Interreg Latvija–Lietuva

European Regional Development Fund

EUROPEAN UNION

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

(Project number: LLI-49, Project acronym: CATCH POLLUTION)

Cost and benefit analysis of catch crop application in Venta and Lielupe River Basin Districts

aplinkos apsaugos politikos centras
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2019

This report has been produced with the financial assistance of the European Union. The contents of this report are the sole responsibility of the Center for Environmental Policy (Lithuania), the Aleksandras Stulginskis University (Lithuania) and the Institute of Agricultural Resources and Economics (Latvia) and can under no circumstances be regarded as reflecting the position of the European Union.

Project implementation period: April 1, 2017 – September 30, 2019
Project number: LLI-49
Project acronym: CATCH POLLUTION
Project budget: 201 845 EUR
ERDF funding: 171 568 EUR
Project supported by Interreg V-A Latvia-Lithuania Cross Border cooperation programme 2014-2020
http://www.latlit.eu/
More info: www.europa.eu

Contents

Abbreviations

AAPC	Aplinkos Apsaugos Politikos Centras (Center for Environmental Policy)
AMF	Arbuscular mycorrhizal fungi
AREI	Institute of Agricultural Resources and Economics
ASU	Aleksandras Stulginskis University
CC	Catch crop
id$	International dollar
LIAE	Lithuanian Institute of Agricultural Economics
LTL	Lithuanian Litas
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
RBD	River Basin District
USD	United States dollar
WTP	Willingness to Pay

List of Tables

List of Figures

1. Introduction

Effects of catch crops (CC), seeded in between of planting of main crops, are described in the separate report of the Project (Report on task *AT1.1. Quantification of the expected nutrient retention rates and other environmental effects*).

The report at hand presents potential costs and benefits of cultivation of the catch crops in the Venta and Lielupe RBs. Results of this Task are directly used in the Decision Support Tool[1], which allows farmers to better understand how much catch crops' application could cost and what benefits they can provide.

The following effects, brought to the society by the catch crops, are analysed in this Project:

- Potential to reduce nutrient leaching
- Nutrient transferring for the next crop
- Potential to reduce GHG emissions
- Potential to increase soil organic carbon content
- Effects associated with control of pests and diseases
- Catch crop potential to reduce soil erosion.

The following catch crops (cover crops) are assessed in terms of the costs and benefits, which their application provides:

- White mustard (*Sinapis alba L*);
- Brown mustard (*Brassica juncea (L.) Czern.*);
- Spring rape (*Brassica napus L. ssp. Oleifera*);
- Winter rape (*Winter rape L*);
- Oil radish (*Raphanus sativus L*);
- Root radish (*Raphanus sativus*);
- Turnip (*Brassica rapa subsp. rapa*);
- Winter rye (*Secale cereale L*);
- White clover (*Trifolium repens L*);
- Red clover (*Trifolium pratense L*);
- White melilot (*Melilotus alba L*);
- Italian ryegrass (*Lolium multiflorum*);
- Perrenial ryegrass (*Lolium perenne L.*);
- Phacelia (*Phacelia tanacetifolia Benth.*);
- Cock's foot (*Dactilis Glomerata*);
- Oat & Black oat (*Avena sativa L & Avena strigosa L.*);
- Buckwheat (*Fagopyrum esculentum Moench*);
- Winter vetch (*Vicia villosa Roth*);
- Pea (*Pisum sativum L*);
- Blue bitter lupin
- Faba bean (Vicia faba).

[1] Developed under the Project at hand

This report was elaborated by experts of the Center for Environmental Policy with input from the agricultural experts of the Aleksandras Stulginskis University (ASU) and the Institute of Agricultural Resources and Economics (AREI).

Catch crops are considered one of the most effective in-field practice farmers can use to reduce contamination of surface and groundwater resources. Also they contribute to the solution of other environmental problems, such as climate change, soil degradation, erosion and other. Moreover, catch crops can provide eco-system services beyond nutrient retention and erosion control. For example, as described in M.E. Schipanski et al. (2014), in the simulation of two cropping systems, cumulatively across the 3-year crop rotation, catch crops increased the provisioning of 8 of the 11 ecosystem services relative to the system without catch crops. Catch crops increased almost all supporting and regulating services, including biomass production, N supply, soil C storage, NO3 retention, erosion control, weed suppression, Arbuscular mycorrhizal fungi (AMF) colonization, and beneficial insect conservation. The exceptions were insect pest suppression and N2O reduction, which were not different or decreased, respectively, in the CC system. Such frameworks provide the means to quantify ecosystem services and facilitate the transition to more multifunctional agricultural systems.

Using examples as above and other references we endeavour to incorporate assessment of ecosystem services in our analysis of benefits catch crops provide to the environment.

Before providing our methodology, used for the cost benefit analysis of the application of certain catch crops, a few aspects need to be stressed, which basically show how distinctive is the catch crop economics:

- Costs and benefits of catch crop usage depend on the specifics of the farmer, his preferences, attitudes (e.g., what agro-ecological knowledge he/she has), the farm, the field, catch crop species, main crop species, soil, weather, climatic conditions, management, pest pressure and other things. Effectiveness of a catch crop depends also on how careful is its management.
- Most costs and benefits of catch crop usage 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 a while to be measurable. The benefits in these cases are also slow and hard to see; they vary year to year, depending on the weather. Cost/benefit analysis should take these processes into account as well.

2. Cost Assessment of Catch Crop Application

2.1. Methodology for Cost Assessment

Cost assessment of application (establishment) of catch crops is quite straightforward. There are direct and indirect costs of catch crop application.

Direct costs:

- Seed
- Establishment
- Termination

Value of time requested to acquire knowledge about catch crops and manage them (managerial costs) could also be considered to be direct costs.

Indirect costs can appear when problems arise: deplete soil moisture, slower soil warming, delayed N release, less flexibility, increased probability of lower yields etc.

The costs of catch crop application depend on many factors including the previous crop, next crop, tillage system, pesticide practices, catch crop species, catch crop planting method, weather conditions etc. Nevertheless, most of the costs associated with the catch crop are in its establishment, which includes planting and seed costs.

The main cost elements to be estimated are as follows:

- cost of seeds;
- cost of machinery and tools for sowing the catch crop;
- cost of machinery and tools for termination of the catch crop;
- operational costs of machinery indicated above;
- labour costs.

In the study at hand we do not account for the value of time requested to acquire knowledge about catch crops and manage them.

In Lithuania, seeding methods and seeding rates were obtained from the project partners from the Aleksandras Stulginskis University (ASU). Information on prices of seeds was obtained from the Lithuanian Agricultural Information and Rural Business Center, companies supplying seeds to the market, i.e. Agrolitpa, Dotnuva Baltic, Kauno grūdai and Scandagra. These sources were contacted either by phone or by email. Final cost calculation was carried out using average prices of seeds.

Catch crops depending on their type can be seeded using different methods – drilled or broadcasted. Usually seed producers provide minimum and maximum seeding rates. Different seeding rates have to be applied using different seeding methods. Based on consultations with partners from the Aleksandras Stulginskis University, average seeding rate was chosen for the majority of catch crops covered under the current project; mostly drilling method can be applied for them. Minimum and maximum seeding rates were chosen only for white and brown mustard and spring rape as these crops can be seeded using both drilling and broadcasting methods.

There are several possible options of the use of machinery and equipment for the catch crop sowing and termination:

- Catch crop seeds can be drilled or broadcasted using seeders with or without soil cultivation, direct sawing seeders or shallow stubble cultivation.
- Catch crop termination can be carried out using disc harrowing, shallow stubble cultivation, rolling or ploughing.

Indicated operations need a tractor, special equipment, fuel and labour.

Information on the costs of use of related machinery and equipment were obtained from the publications of the Lithuanian Institute of Agrarian Economics (LIAE):

- Mechanised agricultural services. Part I. Basic tillage works. 2017;
- Mechanised agricultural services. Part II. Crop care and hay cutting works. 2017.

Costs in the LIAE publications represent total annual machinery and operational costs including tractor and equipment use, repair works, technical maintenance, fuel consumption and labour (including taxes).

Data provided in the LIAE publications vary based on the field size, tractor's capacity and the machinery working width. It should be emphasised that details for the calculation of this total annual cost were not available for the experts of the Project at hand.

According to experts from the ASU and the LIAE, project area (Lielupe, Venta river basins) from the Lithuanian site is dominated by 10 ha fields where catch crops could be cultivated. The most suitable tractor capacity for the majority of works in such size fields is 120 kW, thus it was decided to choose costs of the machinery of the capacity equal or close to the indicated.

In Latvia, the same approach and assumptions were used for catch crop direct cost calculation. Information on prices of seeds was obtained from the Gross Margin Calculation for 2017 (available: www.llkc.lv) and seed-selling company SIA "Latvijas šķirnes sēklas". In case of brown mustard, root radish and turnip seed, prices were taken from Lithuanian seed market observation, because it appeared that there is no seed offer for the mentioned crops in Latvia at the moment.

Information on the costs of the related machinery and equipment used in case of Latvia was obtained from experts of Latvian Rural Advisory and Training Centre, based on special request for information. The price used in the direct cost calculation shows the average cost-price (except company's profit) of the agro-technical service available in the market for Latvian farmers in 2017.

Total annual costs of catch crop application per ha are calculated as:

$$C_{total} = C_{seed} + C_{sowing} + C_{termination}$$

where:

C_{total} – total cost of catch crop application, EUR/ha/year;

C_{seed} – catch crop seed cost, EUR/ha/year;

C_{sowing} – cost of catch crop sowing, EUR/ha/year;

$C_{termination}$ – cost of catch crop termination. EUR/ha/year.

2.2. Unit Costs of Catch Crop Application

As described in Chapter 2.1 on the Methodology of cost calculation, costs of seeds may be calculated for three scenarios. Costs of seeds per hectare according to different seeding rate and different seed price are presented below (Table 1, Table 2).

Average seeding rate is selected for further calculations of total annual costs, except for White mustard, Brown mustard and Spring rape, for which minimum and maximum seeding rates are used for further calculations. The latter depends on the machinery used for sowing - only these catch crops can be sown using the Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW).

Costs of the machinery (various possible combinations) and related cost items for establishment and termination of the catch crops for Lithuania and Latvia are provided in Annex 1.

As indicated in Chapter 2.1, resulting annual costs per ha of establishment and termination of catch crops include catch crop seed cost, and catch crop sowing and termination cost. It was also indicated above, that different sowing and termination methods can be applied for certain catch crops. Ranges of unit costs of combinations of catch crop application (taking into account different sowing and termination methods) are presented in Table 3 and Table 4.

As seen from tables, 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). Approx. 20% difference is due to different year, for which seed prices were collected, and the agricultural market peculiarities in Lithuania and Latvia.

Table 1. Data on cost of catch crop seeds per hectare in Lithuania, 2019

Catch crop	Latin name	Seeding rate, kg/ha			Seed price, EUR/ kg	Cost per hectare according to different seeding rate , EUR/ ha		
		min	max	average		min	max	average
White mustard	Sinapis alba L	10	15	12.5	1.8	17.8	26.7	22.3
Brown mustard	Brassica juncea (L.) Czern.	5	10	7.5	3.3	16.5	33.0	24.8
Spring rape	Brassica napus L. ssp. Oleifera	10	20	15.0	1.5	15.0	30.0	22.5
Winter rape	Winter rape L	8	20	14.0	1.5	12.0	30.0	21.0
Oil radish (Forage radish)	Raphanus sativus L	10	25	17.5	1.7	16.9	42.3	29.6
Root radish	Raphanus sativus	8	12	10.0	7.5	60.0	90.0	75.0
Turnip	Brassica rapa subsp. rapa	5	10	7.5	1.5	7.5	15.0	11.3
Winter rye	Secale cereale L	70	90	80.0	0.2	10.5	13.5	12.0
White clover	Trifolium repens L	8	10	9.0	6.0	48.0	60.0	54.0
Red clover	Trifolium pratense L	10	15	12.5	4.5	45.0	67.5	56.3
White melilot	Melilotus alba L	20	20	20.0	2.8	56.0	56.0	56.0
Italian ryegrass	Lolium multiflorum	20	30	25.0	1.7	34.0	51.0	42.5
Perennial ryegrass	Lolium perenne L.	20	25	22.5	2.4	47.2	59.0	53.1
Phacelia	Phacelia tanacetifolia Benth.	10	12	11.0	5.0	50.0	60.0	55.0
Cock's foot	Dactilis Glomerata	12	14	13.0	5.2	62.76	73.2	68.0
Oat & Black oat	Avena sativa L & Avena strigosa L.	100	120	110.0	0.6	63.0	75.6	69.3
Buckwheat	Fagopyrum esculentum Moench	40	70	55.0	0.8	32.0	56.0	44.0
Winter vetch	Vicia villosa Roth	30	50	40.0	1.2	35.4	59.0	47.2
Pea	Pisum sativum L	100	250	175.0	0.2	20.0	50.0	35.0
Faba bean	*Vicia faba*	180	220	200.0	0.3	50.4	61.6	56.0

Source: Agricultural Information and Rural Busness Center, Agrolitpa, Dotnuva Baltic, Scandagra, Kauno grudai for prices of seeds and calculations of the Author

Note: values that are used in further calculations are marked

Table 2. Data on cost of catch crop seeds per hectare in Latvia, 2017

Catch crop	Latin name	Seeding rate, kg/ha			Seed price, EUR/ kg	Cost per hectare according to different seeding rate , EUR/ ha		
		min	max	average		min	max	average
White mustard	Sinapis alba L	10	15	12.5	1.74	17.4	26.1	21.8
Brown mustard	Brassica juncea (L.) Czern.	5	10	7.5	4.60	23.0	46.0	34.5
Spring rape	Brassica napus L. ssp. Oleifera	10	20	15.0	0.35	3.5	7.0	5.3
Winter rape	Winter rape L	8	20	14.0	0.35	2.8	7.0	4.9
Oil radish (Forage radish)	Raphanus sativus L	10	25	17.5	1.74	17.4	43.5	30.5
Root4 radish	Raphanus sativus	8	12	10.0	7.50	60.0	90.0	75.0
Turnip	Brassica rapa subsp. rapa	5	10	7.5	6.50	32.5	65.0	48.8
Winter rye	Secale cereale L	70	90	80.0	0.12	8.19	10.5	9.4
White clover	Trifolium repens L	8	10	9.0	6.28	50.24	62.8	56.5
Red clover	Trifolium pratense L	10	15	12.5	3.97	39.7	59.6	49.6
White melilot	Melilotus alba L	20	20	20.0	3.22	64.4	64.4	64.4
Italian ryegrass	Lolium multiflorum	20	30	25.0	1.60	32.0	48.0	40.0
Perennial ryegrass	Lolium perenne L.	20	25	22.5	1.90	38.0	47.5	42.8
Phacelia	Phacelia tanacetifolia Benth.	10	12	11.0	2.98	29.8	35.8	32.8
Cock's foot	Dactilis Glomerata	12	14	13.0	3.39	40.68	47.5	44.1
Oat & Black oat	Avena sativa L & Avena strigosa L.	100	120	110.0	0.17	17.1	20.5	18.8
Buckwheat	Fagopyrum esculentum Moench	40	70	55.0	0.27	10.8	18.9	14.9
Winter vetch	Vicia villosa Roth	30	50	40.0	1.24	37.2	62.0	49.6
Pea	Pisum sativum L	100	250	175.0	0.26	26.0	65.0	45.5
Faba bean	*Vicia faba*	180	220	200.0	0.20	36.0	44.0	40.0

Source: Gross Margin Calculation for 2017 (available: www.llkc.lv), unpublishd data of LRATC, Latvijas šķirnes sēklas

Note: values that are used in further calculations are marked

Table 3. Unit costs of catch crop application in Lithuania, Eur/ha

Catch crop	Seed cost per hectare, Eur/ha	Percentage of seed cost in total price	Sowing and termination cost per hectare, Eur/ha	Percentage of sowing and termination cost in total cost	Total unit cost of catch crop application, Eur/ha
White mustard	20-30	29-60%	20-50	40-71%	50-70
Brown mustard	20-30	29-43%	40-50	57-71%	70
Spring rape	15-30	23-43%	30-50	57-77%	45-70
Winter rape	20	12-18%	90-140	82-88%	110-160
Oil radish	30	30-50%	30-70	50-70%	60-100
Root radish	80	50-73%	30-80	27-50%	110-160
Turnip	20	13-17%	50-70	83-88%	60-80
Winter rye	20	7-17%	50-140	83-93%	60-150
White clover	50	29%	120	71%	170
Red clover	60	33%	120	67%	180
White melilot	60	33%	120	67%	180
Italian ryegrass	40	25-44%	50-120	56-75%	90-160
Perrenial ryegrass	50	29%	120	71%	170
Phacelia	60	46-67%	30-70	33-54%	90-130
Cock's foot	70	33-37%	120-140	63-67%	190-210
Oat & Black oat	70	50-70%	30-70	30-50%	100-140
Buckwheat	40	36-57%	30-70	43-64%	70-110
Winter vetch	50	29-50%	50-120	50-71%	100-170
Pea	40	36-57%	30-70	43-64%	70-110
Faba bean	60	46-67%	30-70	33-54%	90-130

Source: Consultant based on market survey and LIAE and Latvian Rural Advisory and Training Centre publications

Table 4. Unit costs of catch crop application in Latvia , Eur/ha

Catch crop	Seed cost per hectare, Eur/ha	Percentage of seed cost in total price	Sowing and termination cost per hectare, Eur/ha	Percentage of sowing and termination cost in total cost	Total unit cost of catch crop application, Eur/ha
White mustard	20-30	25-60%	20-60	40-75%	60-80
Brown mustard	20-50	25-71%	20-60	29-75%	50-90
Spring rape	4-10	6-33%	20-60	67-94%	34-64
Winter rape	5	4-7%	70-120	93-96%	75-125
Oil radish	30	37%	50	63%	80
Forage radish	30	33-50%	30-60	50-67%	70-100
Root radish	80	53-73%	30-70	27-47%	110-150
Turnip	50	45-56%	40-60	44-55%	90-110
Winter rye	10	8-20%	40-120	80-92%	50-130
White clover	60	43%	80	57%	140
Red clover	50	38%	80	62%	130
White melilot	60	43%	80	57%	140
Italian ryegrass	40	33-44%	50-80	56-67%	90-120
Perrenial ryegrass	40	33%	80	67%	120
Phacelia	30	33-50%	30-60	50-67%	60-90
Cock's foot	40	27-33%	80-110	67-73%	120-150
Oat & Black oat	20	25-40%	30-60	60-75%	50-80
Buckwheat	10	14-25%	30-60	75-86%	40-70
Winter vetch	50	36-56%	40-90	44-64%	90-140
Pea	50	45-62%	30-60	38-55%	80-110
Faba bean	40	40-57%	30-60	43-60%	70-100

Source: Consultant based on market survey and publications of the Lithuanian Institute of Agrarian Economics and Latvian Rural Advisory and Training Centre

2.3. Cost of Catch Crop Application in Potential Areas

Based on the current catch crop structure and preferences of farmers, experts predict catch crop structure in Lithuanian and Latvian parts of Lielupė, Venta river basins/sub-basins as presented in Table 5.

