8***	***393.3***	***4.3***
Total for LV	***9.8***	***227.4***	***17.2***	***297.5***	***3.2***
Total	***22.1***	***528.1***	***40.0***	***690.8***	***7.5***

Some effects and benefits of catch cropping can be assessed applying only potential areas at risk. Such are nutrient leaching reduction and nutrient transfer to the next crop benefits.

Table 9. Costs of catch cropping and environmental (social) benefits in potential for catch cropping areas at risk, MEUR/year

River basin / sub-basin	Annual costs in potential areas at risk	Environmental (social) benefits due to				
		Nutrient leaching, nutrient transfer to the next crop	Increase of soil organic carbon, weed control	Soil erosion (based on value per ha)	Soil erosion (based on value per tonne)	GHG emission reduction (based on value per ha)
Lielupe RBD	**7.8**	**4.2**	**184.9**	**14.0**	**1.8**	**241.9**
- Lielupe LT	6.0	2.0	145.0	11.0	1.1	189.6
- Lielupe LV	1.8	2.3	40.0	3.0	0.7	52.3
Venta RBD	**1.0**	**1.5**	**24.4**	**1.8**	**2.3**	**31.9**
- Venta LT	0.5	0.2	13.5	1.0	1.2	17.7
- Venta LV	0.5	1.2	10.9	0.8	1.1	14.2
Total for LT	***6.5***	***2.3***	***158.5***	***12.0***	***2.3***	***207.3***
Total for LV	***2.3***	***3.5***	***50.8***	***3.8***	***1.8***	***66.5***
Total	***8.8***	***5.8***	***209.3***	***15.8***	***4.1***	***273.8***

Monetary cost benefit analysis of reduction of *nutrient leaching and nutrient transfer to the next crop* shows that costs of catch cropping in potential for catch cropping areas at risk exceed environmental benefits calculated as a proportion of overall benefit of the reduction of eutrophication only in the Lithuania part of the Lielupe RBD. Sum of financial and environmental benefits is smaller also only in the Lithuanian part of the Lielupe RBD; catch cropping seems to be beneficial in Venta RBD. This is primarily due to a comparatively small area of water bodies at risk in Venta RBD (thus costs are small) and high (up to 75%) potential nutrient reduction target achievement ratio due to catch cropping in Latvia. In general, Latvia has got better (more than 1) benefit / cost ratio.

If soil ecosystems valuation figures per ha are applied, soil ecosystem services seem to create huge benefits for *climate regulation, soil erosion reduction, weed control and increase of SOC / SOM*. Environmental (social) benefits per year considerably exceed not only costs of catch cropping in areas at risk, but also costs in potential areas. If soil ecosystems valuation per tonne of CO_2 is applied, annual costs of catch cropping in potential areas exceed benefits assessed in all sub-basins of Lielupe and Venta. Brief sensitivity analysis shows that if price of CO_2 increases almost 3 times, benefits become equal to costs.

It should be stressed again that the assessments made are very sensitive to various conditions, so the figures should be treated cautiously. In order to have more reliable benefit values, it is recommended to conduct ecosystem services valuation studies both in Lithuania and Latvia. Such studies would not only provide specific scientific information, describe the attitude of the general public to water resources, their management and priorities, but also, they would be a very important measure of strengthening public awareness of environmental aspects in agricultural sector. In addition, these studies would promote cooperation among ecologists, biologists, economists, agricultural specialists and decision makers.

Action plan and recommendations for catch crop support in Lithuania and Latvia

The analysis performed by the project has shown that when established properly catch crops, along with environmental effects, can provide a range of economic benefits to farmer. Success and effectiveness of catch cropping depends on a number of factors, such as climatic conditions, proper choice and management of crops.