Establishment and termination of the catch crops requires certain unit costs as indicated in Chapter 2.2. Annual costs of catch crop application in potential areas of each Lielupė and Venta basin/sub-basin were calculated multiplying potential catch crop areas in each basin/sub-basin (Table 5) by minimal and maximal costs of certain catch crop application (Annex 2). Calculation results on the costs of catch crop application are provided in Table 6.

Annual cost of catch crop application in potential for catch cropping areas, depending on cost of its components, makes approx**. MEUR 10-17 in Lielupe** river basin and approx. **MEUR 6-10.5 in Venta** river basin.

Annual cost of catch crop application in potential for catch cropping areas, depending on cost of its components, makes approx**. MEUR 10-17 in Lielupe** river basin and approx. **MEUR 6-10.5 in Venta** river basin.

Table 5. Potential areas for catch crop application in Lielupė and Venta river basins/sub-basins, ha

River basin/ sub-basin		White& brown mustard	Spring & winter rape	Oil (forage) & root radish	Italian & perennial ryegrass	Winter rye	Oat & black oat	Buck-wheat	Red & white clovers	Pea	Winter vetch	Phacelia	Total in basin/sub-basin	Total in basin in country	Total in basin
Lielupė RBD	Mūša sub-basin (LT)	32 167	643	14 022	1 635	376	1 286	255	4 405	12	2 643	642	**58 086**	**96 598**	**149 240**
	Lielupė small trib. sub-basin (LT)	13 963	240	6 852	842	143	480	96	2 113	1	1 350	336	**26 416**		
	Nemunėlis sub-basin (LT)	7 241	188	2 540	249	110	377	75	817	3	401	95	**12 096**		
	Lielupe basin (LV)	24 503	241	13 472	1 887	642	1 717	118	4 915	118	4 219	810	**52 642**	**52 642**	
Venta RBD	Venta basin (LT)	20 487	454	8 222	921	263	908	179	2 631	11	1 505	359	**35 940**	**42 362**	**94 842**
	Bartuva basin (LT)	2 715	59	637	61	33	118	23	269	3	106	23	**4 047**		
	Šventoji basin (LT)	1 612	34	377	35	20	69	14	142	1	58	13	**2 375**		
	Venta basin (LV)	28 158	142	11 578	1 626	482	1 250	73	4 880	85	3 508	698	**52 480**	**52 480**	

Source: Expert judgement on percentages of total areas, considering current crop structure, catch crop compatibility with prevailing main crops and potential preferences of farmers.

Table 6. Annual costs of catch crop application in the potential areas in Lielupė and Venta river basins/sub-basins, EUR/year

Catch crop	Lielupė RBD								Venta RBD							
	Mūša sub-basin (LT)		Lielupė small trib. sub-basin (LT)		Nemunėlis sub-basin (LT)		Lielupe basin (LV)		Venta basin (LT)		Bartuva basin (LT)		Šventoji basin (LT)		Venta basin (LV)	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
White & brown mustard	1 608 000	2 252 000	698 000	977 000	362 000	507 000	1 225 000	1 715 000	1 024 000	1 434 000	136 000	190 000	81 000	113 000	1 408 000	1 971 000
Spring & winter rape	29 000	103 000	11 000	38 000	8 000	30 000	11 000	39 000	20 000	73 000	3 000	9 000	2 000	5 000	6 000	23 000
Oil (forage) & root radish	841 000	2 244 000	411 000	1 096 000	152 000	406 000	808 000	2 156 000	493 000	1 316 000	38 000	102 000	23 000	60 000	695 000	1 852 000
Italian & perennial ryegrass	147 000	278 000	76 000	143 000	22 000	42 000	170 000	321 000	83 000	157 000	5 000	10 000	3 000	6 000	146 000	276 000
Winter rye	23 000	56 000	9 000	21 000	7 000	17 000	39 000	96 000	16 000	39 000	2 000	5 000	1 000	3 000	29 000	72 000
Oat & black oat	129 000	180 000	48 000	67 000	38 000	53 000	172 000	240 000	91 000	127 000	12 000	17 000	7 000	10 000	125 000	175 000
Buckwheat	18 000	28 000	7 000	11 000	5 000	8 000	8 000	13 000	13 000	20 000	2 000	3 000	1 000	2 000	5 000	8 000
Red & white clover	749 000	793 000	359 000	380 000	139 000	147 000	836 000	885 000	447 000	474 000	46 000	48 000	24 000	26 000	830 000	878 000
Pea	1 000	1 000	0	0	0	0	8 000	13 000	1 000	1 000	0	0	0	0	6 000	9 000
Winter vetch	264 000	449 000	135 000	230 000	40 000	68 000	422 000	717 000	151 000	256 000	11 000	18 000	6 000	10 000	351 000	596 000
Phacelia	58 000	83 000	30 000	44 000	9 000	12 000	73 000	105 000	32 000	47 000	2 000	3 000	1 000	2 000	63 000	91 000
Total in basin/sub-basin:	**3 867 000**	**6 468 000**	**1 784 000**	**3 008 000**	**783 000**	**1 291 000**	**3 771 000**	**6 300 000**	**2 371 000**	**3 942 000**	**256 000**	**406 000**	**148 000**	**236 000**	**3 664 000**	**5 953 000**
Total in basin in country:	**min: 6 434 000**			**max: 10 767 000**			**3 771 000**	**6 300 000**	**min: 2 775 000**			**max: 4 584 000**			**3 664 000**	**5 953 000**
Total in basin/sub-basin	**min: 10 205 000**				**max: 17 067 000**				**min: 6 439 000**				**max: 10 537 000**			

Source: The author's calculations

2.4. Cost of Catch Crop Application in Potential Areas at Risk

Due to significant impact of agricultural activities, nitrogen concentration limit in some areas is exceeded and these areas are so-called areas at risk. The areas at risk were designated during the development of the River Basin Management Plans and updated, based on the latest monitoring data, by the project experts (Table 7). Catch crop application in the areas at risk would be especially useful.

Table 7. Area at risk in Lielupė and Venta river basins/sub-basins, potential for catch crop application, ha

River basin/sub-basin		Total potential area at risk in sub basin	Total in basin in country		Total in basin	
			ha	% of total potential area	ha	% of total potential area
Lielupė RBD	Mūša sub-basin (LT)	40 660	67 076	69%	85 500	57%
	Lielupė small trib. sub-basin (LT)	26 416				
	Nemunėlis sub-basin (LT)	0				
	Lielupe basin (LV)	18 425	18 425	35%		
Venta RBD	Venta basin (LT)	6 250	6 250	15%	11 360	12%
	Bartuva basin (LT)	0				
	Šventoji basin (LT)	0				
	Venta basin (LV)	5 020	5 020	10%		

Source: The authors calculations

Costs of catch crops application in potential areas a risk in Lithuanian and Latvian parts of Lielupė and Venta basin/sub-basin were calculated multiplying potential catch crop areas at risk (Table 7) by minimal and maximal costs of certain catch crop application per hectare. Calculation results on the costs of catch crop application in potential areas a risk are provided in Table 8.

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% (Table 7) of potential area is area at risk.

Table 8. Annual costs of catch crop application in potential areas at risk in Lielupė and Venta river basins/sub-basins, EUR/year

Potential cost of catch crop application in basin/sub-basin at risk, Eur/year															
Lielupė RBD								Venta RBD							
Mūša sub-basin (LT)		Lielupė small trib. sub-basin (LT)		Nemunėlis sub-basin (LT)		Lielupe basin (LV)		Venta basin (LT)		Bartuva basin (LT)		Šventoji basin (LT)		Venta basin (LV)	
min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
2 707 000	4 528 000	1 784 000	3 008 000	0	0	1 320 000	2 205 000	403 000	670 000	0	0	0	0	366 000	595 000
min: 4 491 000			max: 7 536 000			1 320 000	2 205 000	min: 403 000			max: 670 000			366 000	595 000
min: 5 811 000				max: 9 741 000				min: 769 000				max: 1 265 000			

Source: The author's calculations

3. Benefit Assessment of Catch Crop Application

3.1. Methodology for Benefit Assessment

Benefits which catch crops provide can be distinguished as:

- Direct financial benefits to farmers
- Environmental (social) benefits to the whole society

Both types of benefits together provide economic benefits, which we try to capture as much as possible in our analysis.

3.1.1. Financial benefits

Generally, farmers value agricultural systems based on the main crop yield and short-term profitability. Catch crops, indeed, can positively affect yields by storing nutrients in the soil, helping to supress weeds, pests and diseases, reducing soil erosion, i.e., mainly decreasing the need to apply fertilisers and herbicides. Such benefits can be calculated in monetary terms, though the methodologies are not straightforward. Moreover, one needs to be cautious to avoid double-counting. In the following table (Table 9) we provide our assessment on which effect can be calculated as a direct financial benefit to a farmer.

Table 9. Methodology for calculation financial benefits of catch crops

Effect catch crop provides	Is there a direct financial benefit to a farmer?	Methodology to calculate financial benefit
1. Potential to reduce nutrient leaching	To some extent. Direct financial benefit of this effect is reflected under effect No2 – Nutrient transfer to the next crop.	Direct financial benefit can be calculated via reduced purchase of fertilisers and / or increased yield. This benefit is reflected under effect No2 - Nutrient transfer to the next crop.
2. Nutrient transfer to the next crop	Yes.	Direct financial benefit can be calculated via reduced purchase of fertilisers.
3. Potential to reduce GHG emissions	No.	Not relevant.
4. Potential to increase soil organic carbon content	To some extent. Direct financial benefit of this effect is reflected under effect No2 – Nutrient transfer to the next crop.	Direct financial benefit can be obtained via reduced purchase of fertilisers.
5. Effects associated with control of weeds	Yes.	Direct financial benefit for farmers can be calculated via reduced purchase of herbicides.
6. Catch crop potential to reduce soil erosion	To some extent. Direct financial benefit of this effect is reflected under effect No2 – Nutrient transfer to the next crop.	

Source: The author’s calculations.

More details on calculations and resulting financial benefits are provided in Section 3.2 Results of Benefit Assessment.

3.1.2. Environmental (social) benefits

Agricultural production is highly dependent on the services provided by natural ecosystems. The following ecosystem services (as classified in CICES V5.1[2]) are very important for agriculture:

- Hydrological cycle and water flow regulation
- Control of erosion rates
- Pollination
- Pest control
- Desease control
- Decomposition and fixing processes and their effect on soil quality
- Regulation of temperature and humidity, including ventilation and transpiration

Preliminary assessments indicate that the value of these ecosystem services to agriculture is enormous and often underappreciated (Power, 2010).

On the other side, (mis)management of agriculture processes affect these and other eco-system services. Agriculture can be a reason for the loss of biodiversity, agrochemical contamination and sedimentation of waterways, eutrophication of water bodies, pesticide poisoning of non-target organisms, and emissions of greenhouse gases and pollutants. There is often a mismatch between the benefits, which accrue to the agricultural sector, and the costs, which are typically borne by the society at various scales, from local communities impacted by pesticides in drinking water to the global commons affected by global warming. (Power, 2010) (Figure 1).

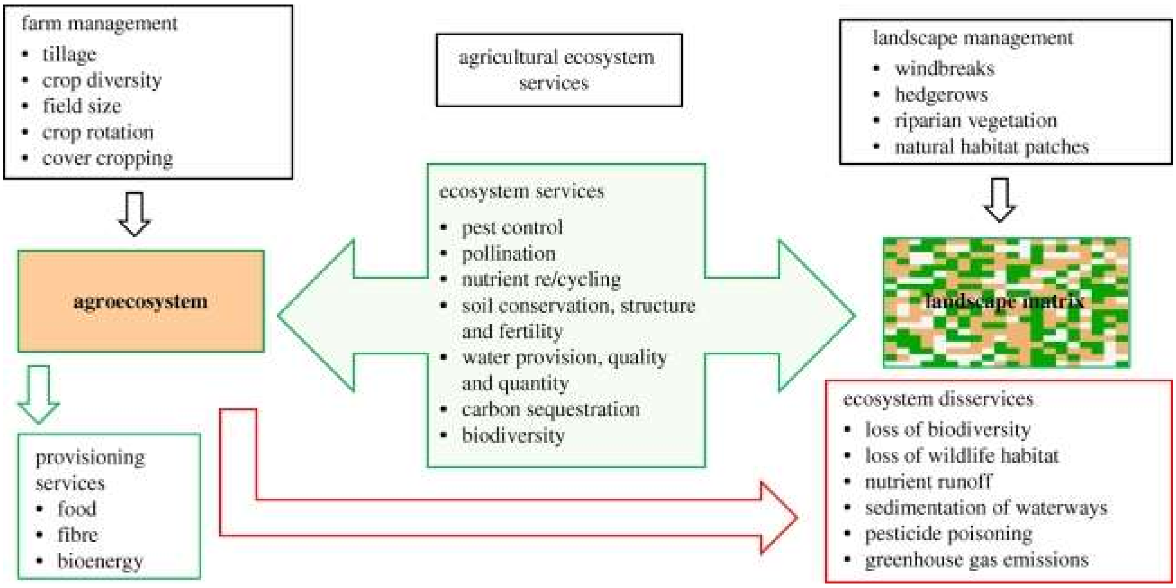

Figure 1. Impacts of farm management and landscape management on the flow of ecosystem services and disservices to and from agroecosystems (taken from *Power, 2010*)

[2] The Common International Classification of Ecosystem Services, as of 01.01.2018

As more effective methods for valuing ecosystem services become available, the potential for 'win–win' scenarios increases. Appropriate agricultural management practices are critical to realizing the benefits of ecosystem services and reducing disservices from agricultural activities.

Monetisation of benefits ecosystem services provide is a difficult task. Some ecosystem services valuations are available in European countries. In Lithuania and Latvia, there are a few studies / surveys carried out, which assessed some ecosystem services (mostly water resources related). We will use these estimates (described in Section 3.1.3. below) in the assessment of values the catch crops might provide to ecosystem services as much as possible.

In the following table (Table 10) we provide our assessment on which effect provides environmental (social) benefit and whether this benefit can be assessed in monetary terms.

Table 10. Methodology for calculation environmental (social) benefits of catch crops

Effect catch crop provides	Is there an environmental (social) benefit?	Methodology to calculate environmental (social) benefit
1. Potential to reduce nutrient leaching	Yes	Environmental (social) benefit can be calculated via reduction of eutrophication.
2. Nutrient transfer to the next crop	To some extent. Environmental benefit of this effect is reflected under effects No1 and No4	Transfer of estimates of benefits because of reduction of eutrophication and to biodiversity, if available
3. Potential to reduce GHG emissions	Yes	Environmental (social) benefit can be calculated using the CO_2 European Emission Allowances system.
4. Potential to increase soil organic carbon content	Yes	Transfer of estimates of benefits to biodiversity, if available
5. Effects associated with control of weeds	To some extent. Could be already incorporated under effect No 4.	Transfer of estimates of benefits to biodiversity, if available
6. Catch crop potential to reduce soil erosion	To some extent. Environmental benefit of this effect could be reflected under effect No4	Transfer of estimates of benefits to biodiversity, if available

Source: The author's calculations.

3.1.3. Monetisation of environmental benefits in Lithuania and Latvia

Monetisation of environmental benefits usually requires quite considerable amount of research. To date, there are eight economic valuation studies in Lithuania (one together with Latvia), where environmental assets were assessed in monetary terms. In Annex 3, we describe results of these studies and values estimated that could be used for the purpose of the project at hand. Two non-monetised studies on the use of the Baltic Sea and the impact of its quality on business are also briefly described. The studies were conducted over the period 1993–2017.

The main conclusion of all contingent valuation studies carried out in Lithuania and Latvia so far is that such studies can and should be conducted since they not only provide specific scientific information, describe the attitude of the general public to water resources, their management and priorities, but also, they are a very important measure of strengthening public awareness of water resources. In addition, these studies promote cooperation among ecologists, biologists, other marine specialists, economists, agricultural specialists and decision makers.

Table 11 provides the results of studies, described in Annex 3, which to some extent and with caution can be used for the cost-benefit analysis of catch crop application.

Table 11. Results of surveys related to the water quality valuation in Lithuania and Latvia, EUR of 2018

Study	Annual amount payable by a household member	National willingness to pay amount per year
1. Baltic Drainage Basin Project, 1995, LT	31.1	Not valuated
2. Baltic Coast Study, 1998, LT	~24	"Nature" of the Nemunas Delta 2 200 000
3. Study on willingness to pay for water quality improvement in the Nevėžis Basin, 2007, LT	7.22	-
4. Study on willingness to pay for water quality improvement in the Neris Basin, 2010, LT	6.8	
5. Meeting the Baltic Sea nutrient reduction targets, 2012, Lithuania Meeting the Baltic Sea nutrient reduction targets, 2012, Latvia	7.1 4.69	17 860 000 7 870 000
6. Marine Environmental Assessment - Economic and Social Analysis, 2018, LV	5.3 – 7.2	8 000 000 – 9 000 000
Figure to be applied for the cost benefit for the project at hand, if relevant	**~7** **~6**	**~17 600 000 for LT** **~ 8 500 000 for LV**

Results on willingness to pay are quite similar, except for the first two studies. The Baltic coast study was very specific and not directly related to water quality valuation; the first Baltic Sea drainage project involved much 'benefit transfer'. Marine Environmental Assessment - Economic and Social Analysis, made in 2018, provided similar personal willingness to pay figures. Therefore, where relevant, 7 EUR/person/year in Lithuania and 6 EUR/person/year in Latvia is applied as a benefit amount received because of the surface water quality improvement.

Moreover, based on the results of the Tyruliai bog ecosystem services assessment, the following ecosystem services are considered relevant to catch crops and results of their assessment can indirectly be applied in the assessment of benefits potentially to be provided by catch crops:

- Filtration/decomposition/detoxification of waste and wastewater; regulation of fresh water chemical status
- Erosion control
- Hydrological cycle and water flow maintenance
- Pollination
- Pest control
- Habitat and shelter provision for breeding and migrating species
- Climate regulation

The experience on economic valuation is too short in Lithuania and Latvia, therefore knowledge gaps exist in all related sectors and ecosystem services.

3.2. Results of Benefit Assessment

In this report we summarise potential financial and social benefits, including monetised benefits to ecosystem services which could be brought by the catch crops. Six types of effects the catch crops provide were described and estimated in the Report on *Task AT1.1. Quantification of the Expected Nutrient Retention Rates and Other Environmental Effects.*

As already noted, in many cases environmental (social) benefits do not have direct impact on a farmer. For example, a reduction of nitrates in streams and lakes does not directly aid farmers in paying catch crop costs. For farmers to benefit, a combination of yield increases or cost reductions must occur.

3.2.1. Benefits of reduced nutrient leaching

As defined in the Methodology section above, direct financial benefit to a farmer can be calculated via reduced purchase of fertilisers. Moreover, reducing nitrates in water-bodies has public benefits which do not directly accrue to farmers. These environmental benefits can be expressed via reduced eutrophication of water bodies.

In addition, nutrient loss can create other costs for a farmer. For example, in order to prevent soil acidification, which can increase with the application of fertilisers, farmers may have to lime their soils.

Financial benefit

Financial benefit of the reduced nutrient leaching is covered under the "nutrient transfer to the next crop" via reduced acquisition of fertilisers (see section 3.2.2.).

Environmental and social benefit

The report on Environmental Effects of Catch Crops, prepared during the same project „Optimal catch crop solutions to reduce pollution in the transboundary Venta and Lielupe river basins" (acr. CATCH POLLUTION), presents that if full catch crop growing potential is utilized, the following reductions of nitrogen load may be achieved in:

- approx. **1800 t/year in the Lielupe RBD** (around 1200 t/year on the Lithuanian side and around 600 t/year on the Latvian side);
- approx. **1100 t/year in the Venta RBD** (around 550 t/year on the Lithuanian side and around 630 t/year on the Latvian side).

As noted in the section on the Methodology, environmental and social benefit can be calculated via reduction of eutrophication in the Baltic sea and/or rivers (Lielupė and Venta) in Lithuania and Latvia. Review of the studies carried out (described in Annex 3) suggests that total benefits of achieving eutrophication reduction goals In Latvia amounts to 8.5 MEUR/year and in Lithuania – 17.6 MEUR/year. It is important to proportionate total benefits and assign parts of them to Lielupe and Venta RBDs in Lithuania and Latvia. For Lithuania this proportionment is made based on the pollution reduction load. In Latvia pollution reduction load and areas at risk are known only for the Lielupe and Venta RBDs, so we base the benefit attribution to Latvian parts of Lielupe and Venta river basins according to the areas at risk (Table 12). To receive total benefit for the Lielupe and Venta Latvian parts, Lithuanian total benefit is divided by the total area at risk in Lithuania (benefit per ha of the area at risk), then divided by 1.2 to reflect Lithuanian and Latvia willingeness to pay per person proportion (7.1/6.0) and multiplied by the area at risk. It has to be stressed that such benefits would be brought if targets were achieved one hundred per cent. However, catch cropping will allow achieving only part of the mentioned pollution load targets and thus benefits would be lower as presented in the table below.

Table 12. Distibution of reduction of nitrogen pollution (total benefits) in basins and sub-basins of Venta and Lielupe RBDs

River basin/sub-basin	Pollution reduction load target, t N/year	Proportion of pollution reduction load	Area at risk, ha	Benefit distribution, if all targets are achieved, based on pollution reduction proportion*, EUR/year
Lithuania				***17 860 000***
Nemunas RBD	2 160	**29 %**	720 000	**5 241 522**
Lielupe RBD	4 800	**65 %**	545 000	**11 647 826**
Venta RBD	400	**5 %**	89 300	**970 652**
Daugava RBD	0	**0 %**	0	**0**
	7 360	*100 %*	1 354 300	
Latvia				***8 500 000***
Lielupe RBD	600		310 300	**3 410 000***
Venta RBD	120		149 500	**1 643 000***
Daugava RBD	not available		not available	
Gauja RBD	not available		not available	

Source: The author's calculations

**-for Latvia, Lithuanian benefit figures are used, adjusted to proportion of area at risk and relation between one person's willingness to pay in Lithuania as 7.1 and in Latvia as 6.0, i.e. 1.2 times less*

Catch cropping is sufficient to achieve the targets only if applied in whole basin/sub-basin in Venta RBD, however, this reduction is not sufficient to achieve pollution reduction targets set for sub-basins of water bodies at risk. Table 13 presents pollution by nitrogen reduction targets and potentials of reduction using relevant catch crops as well as the share of potential target achievement.

Table 13. Nitrogen pollution reduction targets and potentials to achieve them

<table>
<tr><th rowspan="2">River basin/sub-basin</th><th rowspan="2">Pollution reduction targets for sub-basins of water bodies at risk, t/year</th><th colspan="2">Potential reduction of nitrogen load in the whole basin/sub-basin</th><th colspan="3">Potential reduction of nitrogen load in sub-catchments of water bodies at risk</th></tr>
<tr><th>t/year</th><th>share of target achievement, %</th><th>t/year</th><th>share of target achievement, %</th><th>per country</th></tr>
<tr><td>Lielupe RBD</td><td>5400</td><td>1790</td><td>32%</td><td>1230</td><td>23%</td><td></td></tr>
<tr><td>Mūša sub-basin (LT)</td><td>3000</td><td>680</td><td>23%</td><td>530</td><td>18%</td><td rowspan="2">17%</td></tr>
<tr><td>Nemunėlis sub-basin (LT)</td><td>-</td><td>140</td><td>-</td><td>-</td><td>-</td></tr>
</table>

River basin/sub-basin	Pollution reduction targets for sub-basins of water bodies at risk, t/year	Potential reduction of nitrogen load in the whole basin/sub-basin		Potential reduction of nitrogen load in sub-catchments of water bodies at risk		
		t/year	share of target achievement, %	t/year	share of target achievement, %	per country
Lielupė small tributaries sub-basin (LT)	*1800*	300	17%	300	17%	
Latvian part of the Lielupe basin (LV)	*600*	633	105%	400	67%	67%
Venta RBD	***520***	**1130**	217%	**190**	37%	
Bartuva basin (LT)	-	50	-	-	-	
Venta basin (LT)	*400*	420	105%	100	25%	25%
Šventoji basin (LT)	-	30	-	-	-	
Latvian part of the Venta basin (LV)	*120*	630	525%	90	75%	75%

Source: The author's calculations

It should be noted that the share of pollution reduction target achievement in the whole basin/sub-basin presents theoretical potential achievement of the target if catch cropping is applied in all potential areas. However, real effect could be achieved only if catch cropping is established in the areas at risk. Other potential catch cropping areas should not cause pollution.

Based on the share of the target achievement, as indicated in the table above, and on the assumption that the eutrophication reduction benefit value in Latvia and Lithuania, assessed during the valuation study, carried out in all nine Baltic sea countries, and similar other studies, could be applied for the benefit assessment (as presented in Table 12), the following monetary assessment of benefits of catch cropping and thus reduction of nitrogen leaching in sub-catchments of water bodies at risk is provided (Table 14).

Table 14. Benefits to reduce nitrogen leaching in Lielupe and Venta RBDs

River Basin District	Total potential benefit of meeting the Baltic Sea nutrient reduction targets, EUR/year	Area at risk, ha	Nitrogen reduction target proportion, %	Benefit distribution, if all targets are achieved, EUR/year	Share of target achievement by catch cropping	Benefit due to catch cropping in areas at risk, EUR/year
Lithuania	**17 860 000**	**1 354 300**				
Nemunas RBD		720 000	29%			
Lielupe RBD		545 000	65%	11 650 000	17 %	**~2 000 000**
Venta RBD:		89 300	5%	971 000	25 %	**243 000**
Daugava RBD		0	0%	0		
Latvia	**8 500 000**					
Lielupe RBD:		310 300	not available	3 410 100	67 %	**2 273 000**
Venta RBD:		149 500	not available	1 643 000	75 %	**1 232 000**

River Basin District	Total potential benefit of meeting the Baltic Sea nutrient reduction targets, EUR/year	Area at risk, ha	Nitrogen reduction target proportion, %	Benefit distribution, if all targets are achieved, EUR/year	Share of target achievement by catch cropping	Benefit due to catch cropping in areas at risk, EUR/year
Daugava RBD		not available	not available			
Gauja RBD		not available	not available			
Lielupe and Venta LT				*12 620 000*		***2 300 000***
Lielupe and Venta LV				*5 053 000*		***3 506 000***

Source: The author's calculations

Total annual economic benefits of reduction of nutrient leaching in water bodies at risk equal approx. **EUR 4 300 000 in Lielupe** and **EUR 1 500 000 in Venta**.

Additionally, it should be kept in mind that in a long-term perspective, indirect catch crop effect, such as reduction of nitrogen leaching due to increase in soil organic matter, can be expected.

3.2.2. Benefits of nutrient transfer to the next crop

As defined in the Methodology section above, direct financial benefit to a farmer can be calculated via reduced purchase of fertilisers. Moreover, reducing nitrates in water-bodies has public benefits which do not directly accrue to farmers. These environmental benefits can be expressed via reduced eutrophication of water bodies and / or increased biodiversity in water bodies.

Financial benefit

Financial benefit of the "nutrient transfer to the next crop" can be calculated via reduced purchase of fertilisers. This financial benefit also covers benefit of reduced nutrient leaching, as indicated in the section above.

The report on Environmental Effects of Catch Crops, prepared during the same project „Optimal catch crop solutions to reduce pollution in the transboundary Venta and Lielupe river basins" (acr. CATCH POLLUTION), presents that, taking into account potential catch crop areas, every year approx. 5.2 thou tonnes of mineral nitrogen can be credited for the subsequent crops in the Lielupe RBD and 3.3 thou tonnes in the Venta RBD if full catch crop growing potential is utilised (Table 15).

Table 15. Expected nitrogen crediting in basins and sub-basins of Venta and Lielupe RBDs

River basin/sub-basin	Transferring of nitrogen to the subsequent crop, t/year
Lielupe RBD	***5 204***
Mūša sub-basin (LT)	2040
Nemunėlis sub-basin (LT)	422
Lielupė small tributaries sub-basin (LT)	931
Latvian part of the Lielupe basin (LV)	1811
Venta RBD	***3 301***
Bartuva basin (LT)	141
Venta basin (LT)	1258
Šventoji basin (LT)	83
Latvian part of the Venta basin (LV)	1819

Source: The author's calculations

Prices (without VAT) of fertilisers, which are most widely applied in Lithuania and Latvia – ammonium nitrate and carbamide – were taken from the market survey. Having in mind that nitrogen makes only a portion in one unit of weight of a fertiliser, the cost of one tonne of nitrogen, saved by applying catch crops (or price of fertiliser a farmer saves), is proportionally higher (Table 16).

Table 16. Savings of farmer by one tonne of nitrogen transferred to the next crop

Fertiliser	Price of fertiliser, EUR/t	Amount of nitrogen in one unit of weight of fertiliser, %	Price of one tonne of nitrogen transferred to the subsequent crop, EUR/tN	Average price of one tonne of nitrogen transferred to the subsequent crop, EUR/tN
Ammonium nitrate	213	34	618	542
Carbamide	216	46	467	

Source: The author's calculations calculation based on fertiliser market prices

Annual savings of all farmers in Lielupė and Venta river basin districts thus amount to approx. **EUR 2.8 million** and **EUR 1.8 million** respectively. **Lithuanian farmers would save (benefit) in total approx. EUR 2.64 million and Latvian farmers – EUR 2.00 million per year** (Table 17). It should be noted that no payments according to agricultural support programmes to farmers are considered in these calculations, though the latter could aid in defining the payments to farmers from the Rural Development Programmes.

Table 17. Savings (benefits) of farmers due to nutrient transferring to the next crop, EUR/year

River basin/sub-basin	Saving of ammonium nitrate	Saving of carbamide	Average of ammonium nitrate and carbamide saving	Average of ammonium nitrate and carbamide per country
Lielupe RBD	**~3 216 000**	**~2 429 800**	**~2 822 900**	
Mūša sub-basin (LT)	1 260 693	952 486	1 106 590	**~1 840 500**
Nemunėlis sub-basin (LT)	260 790	197 034	228 912	
Lielupė small tributaries sub-basin (LT)	575 346	434 688	505 017	
Latvian part of the Lielupe basin (LV)	1 119 174	845 565	982 370	**~982 400**
Venta RBD	**~2 040 000**	**~1 541 300**	**~1 790 600**	
Bartuva basin (LT)	87 136	65 834	76 485	**~803 900**
Venta basin (LT)	777 428	587 366	682 397	
Šventoji basin (LT)	51 293	38 753	45 023	

River basin/sub-basin	Saving of ammonium nitrate	Saving of carbamide	Average of ammonium nitrate and carbamide saving	Average of ammonium nitrate and carbamide per country
Latvian part of the Venta basin (LV)	1 124 118	849 300	986 709	**~986 700**
Total Lielupe and Venta RBDs	**~5 256 000**	**~3 971 000**	**~4 613 500**	**~4 613 500**

Source: The author's calculations

Total annual financial benefits accrued to farmers of Latvia and Lithuania of catch cropping, which allows nutrient transferring to the next crop, equal approx. **EUR 5 million**.

Environmental and social benefit

As noted in the section on the Methodology, environmental and social benefits of nutrient transfer to the next main crop can be calculated via reduction of eutrophication and increased biodiversity. Social (environmental) benefits of reduction of eutrophication due to catch cropping are described in the Section on Benefits of Reduced Nutrient Leaching.

3.2.3. Benefits of increased soil organic carbon content

Soil organic carbon (SOC) is a measureable component of soil organic matter (SOM). Organic matter contributes to various features of soil: nutrient retention and turnover, soil structure, moisture retention and availability, degradation of pollutants, carbon sequestration and soil resilience. It was assessed and presented in the Report on *Task AT1.1. Quantification of the Expected Nutrient Retention Rates and Other Environmental Effects* that taking into consideration current potential for catch cropping in Venta and Lielupe RBDs and predicted structure thereof, catch crops may contribute to the SOC stock by approx. 30 thou t C/year in the Lielupe RBD and by 19 thou t C/year in the Venta RBD (Table 18).

Table 18. Estimated catch crop contribution to SOC in Venta and Lielupe RBDs

River basin/sub-basin	Potential catch crop contribution to SOC, thou t C/year
Lielupe RBD	***29.6***
Mūša sub-basin (LT)	11.6
Nemunėlis sub-basin (LT)	2.4
Lielupė small tributaries sub-basin (LT)	5.3
Latvian part of the Lielupe basin (LV)	10.3
Venta RBD:	***18.8***
Bartuva basin (LT)	0.8
Venta basin (LT)	7.2
Šventoji basin (LT)	0.5
Latvian part of the Venta basin (LV)	10.4

Source: The author's calculations. Report on Task AT1.1. Quantification of the Expected Nutrient Retention Rates and Other Environmental Effects

As defined in the Methodology section above, direct financial benefit to a farmer can be calculated via reduced purchase of fertilisers (described in the section on benefits of the effect of nutrient transfer to the next crop).

Environmental (social) benefit can be related to the valuation of ecosystem services provided by soil. There are no valuation studies of ecosystem services provided by soil in Latvia and Lithuania, however, simplified benefit transfer could be applied in order to identify benefits via SOC contributions the catch cropping brings to the societies of the two countries.