It has to be admitted that under the local climatic conditions there is a rather big uncertainty regarding catch crop effects. In some years, upon extreme or unfavourable weather conditions, possibilities for effective establishment of catch crops might be pretty limited. Moreover, application of catch crops is a rather new and challenging task for Lithuanian and Latvian farmers as they still lack skills and knowledge regarding the growing technologies and potential effects.

Establishment of catch crops is related to additional costs which in the short-term perspective often do not overweight benefits gained by the farmer, but catch crops always provide some valuable ecosystem services (e.g. increase and support biodiversity, improvement of soil status). For this reason, application of catch crops should first of all be seen as farmers' contribution to a number of valuable ecosystem services and for the provided services farmers should receive a financial support. To encourage a wider application of catch crops, farmers need not only financial but also educational support extending their competences and confidence in the field.

Common Agricultural Policy (CAP) plays a fundamental role in supporting implementation of environmental measures in agriculture. However, despite of all EC efforts of better integration of environmental considerations into CAP, implemented measures so far have been not sufficiently effective and did not contribute to achievement of environmental goals enough. To become a more responsive to current and future challenges, CAP is planned to undergo a reform after 2020. For the next financing period of 2021 – 2027, EC sets high ambitions on environmental and climate change. As a minimum 30-40% of the CAP Pillars funding, Member States will have to allow for environmental and climate goals. New *Green architecture* is planned to be implemented in CAP after 2020. So, under CAP 2021 – 2027, EU countries will further support and incentivise farmers to observe agricultural practices beneficial for the climate and the environment.

In the context of increasing environmental concerns and ambitions of CAP, application of catch crops is recommended to be one of the measures supported under CAP 2021 – 2027 both in Lithuania and Latvia as an efficient means for achievement of environmental objectives especially in the area of water quality protection. CAP 2021-2027 support should promote and facilitate wider application of catch crops and education of farmers in the field. Current support schemes for catch crops in Lithuania should be maintained and extended but the measure should be better targeted and additional requirements and restrictions should be introduced to increase its efficiency. In the same way in Latvia, it is necessary to introduce the support schemes for cultivation of catch crops. Both countries should continue research and improve catch cropping technologies on the basis of the best available knowledge.

In future (e.g. beyond 2027), when sufficient knowledge is built, a mandatory application of catch crops could be considered as an environmental tax for the most intensive farming systems to compensate their threat to environment. However, in the upcoming CAP financial perspective of 2021 - 2027, CAP support should be utilised as much as possible to increase the level of farmers preparedness and attractiveness and acceptance of the measure.

Below recommendations of the project experts for improvement of catch crop support scheme in order to make it better targeted and more efficient in achieving water pollution reduction goals are provided.

Measures to be supported and support mechanism

Analysis of catch crop effects suggests that not all catch crop responses are seen immediately or following the first time of use. Catch cropping is likely to require some long-term commitments to start to see the full benefits[2]. For this reason, short term commitments which are possible under the eco-schemes are not expected to be sufficiently efficient. Thus, the support for catch crops in Lithuania beyond 2020 should be continued under Agri-environment and Climate scheme of the RDP by contracting farmers for minimum 5 years. In Latvia, the support for catch crops should be introduced under Agri-environment and climate or Eco scheme for the next CAP period from 2021.

In Lithuania, the existing measure under Agri-environment and climate scheme of the RDP should be maintained but in order to increase its contribution to achievement of water quality goals its implementation scale has to be considerably extended and additional requirements for the management introduced. On the other hand, any excessive requirements should be avoided and support mechanism should contain a larger degree of flexibility to make catch cropping easier to implement and attractive to farmers.

In order to ensure environmental effectiveness of the supported catch crop measure, to promote the use of appropriate farming practises that mitigate management risks and possible failures, and to apply new knowledge in the farming practices, it is necessary to provide farmers that apply for the support of catch crops with the minimum training on the environmental effects, costs and benefits of catch crop establishment, as well as on appropriate practical agrotechnology necessary for achieving desired environmental effect and prevention of management risks.