Financial benefit

Financial benefit of the reduced nutrient leaching is covered under the "nutrient transfer to the next crop" via reduced acquisition of fertilisers (section 3.2.2.). We assume the same financial gain covers also the SOC contributions from catch cropping.

Environmental and social benefit

The main pillar on which we build our assessment of the benefit the SOC contributes to a society is correlated with changes in soil biodiversity and the generation of supporting ecosystem services.

Many literature sources point out that a variety of ecosystem services provided by soil are actually exceeding services provided by other environmental components, however, this is not yet recognised by a general public and valuation of these ecosystem services is missing.

As it is stressed in the EC report on the implementation of the Soil Thematic Strategy (EC, 2012), „soil functions – despite their fundamental role for the ecosystem and the economy, and unlike air and water – are taken for granted and perceived to be in abundance. Soil degradation generally goes unnoticed, as it is a slow process in which immediate dramatic effects rarely occur."

Economic (i.e. environmental and social) benefits/costs of decline or increase in organic matter are analysed only in occasional studies or are not quantified at all. The impact of organic matter loss on the productivity of soils is much less researched than, e.g., in the case of erosion, making an economic assessment more difficult. Since organic matter loss and soil erosion often occur together, it can be assumed that part of the economic damage ascribed to erosion is in fact related to the loss of soil organic matter and vice versa.

The effect of catch cropping in the project at hand is calculated in tonnes of carbon in soil per year for each river basin and sub-basin (Table 18). Monetary assessment of the benefits the SOC/SOM brings to a society, however, is most often made per hectare. Below range of results of a few monetary assessments of the soil ecosystem services are provided, based on which we build our aseessment (Table 19).

Table 19. Monetary assessment of soil ecosystem services, literature sources

Source	Description	EUR^{2018}/ha/year*	
		min	max
EC, DG Environment, 2018. Providing support in relation to the implementation of the EU Soil Thematic Strategy	Various ecosystem services provided by soil are estimated from 0.12 EUR/ha/year to 20 000 EUR/ha/year	0.12	20000
Sandhu et al., 2008. The Future of Farming: The Value of Ecosystem Services in Conventional and Organic Arable Land.	Total economic value of ES in organic fields ranged from US $1610 to US $19,420/ha/yr and that of conventional fields from US $1270 to US $14,570 per ha/yr. The non-market value of ES in organic fields ranged from US $460 to US $5240 per ha/yr. The range of non-market values of ES in conventional fields was US $50 — 1240 per ha/yr. There were significant differences between organic and conventional fields for the economic values of some ecosystem services.	40	970
Sandhu et al., 2010. The role of supporting ecosystem services in conventional and organic arable farmland.	0.6-11.60 USD/ha/yr for soil formation, 25-430 USD/ha/yr for soil mineralisation	0.5 19	9 330
Costanza et al., 1997. The Value of the World's Ecosystem Services and Natural Capital	53 USD/ha/yr for soil formation	70	70
Jón Örvar Jónsson et al., 2016. Valuation of Soil Ecosystem Services. December 2016Advances in Agronomy, DOI: 10.1016/bs.agron.2016.10.011, Jón Örvar Jónsson, Brynhildur Davidsdottir, Nikolaos P. Nikolaidis	The value of the soil ES estimated was crop and livestock biomass 740–7560 id$ ha− 1 year− 1; filtering of nutrients and contaminants 0–278 id$ ha− 1 year− 1; and climate regulation − 2200 to − 5610 id$ ha− 1 year− 1.	680	6940
Tyrulių pelkės ekosistemų paslaugų įvertinimo galutinė ataskaita, 2017	All the spectrum of ecosystem services (such as food provision, waste, wastewater, pollutants biological treatment and absorption, water and erosion regulation, pest control and climate change control) would amount to 900 EUR/ha/year. If climate change, erosion and food related estimates are not taken into account, the value of 1 ha of soil would amount to 580 EUR/year.	580	580
	Average	***200***	***4130***

**-original figures converted to EUR of 2018*

In addition to the figures on potential benefits ecosystem services of soil, and in particular, the SOC, brings, provided above, and which are used for catch cropping benefit assessment, there are other estimates which need to be described to compose a full picture of ecosystem benefits related to the SOC/SOM.

A survey backed by the European Commission has estimated that society's loss due to soil contamination is about 17.3 billion EUR per year. Provisioning services were assessed at 800 EUR/ha/year - 700 000 EUR/ha/year in Europe[3].

Study of the EC (Görlach, B., 2004), which aimed to assess the economic (environmental, social) impact of soil degradation, showed that in 2004 ,social (economic) costs of contaminated soil (i.e. benefit of clean soil) amounted to 14 - 700 EUR *per person*.

Moreover, in the study of Brady, M.V. et al., 2014, declines in associated ecosystem services are shown to reduce both maximum yield and fertilizer-use efficiency in the future. The average depreciation of soil natural capital, for a 1% relative reduction in SOC concentration, was EUR 144 per ha (SD 47 € ha-1) when discounting future values to their current value at 3%; the variation was explained by site specific factors and the current SOC concentration. Moreover, the results show that soil ecosystem services cannot be fully replaced by purchased inputs, they are imperfect substitutes.

Results of Tyruliai study can be applied indirectly; if ecosystem services of wetlands were to be transferred to reflect ecosystem services of soil, all the spectrum of ecosystem services (such as food provision, waste, wastewater, pollutants biological treatment and absorption, water and erosion regulation, pest control and climate change control) would amount to 900 EUR/ha/year. If climate change, erosion and food related estimates are not taken into account, the value of 1 ha of soil would amount to 580 EUR/year (as shown in the table above).

It should be stressed that economic (social, environmental) benefits of reduction of soil degradation, i.e. increasing soil organic carbon and organic matter, are comparatively more substantial than financial ones (i.e. for a farmer). Moreover, it is very important that benefits will be stronger over time, as the impacts are cumulative and mutually reinforcing. It is estimated that benefits to a society exceed benefits to a farmer by 7 to 10 times.

Based on minimum and maximum average values of the soil organic carbon related ecosystem benefits per ha per year (Table 19), resulting benefit assessments per river basin, per country and in total are provided in Table 20 (if applied in areas at risk) and Table 21 (if applied in all potential for catch cropping areas).

Table 20. Benefits of catch cropping for SOC related soil ecosystem services, if applied in areas at risk, EUR/year

<table>
<tr><th>River basin/sub-basin</th><th>Min</th><th>Max</th><th>In basin in country, min</th><th>In basin in country, max</th><th>Average</th></tr>
<tr><td>Lielupe RBD</td><td>17 000 000</td><td>353 000 000</td><td></td><td></td><td>185 000 000</td></tr>
<tr><td>Mūša sub-basin (LT)</td><td>8 000 000</td><td>168 000 000</td><td rowspan="3">13 300 000</td><td rowspan="3">277 000 000</td><td rowspan="3">145 000 000</td></tr>
<tr><td>Lielupė small tributaries sub-basin (LT)</td><td>5 244 000</td><td>109 000 000</td></tr>
<tr><td>Nemunėlis sub-basin (LT)</td><td>0</td><td>0</td></tr>
</table>

[3] EC, DG Environment, 2018. Providing support in relation to the implementation of the EU Soil Thematic Strategy. Mapping and Assessment of Ecosystems and their Services Soil ecosystems Revision: final 19 March 2018 Service contract No 07.0201/2016/742739/SER/ENV.D.l,, internete: http://www.worldsoilday2017.eu/pdfs/Soils4EU_D1.2_ecosystemservices_MAES.pdf#page=68&zoom=100,0,97

River basin/sub-basin	Min	Max	In basin in country, min	In basin in country, max	Average
Latvian part of the Lielupe basin (LV)	3 667 014	76 263 079	3 700 000	76 300 000	***40 000 000***
Venta RBD	**2 240 000**	**46 520 000**			***24 400 000***
Venta basin (LT)	1 240 000	25 800 000	1 240 000	26 000 000	***13 520 000***
Bartuva basin (LT)	0	0			
Šventoji basin (LT)	0	0			
Latvian part of the Venta basin (LV)	996 500	20 700 000	996 500	20 700 000	***10 860 000***
Total Lielupe and Venta RBDs	19 204 000	400 000 000			**210 000 000**

Source: The author's calculations

Table 21. Benefits of catch cropping for SOC related soil ecosystem services, if applied in potential areas, EUR/year

River basin/sub-basin	Min	Max	In basin in country, min	In basin in country, max	Average
Lielupe RBD					***323 000 000***
Mūša sub-basin (LT)	11 531 067	239 812 200	19 176 359	398 811 743	***209 000 000***
Lielupė small tributaries sub-basin (LT)	5 244 029	109 060 343			
Nemunėlis sub-basin (LT)	2 401 263	49 939 200			
Latvian part of the Lielupe basin (LV)	10 450 339	217 336 257	10 450 000	217 340 000	***114 000 000***
Venta RBD					***205 200 000***
Venta basin (LT)	7 134 706	148 380 857	8 410 000	175 400 000	***92 000 000***
Bartuva basin (LT)	803 399	16 708 329			
Šventoji basin (LT)	471 478	9 805 357			
Latvian part of the Venta basin (LV)	10 418 180	216 667 429	10 420 000	216 700 000	***114 000 000***
Total Lielupe and Venta RBDs	48 454 461	1 007 709 971			***528 000 000***

Source: The author's calculations

3.2.4. Benefits of reduction of soil erosion

Soil biodiversity, in other words, benefits that soil organisms generate for farmers, supports agricultural production. Thus farmers, as well as the whole society receive direct and non direct benefits. Moreover, soil related ecosystem services provide long-term increasing benefits, as effects related to the soil quality, reveal and become more pronounced over time.

According to the Thematic Strategy for Soil Protection (Commission of the European Communities, 2006) degradation processes that affect soil resources include: i) soil erosion, ii) organic matter decline, iii) compaction, iv) salinisation, v) landslides, vi) contamination vii) soil sealing, and viii) loss of biodiversity.

The direct impacts of soil erosion are mainly losses of soil. Erosion also reduces the fertility and productivity of soil. Soil losses can also lead to uprooting of plants and trees. These effects can reduce yields and hence affect agricultural productivity. To compensate for erosion-born yield losses, farmers have to apply more fertilisers or stabilisation and conservation measures to prevent further erosion. Applying more fertilisers may keep yield levels for some time, but will not eliminate the main reasons for erosion.

In addition, erosion causes considerable economic damage outside the area where erosion actually takes place. Off-site impacts are mainly related to the ecosystem services of soils. Most of these impacts are transmitted through the water cycle. This can either occur as physical damage to water bodies (siltation of dams, sedimentation of rivers and canals), or as chemical damages (in many parts of Europe, soil erosion is a primary source of diffuse water pollution). Similarly, sediment loads have a negative impact on natural habitats and on fisheries, affecting commercial and leisure activities. Since erosion weakens the water-holding capacity of the soil, it may increase the risk of floods and landslides.

Report on task *AT1.1. Quantification of the Expected Nutrient Retention Rates and Other Environmental Effects* of the project at hand concludes that catch cropping in Lielupe and Venta RBDs may bring reduction in soil, nitrogen and SOM loss caused by soil erosion (Table 22).

Table 22. Potential effect of catch crops with respect to reduction of soil erosion

	Reduction of soil loss, t/year	Nitrogen protected from being lost, t/year	SOM protected from being lost, t/year
Lielupė RBD (LT):	**27 261**	**48.3**	**832.0**
Mūša river sub-basin	16 686	30.2	521.4
Lielupe small tributaries	3 188	4.6	79.7
Nemunėlis river sub-basin	7 388	13.4	230.9
Venta RBD (LT)	**30 460**	**43.4**	**748.8**
Venta river basin	25 215	32.9	567.3
Bartuva river basin	4 228	9.2	158.6
Šventoji river basin	1 016	1.3	22.9
Lielupė RBD (LV)	**16 631**	**30.9**	**533.4**
Venta RBD (LV)	**27 509**	**58.1**	**1 001.5**

Source: The author's calculations. Report on Task AT1.1. Quantification of the Expected Nutrient Retention Rates and Other Environmental Effects

Effects related to soil erosion are calculated in tonnes per year of soil, nitrogen and SOM loss. Benefits thus would need to be assessed per tonne as well. However, as demonstrated below, this is usually not the case.

Financial (on-site) benefit

Financial benefit of the reduced soil erosion is covered under the "nutrient transfer to the next crop" via reduced acquisition of fertilisers (section 3.2.2.). We assume the same financial gain covers also contributions to good quality soil from catch cropping.

It is also estimated that the private, financial costs of soil degradation, which are suffered by farmers - soil users, range between 0.5 and 2% of agricultural gross value added (Gorlach, 2004). As it is stressed in the same study, while significant, these costs are generally not a major concern in the short run. However, impacts will be felt more strongly over time, as they are cumulative and mutually reinforcing. The social / environmental, in other words, off-site costs or benefits of reduction of soil degradation (erosion) are more substantial.

Social / environmental (off-site) benefit

For the different estimates, these social / environmental costs exceed the on-site costs by a factor of 7 to 10, despite the fact that a large part of these social / environmental costs cannot be quantified (Gorlach, 2004). These costs are generally covered by society: as externalities, they are not reflected in the decision-making framework of land owner and soil users.

Analysis of literature sources shows that valuation of soil erosion has been carried out in a dozen of studies. Benefits related to soil erosion avoidance in Europe vary from **22 EUR/ha/year up to 240 EUR/ha/year** (EC, 2018). The TEEB (The Economics of Ecosystems and Biodiversity) database contains seven projects related to the valuation of soil erosion. The values thereof are in the limits indicated above.

Hacisalihoglu, S. et al., 2010, using "market value of soil" method, calculated in their study that an economic value loss because of soil erosion in the research area averaged to about 88 EUR/ha/year in the pasture lands and about **152 EUR/ha/year** in the agricultural lands (figures adjusted to EUR of 2018).

Estimates for the UK put the total marginal cost of soil degradation at between £206-315 million per year. Evidence suggests that these costs are incurred in many different ways, affecting diverse ecosystems and stakeholders, over a range of spatial and temporal scales. Defra's research project *Cost of soil degradation in England and Wales, 2011* concluded that about 45% of total quantified annual soil degradation costs (benefits) are associated with loss (increase) of organic content of soils, 39% with compaction and *13% with erosion*. 20% of the estimated annual costs of soil degradation are associated with loss of provisioning ecosystem services linked with agricultural production and the remaining 80% of total annual degradation costs are associated with loss of regulating services, the bulk of this (49% of all costs) linked to GHG emissions. Over 70% of erosion and compaction costs are linked to arable farming, whereas almost 60% of loss of organic content is linked to grassland, especially on peat soils. As presented in the mentioned research project, the erosion in England and Wales was calculated to be approximately 2.9 million tonnes per year. An estimated 1 million ha are at risk of erosion there, mainly associated with arable farming on silts and sands. Total annual costs / benefits of erosion (reduction) in England and Wales for all soilscapes was estimated at about £177 million or EUR222 million per year. Based on these figures, we calculated that average benefit of reduction of soil erosion in England and Wales amounts to approx. £177 or **222 EUR/ha/year**. Also, one tonne of „saved" soil brings benefit of approx. **77 EUR/t/year**.

As in the case of valuing SOC / SOM, results of Tyruliai study can be applied indirectly; out of overall ecosystem services of soil its erosion reduction value would amount to approx. **150 EUR/ha/year** (see Annex 3).

Valuations for 1 tonne of soil lost are rarer. Literature sources reviewed (The Cost of Soil Erosion, Iowa, 2013; Telles, 2011; Pimentel, 1995; Petersen, 2016) show that 1 tonne of soil saved from erosion can be valued in different ways and be in the range of 2 to 80 EUR/t of soil saved.

Based on the descriptions and valuation results above, we assume soil erosion reduction benefit can be associated to on **average 164 EUR/ha/year**, if assessed according to area, and to on **average 40 EUR/t/year**, if assessed per tonne of soil saved. Benefits the catch cropping could produce to the reduction of soil erosion, if calculated based on ecosystem valuation per ha, are presented in Table 23. Benefits the catch cropping could produce to the reduction of soil erosion, if calculated based on valuation of soil per kg saved, are presented in Table 24.

Table 23. Benefits of catch cropping for reduction of soil erosion, based on valuation per ha, EUR/year

River basin/sub-basin	Benefit from potential catch cropping areas	Benefit from areas at risk	In basin in country, potential areas	In basin in country, areas at risk
Lielupe RBD			**24 438 000**	**14 000 000**
Mūša sub-basin (LT)	9 512 000	6 645 200	15 818 000	10 971 000
Nemunėlis sub-basin (LT)	1 981 000	0		
Lielupė small tributaries sub-basin (LT)	4 326 000	4 326 000		
Latvian part of the Lielupe basin (LV)	8 620 000	3 025 000	8 620 000	3 025 000
Venta RBD			**15 530 000**	**1 845 000**
Bartuva basin (LT)	663 000	0	6 940 000	1 023 100
Venta basin (LT)	5 885 000	1 023 100		
Šventoji basin (LT)	389 000	0		
Latvian part of the Venta basin (LV)	8 594 000	822 000	8 594 000	822 000
Total Lielupe and Venta RBDs	**40 000 000**	**16 000 000**		

Source: The author's calculations

Table 24. Benefits of catch cropping for reduction of soil erosion, based on valuation per tonne, EUR/year

River basin/sub-basin	Reduction of soil loss, tonne	Benefit from reduction of soil loss, EUR	Benefit from reduction of soil loss in basin in country, EUR
Lielupe RBD	**43 900 000**	**1 800 000**	
Mūša sub-basin (LT)	16 700 000	667 440	1 100 000
Nemunėlis sub-basin (LT)	7 400 000	295 520	
Lielupė small tributaries sub-basin (LT)	3 200 000	127 520	
Latvian part of the Lielupe basin (LV)	16 600 000	665 240	665 000
Venta RBD	**58 000 000**	**2 320 000**	
Bartuva basin (LT)	4 200 000	169 120	1 220 000
Venta basin (LT)	25 200 000	1 008 600	
Šventoji basin (LT)	1 000 000	40 640	
Latvian part of the Venta basin (LV)	27 500 000	1 100 360	1 100 000
Total Lielupe and Venta RBDs	**102 000 000**	**4 100 000**	**4 100 000**

Source: The author's calculations

Two methods of benefit calculation show different results, which may differ up to ten times. The first one, based on benefit per ha, reflects broader soil ecosystem services while the second one, based on tonne of soil loss reduction, usually reflects only provisional ecosystem services.

As seen in previous section and will be seen in the following section, soil related ecosystems are interrelated and thus benefits calculated could be attributed to nutrient movements, soil organic matter volume and climate change regulating capacities.

3.2.5. Potential to reduce GHG emissions

Catch crops, in addition to the effects and benefits, described above, for their ability to reduce nitrogen leaching and erosion, and improve soil health, also play an important role in mitigating the effects of climate change. This is one more ecosystem service, provided by catch cropping.

Climate change adaptation, enabled by catch crops, occur through reduced vulnerability to erosion from extreme rain events, increased soil water management options during droughts or periods of soil saturation, and retention of nitrogen mineralized due to warming. As we noted above, while describing soil organic carbon, soil erosion and other benefits, and as it is stated in Kaye J.P., 2017, there are very few tradeoffs between catch cropping and climate change mitigation and adaptation, suggesting that ecosystem services that are traditionally expected from catch cropping can be promoted synergistically with services related to climate change.

Thus, we suggest two methods of benefit assessment: 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.

Assessment, carried out by the experts of the project at hand (see Report on task AT1.1. Quantification of the expected nutrient retention rates and other environmental effects), suggests that application of catch crops may result in decrease of annual GHG emissions by almost 170 thou t CO2-e in Lielupe RBD and by 107 thou t CO2-e in Venta RBD (Table 25).

Table 25. Potential reduction of GHG emissions in Venta and Lielupe RBDs due to application of catch crops

	Catch crop GHG mitigation effect, thou t CO2-e/yr
Lielupe RBD:	***168.9***
Mūša sub-basin (LT)	65.7
Nemunėlis sub-basin (LT)	14.1
Lielupė small tributaries sub-basin (LT)	30.1
Latvian part of the Lielupe basin (LV)	59.0
Venta RBD:	***106.8***
Bartuva basin (LT)	4.7
Venta basin (LT)	40.3
Šventoji basin (LT)	2.8
Latvian part of the Venta basin (LV)	59.0

Source: The author's calculations

Financial benefit

As noted in Section 3.1.1., financial benefit of climate change mitigation for a farmer is practically non-existent. All the climate change mitigation effects and benefits are for a whole society.

Environmental and social benefit

CO_2 European Emission Allowances system

As known, with the CO_2 European Emission Allowances system, the European Union aims to create a market mechanism that determines a price for CO_2 emissions and creates incentives to reduce emissions in the most cost-effective manner. The latest price of CO_2, available at the time of the study at hand (as of August 15, 2019) was **27.15 EUR per tonne**. Applying this price for the effects available due to catch cropping in basins and sub-basins of Venta and Lielupe, overall benefit reaches MEUR 7.5 per year (Table 26).

Table 26. Benefits of catch cropping from mitigation of GHG emissions in Venta and Lielupe RBDs, EUR/year

<table>
<tr><th>River basin / sub-basin</th><th>Benefit due to GHG mitigation</th><th>Benefit due to GHG mitigation per basin per country</th></tr>
<tr><td>Lielupe RBD:</td><td>4 600 000</td><td></td></tr>
<tr><td>Mūša sub-basin (LT)</td><td>1 784 000</td><td rowspan="3">2 984 000</td></tr>
<tr><td>Nemunėlis sub-basin (LT)</td><td>383 000</td></tr>
<tr><td>Lielupė small tributaries sub-basin (LT)</td><td>817 000</td></tr>
<tr><td>Latvian part of the Lielupe basin (LV)</td><td>1 602 000</td><td>1 602 000</td></tr>
<tr><td>Venta RBD:</td><td>2 900 000</td><td></td></tr>
<tr><td>Bartuva basin (LT)</td><td>128 000</td><td rowspan="3">1 298 000</td></tr>
<tr><td>Venta basin (LT)</td><td>1 094 000</td></tr>
<tr><td>Šventoji basin (LT)</td><td>76 000</td></tr>
<tr><td>Latvian part of the Venta basin (LV)</td><td>1 602 000</td><td>1 602 000</td></tr>
<tr><td>Total LT</td><td>4 300 000</td><td>4 300 000</td></tr>
<tr><td>Total LV</td><td>3 200 000</td><td>3 200 000</td></tr>
<tr><td>Total Lielupe and Venta RBDs</td><td>7 500 000</td><td>7 500 000</td></tr>
</table>

Source: The author's calculations

Valuation of ecosystem services

Monetary valuation of the catch cropping benefit for the GHG mitigation is usually done in synergy with other ecosystem services which soil provides.

Some studies find out that carbon sequestrated in the soil makes approx. 77-99 per cent of all stored value of carbon (Tribouillois H., 2018). In *Cost of soil degradation in England and Wales, 2011*, it is stated that 80% of total annual degradation costs are associated with loss of regulating services, the bulk of this (49% of all costs) linked to GHG emissions.

Jón Örvar Jónsson et al., 2016, estimated that the value of the soil ecosystem services related to climate regulation (based on pilot area in Crete island) equalled to **2200 to 5610 id$ per ha per year** (approx. 2490 to 6340 EUR of 2018). As authors admit themselves, these values differ quite a lot from the ones, provided by other studies, which declare some 20 times smaller values. For example, in the EC study on Assessing the Economic Impacts of Soil Degradation (Görlach, B. et al., 2004) it is stated that climate change related value of soil equals to approx. 60 EUR/ha/year (**75 EUR/ha/year** in 2018 prices). Moreover, in the same study it is claimed that the climate change impact of carbon released from soils is substantial and considerably higher than the total off-site (social) cost of erosion (about 10 times as high). According to Tyruliai study (*Tyrulių pelkės ekosistemų paslaugų įvertinimo galutinė ataskaita, 2017*), benefit, provided by one ha of bog equals approx. **118 EUR/ha/year**.

As indicated in EC, 2018, an alternative to the use of SCC estimates is the approach by Rodríguez-Entrena et al. (2012), who conducted a choice experiment to evaluate the demand for carbon sequestration in olive grove soils in Andalusia (Spain) and came up with a willingness to pay by the general public of 17 EUR per tonne of CO_2 per person (18 EUR of 2018).

Another study worth noting in this context is Noe et al. (2016), who used a Monte Carlo analysis to identify the value of carbon storage in Minnesota prairies; they found an average value of 73 USD per ha per year (82.5 EUR of 2018).

In summary, value per 1 ha regarding the climate regulation, derived from several existing studies via benefit transfer would equal from 75 to 5600 EUR/ha/year (simple average ~2830 EUR/ha/year). These values reflect not identical ecosystem services and the range is much broader than benefits, assessed from soil erosion reduction and SOC increase in Lielupe and Venta RBDs. It can be assumed that benefits assessed based on these values reflect soil organic carbon, soil erosion and soil GHG mitigation related ecosystem services alltogether keeping in mind their tight interrelation (Table 27).

Table 27. Benefits of catch cropping for climate regulation, based on valuation per ha, EUR/year

<table>
<tr><th>River basin/sub-basin</th><th>Benefit from potential catch cropping areas</th><th>Benefit from areas at risk</th><th>In basin in country, potential areas</th><th>In basin in country, areas at risk</th></tr>
<tr><td>Lielupe RBD</td><td></td><td></td><td>422 40 000</td><td>242 000 000</td></tr>
<tr><td>Mūša sub-basin (LT)</td><td>164 383 400</td><td>114 850 000</td><td rowspan="3">273 400 000</td><td rowspan="3">190 000 000</td></tr>
<tr><td>Lielupė small tributaries sub-basin (LT)</td><td>74 757 280</td><td>74 757 300</td></tr>
<tr><td>Nemunėlis sub-basin (LT)</td><td>34 231 680</td><td>0</td></tr>
<tr><td>Latvian part of the Lielupe basin (LV)</td><td>148 980 000</td><td>52 276 000</td><td>150 000 000</td><td>52 300 000</td></tr>
<tr><td>Venta RBD</td><td></td><td></td><td>270 000 000</td><td>32 000 000</td></tr>
<tr><td>Venta basin (LT)</td><td>101 710 000</td><td>17 680 000</td><td rowspan="3">120 000 000</td><td rowspan="3">18 000 000</td></tr>
<tr><td>Bartuva basin (LT)</td><td>11 453 010</td><td>0</td></tr>
<tr><td>Šventoji basin (LT)</td><td>6 721 300</td><td>0</td></tr>
<tr><td>Latvian part of the Venta basin (LV)</td><td>148 520 000</td><td>14 206 000</td><td>150 000 000</td><td>14 210 000</td></tr>
<tr><td>Total Lielupe and Venta RBDs</td><td>~700 000 000</td><td>~274 000 000</td><td></td><td></td></tr>
</table>

Source: The author's calculations

3.2.6. Benefits associated with control of weeds

In Sections 3.1.1. and 3.1.2. on the methodology applied for the comparison of benefits and costs of catch cropping, it was stated that direct financial benefit for farmers can be calculated via reduced purchase of herbicides and economic (environmental, social) benefits can be assumed to be reflected under benefits which soil organic carbon delivers to a society.

Financial benefits

As described in the Report on task *AT1.1. Quantification of the expected nutrient retention rates and other environmental effects,* many field experiments have shown the ability of various catch crops to reduce weed density and biomass. Consequently, catch crops can be a component in the weed control strategy and bring financial benefits to conventional, as well as organic farming by reducing the need of herbicides.

In order to illustrate the possible monetary benefits for farmers incorporating catch crops in weed control strategy, the assumption was taken into account that catch crops by affecting the density of weeds reduce the need for herbicides and thus lead to savings in production costs, which can be expressed in EUR per ha depending on the main crop grown after the catch crop.

1) Strategy: *Catch crop allows to use reduced dose of herbicides*

The recommended doses (full doses) of herbicides are determined for the maximum weed control, the nearest to 100% control[4], to ensure the maximum level of yield. Taking that into account and assuming that 1% of what full herbicide dose per hectar costs reduces the weed density per 1%, the savings in production cost generated by catch crops can be calculated according to the formula (1):

$$C_s = C_{herb} \times WD_{cc} \quad (1),$$

where C_s are savings (EUR/ha) in production costs generated by catch crop ability suppress the weeds; C_{herb} are costs of herbicides (EUR/ha) for main crop and WD_{cc} is reduction (%) of weed density generated by catch crop. In such a strategy herbicides are still used (includes all operational costs), but high weed control can be reached by reduced dose of herbicides (savings in herbicide costs).

2) Strategy: *Catch crop replaces herbicides*

Different catch crop species have different ability to suppress the weeds. For example, white mustard, oil radish and winter rye has the ability to reduce weeds' density close to complete: 74-94% (Table ##1). For full weed control, herbicides should also be used there. However, the main purpose of weed suppression measures is not to eliminate the weeds totally but to decrease the number of weeds to the level that makes no significant impact on changes in yield and yield quality[5]. The studies analysing the effectiveness of herbicides, conclude that reduced doses of herbicides may also control weeds sufficiently without significant yield losses[6], [7], [8]. Also in practice, when planning the use of herbicides, the doses can be calculated according to different levels (low, medium, high) of target efficacy of weed suppresion (varies from 65-90%)[9].

Thus there could be situations when catch crop provides the weed control in sufficient level without use of herbicides. The possible monetary benefit of using catch crops in such situations would be larger, because of absence of herbicides and operational costs of spraying. In such a strategy the savings in production cost generated by catch crops can be calculated according to the formula (2):

$$C_s = C_{herb} + C_{spray} \quad (2),$$

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[4] https://ac.els-cdn.com/S2212670814000840/1-s2.0-S2212670814000840-main.pdf?_tid=4f3f4ad9-5e60-42ec-a348-0ac34bd7b8ed&acdnat=1533994452_8117c65049418a2feea913dc39c12e6f
[5] http://llufb.llu.lv/dissertation-summary/plant-protection/Janis_Kopmanis_l-a.pdf
[6] https://ac.els-cdn.com/S2212670814000840/1-s2.0-S2212670814000840-main.pdf?_tid=4f3f4ad9-5e60-42ec-a348-0ac34bd7b8ed&acdnat=1533994452_8117c65049418a2feea913dc39c12e6f
[7] http://llufb.llu.lv/dissertation-summary/plant-protection/Janis_Kopmanis_l-a.pdf
[8] https://www.sciencedirect.com/science/article/pii/S1161030117301892
[9] http://llufb.llu.lv/dissertation-summary/plant-protection/Janis_Kopmanis_l-a.pdf

where C_s are savings (EUR/ha) in production costs generated by catch crop, if its ability to reduce the weeds' density is close to complete (more than 75%); C_{herb} are costs of herbicides (EUR/ha) for the main crop, Cspray are direct operational costs of spraying herbicides.

The possible monetary benefit (EUR/ha) of catch crops in weed control is calculated for both strategies based on results of studies on catch crop ability to reduce the weed density (Table 29) and material costs for herbicides and direct costs for spraying EUR/ha (calculations of gross margin in agriculture of Latvia, 2017[10], Table 28).

Table 28. Material costs for herbicides and direct costs for spraying (EUR/ha) according to main crop in Latvia, 2017[11]

Position	Main crop species							
	Winter wheat	Winter rye	Winter triticale	Spring barley	Spring wheat	Potatoes	Pea and mixtures with pea	Winter barley
Herbicides*	12.86	9.17	9.17	8	8	20.65	53.07	9.17
Spraying	19.36	19.36	19.36	19.39	19.36	19.36	19.36	19.36

*The full dose costs per ha of *GranstarPremia* or *Primus XL* in case of cereals and full dose costs per ha of *Fenix* in case of legumes are adopted.

The calculation results for the weed control stategy with reduced dose of herbicides (formula (1)) are given in Table 29. It shows the savings in production costs gained by using reduced dose of herbicides within production of main crop. Herbicides are still used (including all operational costs), but optimal weed control can be reached by reduced dose of herbicides because of catch crop‘s effect on weeds.

Table 29. Possible monetary benefit (EUR/ha) of catch crops in weed control strategy with reduced dose of herbicides

Catch crop	Reduction of weed density, % WD_{cc}	Winter wheat	Winter rye	Winter triticale	Spring barley	Spring wheat	Pota-toes	Pea and mixtures with pea	Winter barley
White mustard	94	12.09	8.62	8.62	7.52	7.52	19.41	49.89	8.62
Brown mustard	50	6.43	4.59	4.59	4.00	4.00	10.33	26.54	4.59
Spring rape	80	10.29	7.34	7.34	6.40	6.40	16.52	42.46	7.34
Winter rape	80	10.29	7.34	7.34	6.40	6.40	16.52	42.46	7.34
Oil radish	90	11.57	8.25	8.25	7.20	7.20	18.59	47.76	8.25
Fodder radish	80	10.29	7.34	7.34	6.40	6.40	16.52	42.46	7.34
Root radish	80	10.29	7.34	7.34	6.40	6.40	16.52	42.46	7.34
Turnip	80	10.29	7.34	7.34	6.40	6.40	16.52	42.46	7.34
Winter rye	76	9.77	X	6.97	6.08	6.08	15.69	40.33	6.97
White clover	12	1.54	1.10	1.10	0.96	0.96	2.48	X	1.10
Red clover	62.2	8.00	5.70	5.70	4.98	4.98	12.84	X	5.70
White melilot	60	7.72	5.50	5.50	4.80	4.80	12.39	X	5.50

[10] http://new.llkc.lv/lv/nozares/augkopiba-ekonomika-lopkopiba/sagatavoti-bruto-segumi-par-2017-gadu
[11] http://new.llkc.lv/lv/nozares/augkopiba-ekonomika-lopkopiba/sagatavoti-bruto-segumi-par-2017-gadu

Catch crop	Reduction of weed density, % WD cc	Winter wheat	Winter rye	Winter triticale	Spring barley	Spring wheat	Pota-toes	Pea and mixtures with pea	Winter barley
Italian ryegrass	26.4	3.40	2.42	2.42	2.11	2.11	5.45	14.01	2.42
Perrenial ryegrass	13.9	1.79	1.27	1.27	1.11	1.11	2.87	7.38	1.27
Phacelia	30	3.86	2.75	2.75	2.40	2.40	6.20	15.92	2.75
Cock's foot	42.3	5.44	3.88	3.88	3.38	3.38	8.73	X	3.88
Oats	90	11.57	8.25	8.25	7.20	7.20	18.59	47.76	8.25
Buckwheat	90	11.57	8.25	8.25	7.20	7.20	18.59	47.76	8.25
Winter vetch	30	3.86	2.75	2.75	2.40	2.40	6.20	15.92	2.75
Pea	10	1.29	0.92	0.92	0.80	0.80	2.07	X	0.92
Faba bean	40	5.14	3.67	3.67	3.20	3.20	8.26	X	3.67

The calculation results for the weed control stategy with no herbicides (formula (2)) are given in Table 30. It shows the savings in production costs generated by catch crop, if its ability to reduce the weeds' density in following main crop is close to complete and it can be considered as substitute for the use of herbicides (no herbicides are used).