Thus, project experts envisage that support for catch crop establishment should be followed by mandatory education/ training of applicants. The Trainings related to catch crop issues should be made a part of the overall farmers training programme under Knowledge transfer and information actions of the RDP.

Scope and target areas for application of catch crops

In general, target areas for application of catch crops are those where growing of catch crops between two main crops for the period longer than 50 days is possible.

Though providing a range of environmental effects, catch crops should primarily be seen as a measure targeted at reduction of water pollution. Thus, implementation of the catch crop measure should first of all be focused on the most intensively cultivated agricultural areas that require substantial reduction of nutrient losses. Identification of the target areas should be done in close cooperation with the Ministry of Environment.

In Lithuania, it is proposed that target areas would be compliant with the catchments of water bodies at risk suffering from the elevated nutrient pollution from agriculture as delineated in the latest river basin management plans. In Latvia, catch cropping could also be targeted to Nitrates vulnerable zones if they are appropriately identified and approved by the national legislation. Currently, Nitrates

[2] *White, C.A., Holmes, H.F., Morris, N.L., and Stobart, R.M. 2016. A review of the benefits, optimal crop management practices and knowledge gaps associated with different cover crop species. Research Review No. 90.*

vulnerable zones in Latvia are different from the areas of water bodies at risk. It is proposed by the project experts that priority for implementation of the catch crop measure should be given to the basins water bodies at risk (*Figure 19*).

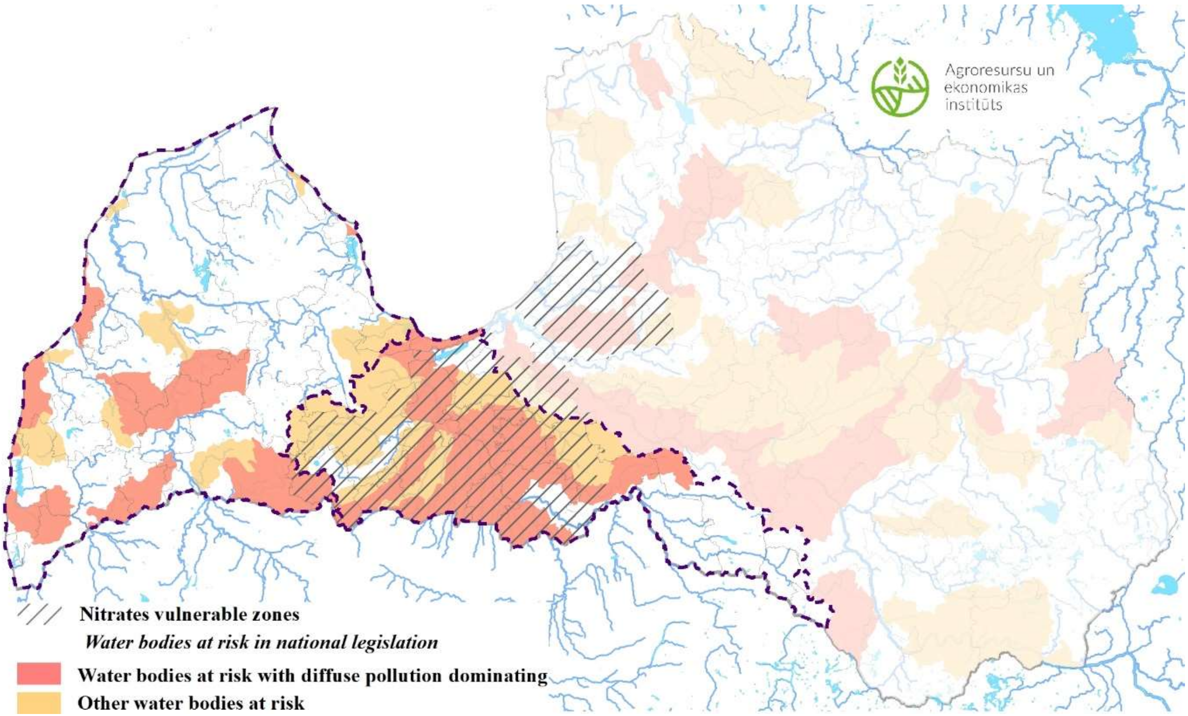


Figure 19. Possible target areas for measures of catch crops in Latvia.

Along with retention of nutrients, catch crops provide a much wider spectrum of environmental benefits and can be useful not only in the areas sensitive to elevated nitrogen leaching. Thus, it is reasonable to support establishment of catch crops in the entire territory of Lithuania and Latvia. In order to ensure desired effect with respect to reduction of nutrient pollution, implementation of the measure should be differentiated by setting special, stricter requirements for target areas.

To avoid fractional implementation of the measure that results in very little effect, the minimum area for catch crop support in the farms operating in the target areas (i.e. basins at water bodies at risk) should make at least 15 % of the farms arable land area. Assessment of potential for growing of post-harvest catch crops demonstrates that this percentage should be easily achieved in most of crop production farms.

In non-target areas, special requirement for the minimum mandatory implementation area is not needed.

Farms in the target areas should be given first priority to access the support for catch cropping. Depending on the national approach for implementation of agri-environmental measures, the support rate in the target areas could be higher than in non-target areas. Such approach would also ensure a more targeted use of funding.

Catch crops in the farm every year can be grown in different fields. Due to unfavourable conditions, establishment of catch crops may turn out not reasonable in some years. To avoid establishment that brings no or minor environmental effect, percentage of the land devoted for catch crops may be allowed to vary in different years so that the contracted area is reached by the end of the contract period (e.g. supported area of catch crops each year could vary within 20%).

Crops to be supported as catch crops

After summarising project experts' proposals regarding suitable catch crops in Venta and Lielupe RBDs and the list of crops currently supported as catch crops under the RDP Agri-environment and climate measure in Lithuania, the following list of potential catch crops can be derived:

Brassicas:

- white and brown mustard,
- spring and winter rape,
- oil (forage) and root (tillage) radish,
- winter turnip rape.

Leguminous:

- winter vetch,
- pea,
- bean,
- blue bitter lupine,
- white and red clover,
- *white melilot,*
- *alfalfa,*
- *birds-foot trefoil,*
- *seradella*

Grasses/ cereals:

- winter rye,
- Italian ryegrass,
- oat and black oat,
- *perennial ryegrass*
- *cock's foot.*

Other:

- buckwheat,
- phacelia,
- *sunflower.*

Some of these crops (e.g. cock's foot, perennial ryegrass, birds-foot trefoil) are more suitable for growing as undersow. If sown after the harvest they produce little biomass and possess a relatively low potential to capture excessive nitrogen from the soil. Moreover, practical experiences about growing of some catch crops (e.g. sunflower, seradella, birds-foot trefoil) is still lacking both in Lithuania and Latvia. Therefore, in the target areas, where reduction of nutrient pollution is of the prime importance, growing of such catch crops (they are written in Italic) is not reasonable. For larger crop diversity, those crops are only recommended to be supported in non-target areas.

Crops that are selected by the farmer for catch cropping should differ from the main crops grown before and after them, so that, in addition to the nitrogen uptake, catch crops would also act as a crop rotation element and promoter of biodiversity. Crops from the prescribed list of crops can be grown as a single crop or in mixtures composed of 2 or more crops of the different families.

To facilitate higher effectiveness of the measure with respect to reduction of nutrient leaching, catch crops having the largest nitrogen retention capacities should dominate in the target areas. Of all recommended crops, nitrogen retention potential of brassicas (mustards and radishes) and phacelia is the largest. Considering this, it is recommended to set the requirement that in the target areas at least 30% of the catch crop support area is devoted for mustards/ radishes/ phacelia when catch crops are grown either as single crops or in mixtures. Areas of leguminous crops which have the lowest nitrogen retention capacity should make no more than 15% of the catch crop support area in target areas. It is recommended that leguminous in the target areas would be grown in mixtures only.