Table 30. Possible monetary benefit (EUR/ha) of catch crops in weed control strategy with no herbicides

Catch crop	Reduction of weed density, % WD cc	Spring barley	Spring wheat	Potatoes	Pea and mixtures with pea
White mustard	94	27.39	27.36	40.01	72.43
Spring rape	80	27.39	27.36	40.01	72.43
Winter rape	80	27.39	27.36	40.01	72.43
Oil radish	90	27.39	27.36	40.01	72.43
Fodder radish	80	27.39	27.36	40.01	72.43
Root radish	80	27.39	27.36	40.01	72.43
Turnip	80	27.39	27.36	40.01	72.43
Winter rye	76	27.39	27.36	40.01	72.43
Oats	90	27.39	27.36	40.01	72.43
Buckwheat	90	27.39	27.36	40.01	72.43

The possible monetary effect of catch crops in weed control should be seen as a side benefit for the farmer and can not be generalized, because there are a lot of other factors having influence on the process. Weeds control with catch crops usually requires careful management and agro-ecological knowledge to be effective[12]. Also the risk of success is higher, because it is a biological tool.

Environmental (social) benefits

As noted in the chapter on the methodology, quantification of ecosystem services provided by catch crops regarding weed control, is not assessed separately. It is suggested to apply valuation provided for the soil organic carbon / soil organic matter.

[12] https://aae.wisc.edu/pdmitchell/Production/EconomicsCoverCrops.pdf

4. Cost Benefit Analysis of Catch Crop Application

4.1. Comparison of costs and benefits

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.

We assume costs of catch cropping are the same (average) when considering different effects of catch crops (details in the chapter on Cost Assessment of Catch Crop Application); benefits, however, differ, and in our assessment are calculated per each effect catch cropping brings. Nevertheless, effects related to the reduction of nutrient leaching and nutrient transfer to the next crop are directly interrelated, so are also their benefits.

4.1.1. Nitrogen leaching

Summary of catch cropping costs and both direct financial and environmental (social) benefits due to nitrogen leaching reduction is presented in Table 31.

It should be emphasised that the financial benefit covers not only effect from reduced nutrient leaching, but also effect from nutrient transfer to the next crop. The same applies to the environmental (social) benefit – it reflects also value which is brought to a society because of nutrient transfer to the next crop.

Table 31. Annual average costs and financial and environmental (social) benefits of catch cropping for reduction of nutrient leaching, MEUR/year

River basin / sub-basin	Costs in potential areas at risk	Financial benefit to farmers*	Environmental benefit from areas at risk	Sum of financial and environmental benefits
Lielupe RBD	**7.8**	**2.8**	**4.3**	**7.1**
Mūša sub-basin (LT)	3.6	1.1		
Nemunėlis sub-basin (LT)	0	0.2		
Lielupė small tributaries sub-basin (LT)	2.4	0.5		
Total Lielupe LT	***6.0***	***1.8***	***2.0***	***3.8***
Lielupe LV	***1.8***	***1.0***	***2.3***	***3.3***
Venta RBD	**1.0**	**1.8**	**1.5**	**3.3**
Bartuva basin (LT)	0	0.08		
Venta basin (LT)	0.5	0.7		
Šventoji basin (LT)	0	0.05		
Total Venta LT	***0.5***	***0.8***	***0.24***	***1.0***
Venta LV	***0.5***	***1.0***	***1.23***	***2.2***
Total for LT	***6.5***	***2.6***	***2.3***	***4.9***
Total for LV	***2.3***	***2.0***	***3.5***	***5.5***
Total	***~8.8***	***4.6***	***~5.8***	***~10.4***

**-financial benefit is assumed to be the same in the case of nutrient leaching reduction and nutrient transfer to the nex crop*
Source: The author's calculations

Monetary cost benefit analysis 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 Lielupe RBD Lithuanian part. Sum of financial and environmental benefits is smaller also only in the Lielupe RBD in Lithuania. Catch cropping seems to be beneficial in Venta RBD both in Latvia and Lithuania. This is primarily due to a comparatively small area of water bodies at risk in Venta RBD (thus costs are small). In general, Latvia has got better (positive) benefit / cost ratio. This is also because pollution load reduction target achievement via catch cropping is higher in Latvia than Lithuania.

4.1.2. Nutrient transfer to the next crop

Nutrient transfer to the next crop provides direct financial benefits to farmers and environmental (social) benefits to a society due to reduced eutrophication. Both are presented in the above section (Table 31).

4.1.3. Soil organic carbon content

Soil organic carbon / soil organic matter content provides various benefits, described above in section 3.2.3. Comparison of annual average costs and financial and economic benefits of catch cropping for the increase of SOC/SOM is provided in Table 32.

Table 32. Annual average costs and financial and environmental (social) benefits of catch cropping for increase of SOC/SOM, MEUR/year

River basin / sub-basin	Costs in potential areas	Costs in potential areas at risk	Financial benefit to farmers	Environmental benefit from potential areas	Environmental benefit from areas at risk
Lielupe RBD	**13.6**	**7.8**	**2.8**	**323**	**185**
Mūša sub-basin (LT)	5.2	3.6	1.1	125	88
Nemunėlis sub-basin (LT)	1.0	0	0.2	26	0
Lielupė small tributaries sub-basin (LT)	2.4	2.4	0.5	57	57
Total Lielupe LT	***8.6***	***6.0***	***1.8***	***209***	***145***
Lielupe LV	***5.0***	***1.8***	***1.0***	***114***	***40***
Venta RBD	**8.5**	**1.0**	**1.8**	**191**	**24**
Bartuva basin (LT)	0.3	0	0.08	9	0
Venta basin (LT)	3.2	0.5	0.7	78	14
Šventoji basin (LT)	0.2	0	0.05	5	0
Total Venta LT	***3.7***	***0.5***	***0.8***	***78***	***14***
Venta LV	***4.8***	***0.5***	***1.0***	***114***	***11***
Total for LT	***12.3***	***6.5***	***2.6***	**290**	**158**
Total for LV	***9.8***	***2.3***	***2.0***	**230**	**51**
Total	***~22.1***	***~8.8***	***4.6***	**528**	**200**

Source: The author's calculations

Ecosystem services enhanced by the SOC / SOM are very beneficial and comparison of costs and benefits confirms this. Environmental (social) benefits per year due to increase of SOC / SOM exceed not only costs of catch cropping in areas at risk, but also costs in potential areas by 20-100 times in different basins/subbasins.

4.1.4. Soil erosion

Soil provides a huge variety of ecosystem services. As mentioned, it can be difficult to separate benefits brought by soil organic carbon, nutrients in soil and avoidance of soil erosion. This should be kept in mind while interpreting tables on cost and benefit comparison and in general in this study.

Comparison of annual average costs and financial and economic benefits of catch cropping for the reduction of soil erosion is provided in Table 33. Here we do not consider financial benefit to a farmer potentially brought by a reduced amount of fertilisers required.

Table 33. Annual average costs and financial and environmental (social) benefits of catch cropping for reduction of soil erosion, MEUR/year

River basin / sub-basin	Costs in potential areas	Costs in potential areas at risk	Environmental benefit from potential areas, benefit calculated per ha	Environmental benefit from areas at risk, benefit calculated per ha	Environmental benefit, benefit calculated per tonne of soil
Lielupe RBD	**13.6**	**7.8**	**24.4**	**14.0**	**1.78**
Mūša sub-basin (LT)	5.2	3.6	9.5	6.6	0.7
Nemunėlis sub-basin (LT)	1.0	0.0	2	0	0.3
Lielupė small tributaries sub-basin (LT)	2.4	2.4	4.3	4.3	0.1
Total Lielupe LT	***8.6***	***6.0***	***15.8***	**11.0**	***1.1***
Lielupe LV	***5.0***	***1.8***	***8.6***	**3.0**	***0.7***
Venta RBD	**8.5**	**1.0**	**15.5**	**1.8**	**1.1**
Bartuva basin (LT)	0.3	0.0	0.7	0	0.2
Venta basin (LT)	3.2	0.5	5.9	1.0	1.0
Šventoji basin (LT)	0.2	0.0	0.4	0	0.04
Total Venta LT	***3.7***	***0.5***	***6.9***	***1.0***	***1.2***
Venta LV	***4.8***	***0.5***	***8.6***	***0.8***	***1.1***
Total for LT	***12.3***	***6.5***	***22.8***	***12.0***	***1.1***
Total for LV	***9.8***	***2.3***	***17.2***	***3.9***	***1.8***
Total	***~22.1***	***~8.8***	***40.0***	***15.8***	***2.9***

Source: The author's calculations

The table above demonstrates how a method of the benefit assessment influences benefit/cost ratio. As shown in the table, environmental benefit, valuated as an ecosystem service, is much higher than the benefit calculated based on values of various research given to one tonne of soil saved. One explanation is that one tonne of soil seems to more often being assessed taking into consideration more financial than social aspects.

4.1.5. GHG emission regulation

In the area of climate change, soil ecosystem services play at least double role: first, maintain healthy soils and by building-up of organic matter enhances the role of soil as a sink for atmospheric CO_2. On the other hand, soil degradation would lead to the release of carbon from soils. Thus synergy of soil ecosystem services and protection of them by an efficient application of catch crops is extremely important. This synergy can be mirrored in benefit assessment, i.e. benefits, calculated for soil's climate regulation can be considered covering also benefits provided by reduction of soil erosion and increase of SOC / SOM. To some extent also reduction of nutrient loss can be regarded covered by the benefits provided in Table 34, where costs and benefits are compared.

Table 34. Annual average costs and environmental (social) benefits of catch cropping for climate change regulation, MEUR/year

River basin / sub-basin	Costs in potential areas	Costs in potential areas at risk	Financial benefit to farmers	Environmen-tal benefit from potential areas, benefit calculated per ha	Environmen-tal benefit from areas at risk, benefit calculated per ha	Environmen-tal benefit, benefit calculated per tonne of CO_2
Lielupe RBD	**13.6**	**7.8**	**0**	**422**	**242**	**4.6**
Mūša sub-basin (LT)	5.2	3.6	0	164	**115**	1.8
Nemunėlis sub-basin (LT)	1.0	0.0	0	34	**0**	0.4
Lielupė small tributaries sub-basin (LT)	2.4	2.4	0	75	**75**	0,8
Total Lielupe LT	**8.6**	***6.0***	***0***	***273***	**190**	**3.0**
Lielupe LV	**5.0**	***1.8***	***0***	***149***	**52**	1.6
Venta RBD	**8.5**	**1.0**	**0**	**268**	**32**	**2.9**
Bartuva basin (LT)	0.3	0.0	0	11	**0**	0.1
Venta basin (LT)	3.2	0.5	0	102	**18**	1.1
Šventoji basin (LT)	0.2	0.0	0	7	**0**	0.1
Total Venta LT	**3.7**	***0.5***	***0***	***120***	**18**	**1.3**
Venta LV	**4.8**	***0.5***	***0***	***149***	**14**	1.6
Total for LT	***12.3***	***6.5***	***0***	***393***	***207***	***4.3***
Total for LV	***9.8***	***2.3***	***0***	***297***	***66***	***3.2***
Total	***~22.1***	***~8.8***	***0***	***691***	***274***	***7.5***

Source: The author's calculations

If soil ecosystems valuation figures per ha are applied, soil ecosystem services seem to create huge benefits for climate regulation, soil erosion reduction and increase of SOC / SOM. Environmental (social) benefits per year exceed not only costs of catch cropping in areas at risk, but also costs in potential areas by 28-35 times in different basins/subbasins.

If soil ecosystems valuation per tonne of CO_2 is applied, annual costs of catch crop establishment and termination in potential for catch cropping areas exceed benefits assessed in all sub-basins (note that effects/benefits in this case are related only to potential areas, not to potential areas at risk). Brief sensitivity analysis we made shows that if the price of CO_2 increases approx. 3 times, benefits become equal to costs in potential areas in Lielupe and Venta RBDs.

4.1.6. Weed and pest control

As described above, biodiversity affects the capacity of agriculture to deliver ecosystem services, in particular those related to biocontrol and water quality. Weeds cause an estimated crop yield loss of about 43% world-wide (Lemessa F. et al., 2015). Financial and economic (social and environmental) benefits are assessed only in a few studies. We applied two scenarios (strategies) for financial benefit calculation and used SOC / SOM estimates for economic (social and environmental) benefit calculation.

Table 35. Annual average costs and financial and environmental (social) benefits of catch cropping for weed control, MEUR/year

River basin / sub-basin	Costs in potential areas	Costs in potential areas at risk	Environmental (social) benefits from potential areas*
Lielupe RBD	**13.6**	**7.8**	**323**
Mūša sub-basin (LT)	5.2	3.6	125
Lielupė small tributaries sub-basin (LT)	2.4	2.4	26
Nemunėlis sub-basin (LT)	1.0	0.0	57
Total Lielupe LT	***8.6***	***6.0***	***209***
Lielupe LV	***5.0***	***1.8***	***114***
Venta RBD	**8.5**	**1.0**	**191**
Venta basin (LT)	3.2	0.5	9
Bartuva basin (LT)	0.3	0.0	78
Šventoji basin (LT)	0.2	0.0	5
Total Venta LT	***3.7***	***0.5***	***78***
Venta LV	***4.8***	***0.5***	***114***
Total for LT	***12.3***	***6.5***	***290***
Total for LV	***9.8***	***2.3***	***230***
Total	***~22.1***	***~8.8***	***528***

Source: The author's calculations

**- the same as for the SOC/SOM*

Illustrative figures show the potential financial and economic benefit of applying catch cropping for weed control. It should be stressed that environmental benefit reflects not only ecosystem services provided by catch cropping for weed control, but also for other important characteristics of soil, water pollution control and similar.

4.2. Summary, Conclusions and Recommendations

The report at hand presents potential costs and benefits of catch cropping in the Venta and Lielupe RBs. Results of this Task are directly used in the Decision Support Tool[13], which allows farmers to better understand how much catch crops' application could cost and what financial benefits they can provide.

The following effects, brought not only to a farmer, but to a whole society by the catch crops, are analysed:

- 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

[13] Developed under the Project at hand.

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 36. 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	In potential for catch cropping areas at risk	Reduced amount of fertilizers (savings of nutrients)
Lielupe RBD	**13.6**	**7.8**	**2.8**
- *Lielupe LT*	*8.6*	*6.0*	*1.8*
- *Lielupe LV*	*5.0*	*1.8*	*1.0*
Venta RBD	**8.5**	**1.0**	**1.8**
- *Venta LT*	*3.7*	*0.5*	*0.8*
- *Venta LV*	*4.8*	*0.5*	*1.0*
Total for LT	***12.3***	***6.5***	***2.6***
Total for LV	***9.8***	***2.3***	***2.0***
Total	***22.1***	***8.8***	***4.6***

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

Table 37. 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 38. 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.