Management requirements

Timely establishment of catch crops is very important them to grow sufficient biomass and achieve the largest nutrient retention rate. Late sown crops do not produce sufficient biomass and not ensure efficient utilisation of excess nutrients. For this reason, we propose sowing time of catch crops in the target areas to be no later than August 20, but optimal sowing time is until August 15. In non-target areas or in Eco-schemes later sowing (e.g. by September 15 as it is now in Lithuania) may be allowed. Then, later sown crops will act as winter cover crops but not as nitrogen trapping catch crops.

Farmers should ensure sufficient catch crop biomass production. For this, catch crops have to be sown with at least minimum sowing rate as provided in the table below.

Table 10. Recommended minimum sowing rates of catch crops

Crop	Minimum sowing rate when sowing as a single catch crop, kg/ha
White mustard	8
Brown mustard	5
Spring rape	10
Winter rape	8
Oil (forage) radish	12
Root (tillage) radish	10
Winter turnip rape	7
White clover	8
Red clover	15
Winter vetch	45
Pea	150
Bean	180
Blue bitter lupine	100
Winter rye	70
Italian ryegrass	20
Oat and black oat	100
Buckwheat	40
Phacelia	7
Alfalfa	*20*
Sunflower	*40*
Seradella	*40*
Cock's foot	*12*
White melilot	*20*
Perennial ryegrass	*20*
Birds foot trefoil	*10*

To calculate sowing rates for species mixtures, the monoculture sowing rate for each species must be multiplied by the proportion desired in the mixture. In some cases, the sowing rate can be increased by 20% to ensure proper cover development.

Support for catch crops should not be restricted exclusively to crops sown after the harvest of the main crop. Harvest of some main crops may in some cases be delayed beyond August 20 and that limits timely establishment of postharvest catch crops. To extend catch cropping potential, farmers should be allowed to sow catch crops into the main crops (e.g. winter triticale, spring barley, spring wheat, oat) 2-3 weeks before their harvest. Catch crops can be sown by broadcasting seeds with a standard sowing rate increased by 30%.

Catch crop residues should remain in the field until spring. Catch crop biomass plays an important environmental role, therefore its grazing or removal for forage would decrease an environmental effect. For this reason, the largest share of the catch crop biomass should be left in the field, its usage for forage should be prohibited.

Incorporation of catch crop residues has a number of demonstrated benefits: it increases soil organic matter content, crop yield, and soil aggregate stability, and enhances soil life. Requirement to incorporate residues in spring limit application of the measure in no-till farms. Hence these farms may be exempted from the requirements for residue incorporation.

Fertilization of catch crops in autumn, application of plant protection products or use of glyphosates for termination of catch crops in spring should be prohibited.

Farmers granted support for establishment of catch crops in the target areas should be obliged to make soil analyses in autumn and spring at least few times over the 5-year commitment period. The data of these analyses would later serve for the assessment of effectiveness of the measure.

Payment

The main objective of the agri-environment scheme of the RDP is to support farmers for adopting more environmentally friendly farming practices and providing valuable ecosystem services.

Regulation anticipates that support covers actual compliance costs. The payment is justified by the additional costs and/or loss of income (plus transaction costs) that the farmer has to bear due to the uptake of the measure. The possibility to award farmers a premium for the ecosystem services provided however is not foreseen.

It has been stated in a number of reports from the European Court of Auditors that pour targeting of agri-environmental measures is a serious weakness of the RDP in many member states. Payments for the practices that are not needed in the particular area for achieving specific objectives had been wasteful use of resources.