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Annex 1. Annual Unit Costs of Machinery and Operation for Establishment and Termination of Catch Crops

Unit costs of catch crop machinery and operation in Lithuania, EUR/ha/year (2017)

Catch crop	Catch crop sowing									Catch crop termination						Total costs of machinery and operation
	Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Hanged pneumatic cereal seeder (tractor capacity 83 kW)	Hanged pneumatic rape seeder (tractor capacity 83 kW)	Hanged pneumatic herb seeder (tractor capacity 83 kW)	Combined cereal seeder with soil cultivation (tractor capacity 120 kW)	Combined rape seeder with soil cultivation (tractor capacity 120 kW)	Direct sowing (stubbly) cereal seeder (tractor capacity 120 kW)	Direct sowing (stubbly) rape seeder (tractor capacity 120 kW)	Disc harrowing		Shallow stubble cultivation (tractor capacity 120 kW)	Rolling (tractor capacity 83 kW)	Reversible hanged plough (tractor capacity 102 kW)	Reversible trailing plough (tractor capacity 120 kW)	
										working width of the machine 3 m (tractor capacity 120 kW)	working width of the machine 5 m (tractor capacity 120 kW)					
White mustard	23											20,38				**43,38**
	23															**23,00**
									25,34			20,38				**45,72**
							33,97					20,38				**54,35**
Brown mustard	23											20,38				**43,38**
									25,34			20,38				**45,72**
							33,97					20,38				**54,35**
Spring rape	23											20,38				**43,38**
									25,34			20,38				**45,72**
							33,97					20,38				**54,35**
							33,97									**33,97**
Winter rape		33,97		16,12											64,18	**114,27**
		33,97		16,12						26,84					64,18	**141,11**
		33,97		16,12							21,82				64,18	**136,09**
		33,97		16,12									8,01		64,18	**122,28**
		33,97		16,12										64,38		**114,47**

Catch crop	Catch crop sowing									Catch crop termination						Total costs of machinery and operation
	Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Hanged pneumatic cereal seeder (tractor capacity 83 kW)	Hanged pneumatic rape seeder (tractor capacity 83 kW)	Hanged pneumatic herb seeder (tractor capacity 83 kW)	Combined cereal seeder with soil cultivation (tractor capacity 120 kW)	Combined rape seeder with soil cultivation (tractor capacity 120 kW)	Direct sowing (stubbly) cereal seeder (tractor capacity 120 kW)	Direct sowing (stubbly) rape seeder (tractor capacity 120 kW)	Disc harrowing: working width of the machine 3 m (tractor capacity 120 kW)	Disc harrowing: working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Rolling (tractor capacity 83 kW)	Reversible hanged plough (tractor capacity 102 kW)	Reversible trailing plough (tractor capacity 120 kW)	
		33,97		16,12						26,84				64,38		**141,31**
		33,97		16,12							21,82			64,38		**136,29**
		33,97		16,12									8,01	64,38		**122,48**
		33,97			17,18										64,18	**115,33**
		33,97			17,18					26,84					64,18	**142,17**
		33,97			17,18						21,82				64,18	**137,15**
		33,97			17,18								8,01		64,18	**123,34**
		33,97			17,18									64,38		**115,53**
		33,97			17,18					26,84				64,38		**142,37**
		33,97			17,18						21,82			64,38		**137,35**
		33,97			17,18								8,01	64,38		**123,54**
							33,97								64,18	**98,15**
							33,97			26,84					64,18	**124,99**
							33,97				21,82				64,18	**119,97**
							33,97						8,01		64,18	**106,16**
							33,97							64,38		**98,35**
							33,97			26,84				64,38		**125,19**
							33,97				21,82			64,38		**120,17**
							33,97						8,01	64,38		**106,36**
									25,34						64,18	**89,52**
									25,34	26,84					64,18	**116,36**
									25,34		21,82				64,18	**111,34**

Catch crop	Catch crop sowing									Catch crop termination						Total costs of machinery and operation
	Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Hanged pneumatic cereal seeder (tractor capacity 83 kW)	Hanged pneumatic rape seeder (tractor capacity 83 kW)	Hanged pneumatic herb seeder (tractor capacity 83 kW)	Combined cereal seeder with soil cultivation (tractor capacity 120 kW)	Combined rape seeder with soil cultivation (tractor capacity 120 kW)	Direct sowing (stubbly) cereal seeder (tractor capacity 120 kW)	Direct sowing (stubbly) rape seeder (tractor capacity 120 kW)	Disc harrowing: working width of the machine 3 m (tractor capacity 120 kW)	Disc harrowing: working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Rolling (tractor capacity 83 kW)	Reversible hanged plough (tractor capacity 102 kW)	Reversible trailing plough (tractor capacity 120 kW)	
									25,34				8,01		64,18	**97,53**
									25,34					64,38		**89,72**
									25,34	26,84				64,38		**116,56**
									25,34		21,82			64,38		**111,54**
									25,34				8,01	64,38		**97,73**
Oil radish		33,97		16,12								20,38				**70,47**
(Forage radish)		33,97		16,12												**50,09**
		33,97			17,18							20,38				**71,53**
		33,97			17,18											**51,15**
									25,34			20,38				**45,72**
									25,34							**25,34**
							33,97					20,38				**54,35**
							33,97									**33,97**
Root radish		33,97		16,12								20,38				**70,47**
		33,97		16,12						26,84						**76,93**
		33,97		16,12							21,82					**71,91**
		33,97		16,12												**50,09**
		33,97			17,18							20,38				**71,53**
		33,97			17,18					26,84						**77,99**
		33,97			17,18						21,82					**72,97**
		33,97			17,18											**51,15**

Catch crop	Catch crop sowing: Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW)	Catch crop sowing: Shallow stubble cultivation (tractor capacity 120 kW)	Catch crop sowing: Hanged pneumatic cereal seeder (tractor capacity 83 kW)	Catch crop sowing: Hanged pneumatic rape seeder (tractor capacity 83 kW)	Catch crop sowing: Hanged pneumatic herb seeder (tractor capacity 83 kW)	Catch crop sowing: Combined cereal seeder with soil cultivation (tractor capacity 120 kW)	Catch crop sowing: Combined rape seeder with soil cultivation (tractor capacity 120 kW)	Catch crop sowing: Direct sowing (stubbly) cereal seeder (tractor capacity 120 kW)	Catch crop sowing: Direct sowing (stubbly) rape seeder (tractor capacity 120 kW)	Catch crop termination: Disc harrowing: working width of the machine 3 m (tractor capacity 120 kW)	Catch crop termination: Disc harrowing: working width of the machine 5 m (tractor capacity 120 kW)	Catch crop termination: Shallow stubble cultivation (tractor capacity 120 kW)	Catch crop termination: Rolling (tractor capacity 83 kW)	Catch crop termination: Reversible hanged plough (tractor capacity 102 kW)	Catch crop termination: Reversible trailing plough (tractor capacity 120 kW)	Total costs of machinery and operation
							33,97					20,38				**54,35**
							33,97			26,84						**60,81**
							33,97				21,82					**55,79**
							33,97									**33,97**
									25,34			20,38				**45,72**
									25,34	26,84						**52,18**
									25,34		21,82					**47,16**
									25,34							**25,34**
Turnip		33,97		16,12								20,38				**70,47**
		33,97			17,18							20,38				**71,53**
							33,97					20,38				**54,35**
									25,34			20,38				**45,72**
Winter rye		33,97	16,96												64,18	**115,11**
		33,97	16,96							26,84					64,18	**141,95**
		33,97	16,96								21,82				64,18	**136,93**
		33,97	16,96										8,01		64,18	**123,12**
		33,97	16,96											64,38		**115,31**
		33,97	16,96							26,84				64,38		**142,15**
		33,97	16,96								21,82			64,38		**137,13**
		33,97	16,96										8,01	64,38		**123,32**
		33,97	16,96									20,38				**71,31**
						35,92									64,18	**100,1**

LLI-49 project CATCH POLLUTION

Cost and benefit analysis of catch crop application in Venta and Lielupe RBDs

Catch crop	Catch crop sowing									Catch crop termination						Total costs of machinery and operation
	Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Hanged pneumatic cereal seeder (tractor capacity 83 kW)	Hanged pneumatic rape seeder (tractor capacity 83 kW)	Hanged pneumatic herb seeder (tractor capacity 83 kW)	Combined cereal seeder with soil cultivation (tractor capacity 120 kW)	Combined rape seeder with soil cultivation (tractor capacity 120 kW)	Direct sowing (stubbly) cereal seeder (tractor capacity 120 kW)	Direct sowing (stubbly) rape seeder (tractor capacity 120 kW)	Disc harrowing: working width of the machine 3 m (tractor capacity 120 kW)	Disc harrowing: working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Rolling (tractor capacity 83 kW)	Reversible hanged plough (tractor capacity 102 kW)	Reversible trailing plough (tractor capacity 120 kW)	
						35,92				26,84					64,18	**126,94**
						35,92					21,82				64,18	**121,92**
						35,92							8,01		64,18	**108,11**
						35,92								64,38		**100,3**
						35,92				26,84				64,38		**127,14**
						35,92					21,82			64,38		**122,12**
						35,92							8,01	64,38		**108,31**
						35,92						20,38				**56,3**
								26,56							64,18	**90,74**
								26,56		26,84					64,18	**117,58**
								26,56			21,82				64,18	**112,56**
								26,56					8,01		64,18	**98,75**
								26,56						64,38		**90,94**
								26,56		26,84				64,38		**117,78**
								26,56			21,82			64,38		**112,76**
								26,56					8,01	64,38		**98,95**
								26,56				20,38				**46,94**
White clover		33,97			17,18										64,18	**115,33**
		33,97			17,18									64,38		**115,53**
Red clover		33,97			17,18										64,18	**115,33**
		33,97			17,18									64,38		**115,53**

Catch crop	Catch crop sowing									Catch crop termination						Total costs of machinery and operation
	Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Hanged pneumatic cereal seeder (tractor capacity 83 kW)	Hanged pneumatic rape seeder (tractor capacity 83 kW)	Hanged pneumatic herb seeder (tractor capacity 83 kW)	Combined cereal seeder with soil cultivation (tractor capacity 120 kW)	Combined rape seeder with soil cultivation (tractor capacity 120 kW)	Direct sowing (stubbly) cereal seeder (tractor capacity 120 kW)	Direct sowing (stubbly) rape seeder (tractor capacity 120 kW)	Disc harrowing: working width of the machine 3 m (tractor capacity 120 kW)	Disc harrowing: working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Rolling (tractor capacity 83 kW)	Reversible hanged plough (tractor capacity 102 kW)	Reversible trailing plough (tractor capacity 120 kW)	
White melilot		33,97			17,18										64,18	**115,33**
		33,97			17,18									64,38		**115,53**
Italian ryegrass		33,97			17,18							20,38				**71,53**
		33,97			17,18										64,18	**115,33**
		33,97			17,18											**51,15**
Perrenial ryegrass		33,97			17,18									64,38		**115,53**
Phacelia		33,97		16,12								20,38				**70,47**
		33,97		16,12												**50,09**
		33,97			17,18							20,38				**71,53**
		33,97			17,18											**51,15**
							33,97					20,38				**54,35**
							33,97									**33,97**
									25,34			20,38				**45,72**
									25,34							**25,34**
Cock's foot		33,97			17,18										64,18	**115,33**
		33,97			17,18									64,38		**115,53**
		33,97			17,18					26,84					64,18	**142,17**
		33,97			17,18					26,84				64,38		**142,37**
		33,97			17,18						21,82				64,18	**137,15**
		33,97			17,18						21,82			64,38		**137,35**
Oat & Black oat		33,97	16,96									20,38				**71,31**

Catch crop	**Catch crop sowing**									**Catch crop termination**						**Total costs of machinery and operation**
	Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW)	**Shallow stubble cultivation (tractor capacity 120 kW)**	**Hanged pneumatic cereal seeder (tractor capacity 83 kW)**	**Hanged pneumatic rape seeder (tractor capacity 83 kW)**	**Hanged pneumatic herb seeder (tractor capacity 83 kW)**	**Combined cereal seeder with soil cultivation (tractor capacity 120 kW)**	**Combined rape seeder with soil cultivation (tractor capacity 120 kW)**	**Direct sowing (stubbly) cereal seeder (tractor capacity 120 kW)**	**Direct sowing (stubbly) rape seeder (tractor capacity 120 kW)**	**Disc harrowing**		**Shallow stubble cultivation (tractor capacity 120 kW)**	**Rolling (tractor capacity 83 kW)**	**Reversible hanged plough (tractor capacity 102 kW)**	**Reversible trailing plough (tractor capacity 120 kW)**	
										working width of the machine 3 m (tractor capacity 120 kW)	**working width of the machine 5 m (tractor capacity 120 kW)**					
		33,97	16,96													**50,93**
						35,92						20,38				**56,3**
						35,92										**35,92**
								26,56				20,38				**46,94**
								26,56								**26,56**
Buckwheat		33,97	16,96									20,38				**71,31**
		33,97	16,96													**50,93**
						35,92						20,38				**56,3**
						35,92										**35,92**
								26,56				20,38				**46,94**
								26,56								**26,56**
Winter vetch		33,97	16,96									20,38				**71,31**
		33,97	16,96												64,18	**115,11**
		33,97	16,96											64,38		**115,31**
						35,92						20,38				**56,3**
						35,92									64,18	**100,1**
						35,92								64,38		**100,3**
								26,56				20,38				**46,94**
								26,56							64,18	**90,74**
								26,56						64,38		**90,94**
Pea		33,97	16,96									20,38				**71,31**

Catch crop	Catch crop sowing									Catch crop termination						Total costs of machinery and operation
	Shallow stubble cultivation with seed broadcasting (tractor capacity 120kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Hanged pneumatic cereal seeder (tractor capacity 83 kW)	Hanged pneumatic rape seeder (tractor capacity 83 kW)	Hanged pneumatic herb seeder (tractor capacity 83 kW)	Combined cereal seeder with soil cultivation (tractor capacity 120 kW)	Combined rape seeder with soil cultivation (tractor capacity 120 kW)	Direct sowing (stubbly) cereal seeder (tractor capacity 120 kW)	Direct sowing (stubbly) rape seeder (tractor capacity 120 kW)	Disc harrowing: working width of the machine 3 m (tractor capacity 120 kW)	Disc harrowing: working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation (tractor capacity 120 kW)	Rolling (tractor capacity 83 kW)	Reversible hanged plough (tractor capacity 102 kW)	Reversible trailing plough (tractor capacity 120 kW)	
		33,97	16,96													**50,93**
						35,92						20,38				**56,3**
						35,92										**35,92**
								26,56				20,38				**46,94**
								26,56								**26,56**
Faba bean		33,97	16,96									20,38				**71,31**
		33,97	16,96													**50,93**
						35,92						20,38				**56,3**
						35,92										**35,92**
								26,56				20,38				**46,94**
								26,56								**26,56**

Unit costs of catch crop machinery and operation in Latvia, EUR/ha/year (2017)

Catch crop	Machinery					Catch termination					Total costs of machinery and operation
						Disc harrowing					
	Shallow stubble cultivation with seed broadcasting, (tractor capacity 120kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Hanged pneumatic seeder, (tractor capacity 83 kW)	Combined seeder with soil cultivation, (tractor capacity 120 kW)	Direct sowing (stubbly) seeder, (tractor capacity 120 kW)	working width of the machine 3 m (tractor capacity 120 kW)	working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Rolling, (tractor capacity 83 kW)	Reversible hanged plough, (tractor capacity 102 kW)	
White mustard	21,61							15,86			**37,47**
	21,61										**21,61**
					26,16			15,86			**42,02**
					26,16						**26,16**
				41,71				15,86			**57,57**
				41,71							**41,71**
Brown mustard	21,61							15,86			**37,47**
	21,61										**21,61**
					26,16			15,86			**42,02**
					26,16						**26,16**
				41,71				15,86			**57,57**
				41,71							**41,71**
Spring rape	21,61							15,86			**37,47**
	21,61										**21,61**
					26,16			15,86			**42,02**
					26,16						**26,16**
				41,71				15,86			**57,57**
				41,71							**41,71**

Catch crop	Machinery					Catch termination					Total costs of machinery and operation
						Disc harrowing					
	Shallow stubble cultivation with seed broadcasting, (tractor capacity 120kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Hanged pneumatic seeder, (tractor capacity 83 kW)	Combined seeder with soil cultivation, (tractor capacity 120 kW)	Direct sowing (stubbly) seeder, (tractor capacity 120 kW)	working width of the machine 3 m (tractor capacity 120 kW)	working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Rolling, (tractor capacity 83 kW)	Reversible hanged plough, (tractor capacity 102 kW)	
Winter rape		15,86	16,52							45,44	**77,82**
		15,86	16,52			26,88				45,44	**104,70**
		15,86	16,52				29,68			45,44	**107,50**
		15,86	16,52						14,05	45,44	**91,87**
					26,16					45,44	**71,60**
					26,16	26,88				45,44	**98,48**
					26,16		29,68			45,44	**101,28**
					26,16				14,05	45,44	**85,65**
				41,71						45,44	**87,15**
				41,71		26,88				45,44	**114,03**
				41,71			29,68			45,44	**116,83**
				41,71					14,05	45,44	**101,20**
Oil radish		15,86	16,52					15,86			**48,24**
(Forage radish)		15,86	16,52								**32,38**
				41,71				15,86			**57,57**
				41,71							**41,71**
					26,16			15,86			**42,02**
					26,16						**26,16**
Root radish		15,86	16,52					15,86			**48,24**
		15,86	16,52			26,88					**59,26**

Catch crop	Machinery					Catch termination					Total costs of machinery and operation
						Disc harrowing					
	Shallow stubble cultivation with seed broadcasting, (tractor capacity 120kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Hanged pneumatic seeder, (tractor capacity 83 kW)	Combined seeder with soil cultivation, (tractor capacity 120 kW)	Direct sowing (stubbly) seeder, (tractor capacity 120 kW)	working width of the machine 3 m (tractor capacity 120 kW)	working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Rolling, (tractor capacity 83 kW)	Reversible hanged plough, (tractor capacity 102 kW)	
		15,86	16,52				29,68				**62,06**
		15,86	16,52								**32,38**
				41,71				15,86			**57,57**
				41,71		26,88					**68,59**
				41,71			29,68				**71,39**
				41,71							**41,71**
					26,16			15,86			**42,02**
					26,16	26,88					**53,04**
					26,16		29,68				**55,84**
					26,16						**26,16**
Turnip		15,86	16,52					15,86			**48,24**
				41,71				15,86			**57,57**
					26,16			15,86			**42,02**
Winter rye		15,86	16,52							45,44	**77,82**
		15,86	16,52			26,88				45,44	**104,70**
		15,86	16,52				29,68			45,44	**107,50**
		15,86	16,52						14,05	45,44	**91,87**
		15,86	16,52					15,86			**48,24**
					26,16					45,44	**71,60**
					26,16	26,88				45,44	**98,48**

Catch crop	Machinery					Catch termination					Total costs of machinery and operation
						Disc harrowing					
	Shallow stubble cultivation with seed broadcasting, (tractor capacity 120kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Hanged pneumatic seeder, (tractor capacity 83 kW)	Combined seeder with soil cultivation, (tractor capacity 120 kW)	Direct sowing (stubbly) seeder, (tractor capacity 120 kW)	working width of the machine 3 m (tractor capacity 120 kW)	working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Rolling, (tractor capacity 83 kW)	Reversible hanged plough, (tractor capacity 102 kW)	
					26,16		29,68			45,44	**101,28**
					26,16				14,05	45,44	**85,65**
					26,16			15,86			**42,02**
				41,71						45,44	**87,15**
				41,71		26,88				45,44	**114,03**
				41,71			29,68			45,44	**116,83**
				41,71					14,05	45,44	**101,20**
				41,71				15,86			**57,57**
White clover		15,86	16,52							45,44	**77,82**
Red clover		15,86	16,52							45,44	**77,82**
White melilot		15,86	16,52							45,44	**77,82**
Italian ryegrass		15,86	16,52					15,86			**48,24**
		15,86	16,52							45,44	**77,82**
Perrenial ryegrass		15,86	16,52							45,44	**77,82**
Phacelia		15,86	16,52					15,86			**48,24**
		15,86	16,52								**32,38**
					26,16			15,86			**42,02**
					26,16						**26,16**
				41,71				15,86			**57,57**
				41,71							**41,71**