Current support system is based on a flat rate payments though differentiated payments would allow better targeting and more efficient implementation of agri-environmental measures. Scientists from UK, US, Denmark and European Commission's Joint Research Centre state that it is worth going for more individualised, complex schemes in spite of the much higher administrative costs implied by this approach. Indeed, they conclude that the additional implementation costs that accompany policies that account more fully for variation in the costs faced by landowners would be worth bearing even if they constituted more than 70% of the payments that would otherwise go to farmers[3.]

[3] http://capreform.eu/the-cost-of-flat-rate-agri-environmental-measures/

Compensation payment for catch crops in Lithuania is 134 Eur/ha. The measure is not targeted to any specific area, all farmers receive equal support. The payment covers

- compensation for the income lost due to reduced crop production resulting from adopting of environmental practices (66 Eur)
- additional costs for
  - sowing (5,62 Eur)
  - seed (39,31 Eur)
  - stubble cultivation (2.81 Eur)
- transaction costs (20 Eur).

Compensation for the lost income due to decreased crop production makes the largest share of the payment, though validity of this payment component is rather debatable as no reliable evidence exists that catch crops reduce production of later sown cash crops. Opposite, growing of catch crops often increase yield of the next crop and only when residue with low N content is incorporated yields of the next cash crop may decrease. This risk can be managed by proper selection of catch crops. Yet, production losses are also possible due to delayed sowing of the next crop. Here, it has to be taken into account that post-harvest catch crops are usually pre-crops for spring crops. So, if production losses are accounted for, only potential losses of spring crop yields have to be considered. Currently the compensation for lost income is estimated based on potential losses of winter wheat, barley and winter triticale yields. To better reflect real losses incurred by farmers due to establishment of post-harvest catch crops, it is recommended to revise the calculation for compensation of lost income taking into account potential losses of spring crop yields (e.g. summer wheat, summer barley, oat).

Additionally, it has to be admitted, that areas of river basins at risk which are supposed to be target areas for establishment of catch crops are dominated with fertile soils and intensive crop production. Based on the statistical data from 2014 – 2018, crop yields in these areas are approx. 30% higher than in the rest of the country. Respectively, income losses due to reduced crop yields in the target areas are also higher than elsewhere.

In this situation, payment which provides uniform compensation for reduced yield in all over the country is more attractive for farmers operating in less productive areas and is less attractive for those in the productive areas where real losses are higher and where implementation of the measure is needed most. To make the payment fairer, potential income losses have to be estimated individually for target and non-target areas. This would introduce some differentiation of the payment and make it more adaptive.

As agricultural activities in the target areas are intensive and result in large amounts of nitrogen being lost from the fields and transported into water bodies, the existing catch crop application potential is not sufficient to compensate for the negative effects of agriculture. In the target areas, farmers should be encouraged to establish larger areas of catch crops than the mandatory minimum.

Assessment of catch crop growing potential demonstrates that in the target areas it usually does not exceed 25 % of the arable land. Crop structure with a large share of winter crops (mainly winter wheat and winter rape) is a limiting factor for wider application of post-harvest catch crops. Considering current crop structure in the target areas, further extension of catch cropping potential will require some shifting from winter cereals to summer crops and larger crop variety. As winter crops are more profitable, this shift would result in income losses which have to be compensated. Income losses related to replacing winter cereals (such as winter wheat and winter rape) with spring crops (e.g. barley) can be an argument for higher payments for farmers extending catch crop areas beyond 25% of the farms arable land.

Also, in target areas farmers should be compensated for additional costs for soil analyses.

Considering the provided recommendations for calculation of the payment rate, there should be 3 tariffs of payment for catch cropping defined. The lowest payment rate would apply for establishment of catch crops in non-target areas, the medium rate – for catch cropping in the target areas when for catch crops from 15 to 25% of the farms' arable land area is devoted, and the largest rate – for catch cropping in the target areas when catch crops cover over 25% of the farms' arable land area.