Catch crop	Machinery					Catch termination					Total costs of machinery and operation
						Disc harrowing					
	Shallow stubble cultivation with seed broadcasting, (tractor capacity 120kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Hanged pneumatic seeder, (tractor capacity 83 kW)	Combined seeder with soil cultivation, (tractor capacity 120 kW)	Direct sowing (stubbly) seeder, (tractor capacity 120 kW)	working width of the machine 3 m (tractor capacity 120 kW)	working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Rolling, (tractor capacity 83 kW)	Reversible hanged plough, (tractor capacity 102 kW)	
Cock's foot		15,86	16,52							45,44	**77,82**
		15,86	16,52			26,88				45,44	**104,70**
		15,86	16,52				29,68			45,44	**107,50**
Oat & Black oat		15,86	16,52					15,86			**48,24**
		15,86	16,52								**32,38**
					26,16			15,86			**42,02**
					26,16						**26,16**
				41,71				15,86			**57,57**
				41,71							**41,71**
Buckwheat		15,86	16,52					15,86			**48,24**
		15,86	16,52								**32,38**
				41,71				15,86			**57,57**
				41,71							**41,71**
					26,16			15,86			**42,02**
					26,16						**26,16**
Winter vetch		15,86	16,52					15,86			**48,24**
		15,86	16,52							45,44	**77,82**
					26,16			15,86			**42,02**
					26,16					45,44	**71,60**
				41,71				15,86			**57,57**

Catch crop	Machinery					Catch termination					Total costs of machinery and operation
						Disc harrowing					
	Shallow stubble cultivation with seed broadcasting, (tractor capacity 120kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Hanged pneumatic seeder, (tractor capacity 83 kW)	Combined seeder with soil cultivation, (tractor capacity 120 kW)	Direct sowing (stubbly) seeder, (tractor capacity 120 kW)	working width of the machine 3 m (tractor capacity 120 kW)	working width of the machine 5 m (tractor capacity 120 kW)	Shallow stubble cultivation, (tractor capacity 120 kW)	Rolling, (tractor capacity 83 kW)	Reversible hanged plough, (tractor capacity 102 kW)	
				41,71						45,44	**87,15**
Pea		15,86	16,52					15,86			**48,24**
		15,86	16,52								**32,38**
				41,71				15,86			**57,57**
				41,71							**41,71**
					26,16			15,86			**42,02**
					26,16						**26,16**
Faba bean		15,86	16,52					15,86			**48,24**
		15,86	16,52								**32,38**
				41,71				15,86			**57,57**
				41,71							**41,71**
					26,16			15,86			**42,02**
					26,16						**26,16**

Annex 2. Total Annual Unit Costs of Catch Crop Establishment and Termination

Total annual unit cost of catch crop establishment and termination in Lithuania, EUR/ha/year (2017)

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
White mustard	Shallow stubble cultivation with seed broadcasting	Shallow stubble cultivation	30	43%	40	57%	**70**
	Shallow stubble cultivation with seed broadcasting	-	30	60%	20	40%	**50**
	Direct sowing (stubbly) rape seeder	Shallow stubble cultivation	20	29%	50	71%	**70**
	Combined rape seeder with soil cultivation	Shallow stubble cultivation	20	29%	50	71%	**70**
Brown mustard	Shallow stubble cultivation with seed broadcasting	Shallow stubble cultivation	30	43%	40	57%	**70**
	Direct sowing (stubbly) rape seeder	Shallow stubble cultivation	20	29%	50	71%	**70**
	Combined rape seeder with soil cultivation	Shallow stubble cultivation	20	29%	50	71%	**70**
Spring rape	Shallow stubble cultivation with seed broadcasting	Shallow stubble cultivation	30	43%	40	57%	**70**
	Direct sowing (stubbly) rape seeder	Shallow stubble cultivation	15	23%	50	77%	**65**
	Combined rape seeder with soil cultivation	Shallow stubble cultivation	15	23%	50	77%	**65**
	Combined rape seeder with soil cultivation	-	15	33%	30	67%	**45**
Winter rape	Shallow stubble cultivation + Hanged pneumatic rape seeder	Reversible trailing plough	20	15%	110	85%	**130**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Disc harrowing working width of the machine 3 m + Reversible trailing plough	20	13%	140	88%	**160**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Disc harrowing working width of the machine 5 m + Reversible trailing plough	20	13%	140	88%	**160**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Rolling + Reversible trailing plough	20	14%	120	86%	**140**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Reversible hanged ploug	20	15%	110	85%	**130**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	20	13%	140	88%	**160**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	20	13%	140	88%	**160**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Rolling + Reversible hanged plough	20	14%	120	86%	**140**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible trailing plough	20	14%	120	86%	**140**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 3 m + Reversible trailing plough	20	13%	140	88%	**160**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 5 m	20	13%	140	88%	**160**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
		+ Reversible trailing plough					
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Rolling + Reversible trailing plough	20	14%	120	86%	**140**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible hanged plough	20	14%	120	86%	**140**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	20	13%	140	88%	**160**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	20	13%	140	88%	**160**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Rolling + Reversible hanged plough	20	14%	120	86%	**140**
	Combined rape seeder with soil cultivation	Reversible trailing plough	20	17%	100	83%	**120**
	Combined rape seeder with soil cultivation	Disc harrowing working width of the machine 3 m + Reversible trailing plough	20	14%	120	86%	**140**
	Combined rape seeder with soil cultivation	Disc harrowing working width of the machine 5 m + Reversible trailing plough	20	14%	120	86%	**140**
	Combined rape seeder with soil cultivation	Rolling + Reversible trailing plough	20	15%	110	85%	**130**
	Combined rape seeder with soil cultivation	Reversible hanged plough	20	17%	100	83%	**120**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Combined rape seeder with soil cultivation	Disc harrowing working width of the machine 3 m + Reversible hanged plough	20	13%	130	87%	**150**
	Combined rape seeder with soil cultivation	Disc harrowing working width of the machine 5 m + Reversible hanged plough	20	14%	120	86%	**140**
	Combined rape seeder with soil cultivation	Rolling + Reversible hanged plough	20	15%	110	85%	**130**
	Direct sowing (stubbly) rape seeder	Reversible trailing plough	20	18%	90	82%	**110**
	Direct sowing (stubbly) rape seeder	Disc harrowing working width of the machine 3 m + Reversible trailing plough	20	14%	120	86%	**140**
	Direct sowing (stubbly) rape seeder	Disc harrowing working width of the machine 5 m + Reversible trailing plough	20	15%	110	85%	**130**
	Direct sowing (stubbly) rape seeder	Rolling + Reversible trailing plough	20	17%	100	83%	**120**
	Direct sowing (stubbly) rape seeder	Reversible hanged ploug	20	18%	90	82%	**110**
	Direct sowing (stubbly) rape seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	20	14%	120	86%	**140**
	Direct sowing (stubbly) rape seeder	Disc harrowing working width of the machine 5 m	20	15%	110	85%	**130**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
		+ Reversible hanged plough					
	Direct sowing (stubbly) rape seeder	Rolling + Reversible hanged plough	20	17%	100	83%	**120**
Oil radish	Shallow stubble cultivation + Hanged pneumatic rape seeder	Shallow stubble cultivation	30	30%	70	70%	**1000**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	-	30	38%	50	63%	**80**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Shallow stubble cultivation	30	30%	70	70%	**100**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	-	30	38%	50	63%	**80**
	Direct sowing (stubbly) rape seeder	Shallow stubble cultivation	30	38%	50	63%	**80**
	Direct sowing (stubbly) rape seeder	-	30	50%	30	50%	**60**
	Combined rape seeder with soil cultivation	Shallow stubble cultivation	30	38%	50	63%	**80**
	Combined rape seeder with soil cultivation	-	30	50%	30	50%	**60**
Root radish	Shallow stubble cultivation + Hanged pneumatic rape seeder	Shallow stubble cultivation	80	53%	70	47%	**150**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Disc harrowing working width of the machine 3 m	80	50%	80	50%	**160**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	Disc harrowing working width of the machine 5 m	80	53%	70	47%	**150**
	Shallow stubble cultivation + Haaged pneumatic rape seeder	-	80	62%	50	38%	**130**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Shallow stubble cultivation	80	53%	70	47%	**150**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 3 m	80	50%	80	50%	**160**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 5 m	80	53%	70	47%	**150**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	-	80	62%	50	3%	**130**
	Combined rape seeder with soil cultivation	Shallow stubble cultivation	80	62%	50	38%	**130**
	Combined rape seeder with soil cultivation	Disc harrowing working width of the machine 3 m	80	7%	60	43%	**140**
	Combined rape seeder with soil cultivation	Disc harrowing working width of the machine 5 m	80	57%	60	43%	**140**
	Combined rape seeder with soil cultivation	-	80	73%	30	278%	**110**
	Direct sowing (stubbly) rape seeder	Shallow stubble cultivation	80	62%	50	38%	**130**
	Direct sowing (stubbly) rape seeder	Disc harrowing working width of the machine 3 m	80	62%	50	38%	**130**
	Direct sowing (stubbly) rape seeder	Disc harrowing working width of the machine 5 m	80	62%	50	38%	**130**
	Direct sowing (stubbly) rape seeder	-	80	73%	30	27%	**110**
Turnip	Shallow stubble cultivation + Hanged pneumatic rape seeder	Shallow stubble cultivation	10	13%	70	88%	**80**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Shallow stubble cultivation	10	13%	70	88%	**80**
	Combines rape seeder with soil cultivation	Shallow stubble cultivation	10	17%	50	83%	**60**
	Direct sowing (stubbly) rape seeder	Shallow stubble cultivation	10	17%	50	83%	**60**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
Winter rye	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Reversible trailing plough	10	8%	120	92%	**130**
	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Disc harrowing working width of the machine 3 m + Reversible trailing plough	10	7%	140	93%	**150**
	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Disc harrowing working width of the machine 5 m + Reversible trailing plough	10	7%	140	93%	**150**
	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Rolling + Reversible trailing plough	10	8%	120	92%	**130**
	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Reversible hanged plough	10	8%	120	92%	**130**
	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	10	7%	140	93%	**150**
	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	10	7%	140	93%	**150**
	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Rolling + Reversible hanged plough	10	8%	120	92%	**130**
	Shallow stubble cultivation + Hanged pneumatic cereal seeder	Shallow stubble cultivation	10	13%	70	88%	**80**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Combined cereal seeder with soil cultivation	Reversible trailing plough	10	9%	100	91%	**110**
	Combined cereal seeder with soil cultivation	Disc harrowing working width of the machine 3 m + Reversible trailing plough	10	7%	130	93%	**140**
	Combined cereal seeder with soil cultivation	Disc harrowing working width of the machine 5 m + Reversible trailing plough	10	8%	120	92%	**130**
	Combined cereal seeder with soil cultivation	Rolling + Reversible trailing plough	10	8%	110	92%	**120**
	Combined cereal seeder with soil cultivation	Reversible hanged plough	10	9%	100	91%	**110**
	Combined cereal seeder with soil cultivation	Disc harrowing working width of the machine 3 m + Reversible hanged plough	10	7%	130	93%	**140**
	Combined cereal seeder with soil cultivation	Disc harrowing working width of the machine 5 m + Reversible hanged plough	10	8%	120	92%	**130**
	Combined cereal seeder with soil cultivation	Rolling + Reversible hanged plough	10	8%	110	92%	**120**
	Combined cereal seeder with soil cultivation	Shallow stubble cultivation	10	14%	60	86%	**70**
	Direct sowing (stubbly) cereal seeder	Reversible trailing plough	10	10%	90	90%	**100**
	Direct sowing (stubbly) cereal seeder	Disc harrowing working width of the machine 3 m	10	8%	120	92%	**130**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
		+ Reversible trailing plough					
	Direct sowing (stubbly) cereal seeder	Disc harrowing working width of the machine 5 m + Reversible trailing plough	10	8%	110	92%	**120**
	Direct sowing (stubbly) cereal seeder	Rolling + Reversible trailing plough	10	9%	100	91%	**110**
	Direct sowing (stubbly) cereal seeder	Reversible hanged plough	10	10%	90	90%	**100**
	Direct sowing (stubbly) cereal seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	10	8%	120	92%	**130**
	Direct sowing (stubbly) cereal seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	10	8%	110	92%	**120**
	Direct sowing (stubbly) cereal seeder	Rolling + Reversible hanged plough	10	9%	100	91%	**110**
	Direct sowing (stubbly) cereal seeder	Shallow stubble cultivation	10	17%	50	83%	**60**
White clover	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible trailing plough	50	29%	120	71%	**170**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible hanged plough	50	29%	120	71%	**170**
Red clover	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible trailing plough	60	33%	120	67%	**180**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible hanged plough	60	33%	120	67%	**180**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
White melilot	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible trailing plough	60	33%	120	67%	**180**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible hanged plough	60	33%	120	67%	**180**
Italian ryegrass	Shallow stubble cultivation + Hanged pneumatic herb seeder	Shallow stubble cultivation	40	36%	70	64%	**110**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible trailing plough	40	25%	120	75%	**160**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	-	40	44%	50	56%	**90**
Perrenial ryegrass	Shallow stubble cultivation + Hanged pneumatic herb seeder	Reversible hanged plough	50	29%	120	71%	**170**
Phacelia	Shallow stubble cultivation + Hanged pneumatic rape seeder	Shallow stubble cultivation	60	46%	70	54%	**130**
	Shallow stubble cultivation + Hanged pneumatic rape seeder	-	60	55%	50	45%	**110**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	Shallow stubble cultivation	60	46%	70	54%	**130**
	Shallow stubble cultivation + Hanged pneumatic herb seeder	-	60	55%	50	45%	**110**
	Combined rape seeder with soil cultivation	Shallow stubble cultivation	60	55%	50	45%	**110**
	Combined rape seeder with soil cultivation	-	60	67%	30	33%	**90**
	Direct sowing (stubbly) rape seeder	Shallow stubble cultivation	60	55%	50	45%	**110**
	Direct sowing (stubbly) rape seeder	-	60	67%	30	33%	**90**
Cock's foot	Shallow stubble culivation + Hanged pneumatic herb seeder	Reversible trailing plough	70	37%	120	63%	**190**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Shallow stubble culivation + Hanged pneumatic herb seeder	Reversible hanged plough	70	37%	120	63%	**190**
	Shallow stubble culivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 3 m + Reversible trailing plough	70	33%	140	67%	**210**
	Shallow stubble culivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	70	33%	140	67%	**210**
	Shallow stubble culivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 5 m + Reversible trailing plough	70	33%	140	67%	**210**
	Shallow stubble culivation + Hanged pneumatic herb seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	70	33%	140	67%	**210**
Oat & Black oat	Shallow stubble culivation + Hanged pneumatic cereal seeder	Shallow stubble cultivation	70	50%	70	50	**140**
	Shallow stubble culivation + Hanged pneumatic cereal seeder	-	70	58%	50	42%	**120**
	Combined cereal seeder with soil cultivation	Shallow stubble cultivation	70	54%	60	46%	**130**
	Combined cereal seeder with soil cultivation	-	70	64%	40	36%	**110**
	Direct sowing (stubbly) cereal seeder	Shallow stubble cultivation	70	58%	50	42%	**120**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Direct sowing (stubbly) cereal seeder	-	70	70%	30	30%	**100**
Buckwheat	Shallow stubble culivation + Hanged pneumatic cereal seeder	Shallow stubble cultivation	40	36%	70	64%	**110**
	Shallow stubble culivation + Hanged pneumatic cereal seeder	-	40	44%	50	56%	**90**
	Combined cereal seeder with soil cultivation	Shallow stubble cultivation	40	40%	60	60%	**100**
	Combined cereal seeder with soil cultivation	-	40	50%	40	50%	**80**
	Direct sowing (stubbly) cereal seeder	Shallow stubble cultivation	40	44%	50	56%	**90**
	Direct sowing (stubbly) cereal seeder	-	40	5%	30	43%	**70**
Winter vetch	Shallow stubble culivation + Hanged pneumatic cereal seeder	Shallow stubble cultivation	50	42%	70	58%	**120**
	Shallow stubble culivation + Hanged pneumatic cereal seeder	Reversible trailing plough	50	29%	120	71%	**170**
	Shallow stubble culivation + Hanged pneumatic cereal seeder	Reversible hanged plough	50	29%	120	71%	**170**
	Combined cereal seeder with soil cultivation	Shallow stubble cultivation	50	45%	60	55%	**110**
	Combined cereal seeder with soil cultivation	Reversible trailing plough	50	33%	100	67%	**150**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Combined cereal seeder with soil cultivation	Reversible hanged plough	50	33%	100	67%	**150**
	Direct sowing (stubbly) cereal seeder	Shallow stubble cultivation	50	50%	50	50%	**100**
	Direct sowing (stubbly) cereal seeder	Reversible trailing plough	50	36%	90	64%	**140**
	Direct sowing (stubbly) cereal seeder	Reversible hanged plough	50	36%	90	64%	**140**
Pea	Shallow stubble culivation + Hanged pneumatic cereal seeder	Shallow stubble cultivation	40	36%	70	64%	**110**
	Shallow stubble culivation + Hanged pneumatic cereal seeder	-	40	44%	50	56%	**90**
	Combined cereal seeder with soil cultivation	Shallow stubble cultivation	40	40%	60	60%	**100**
	Combined cereal seeder with soil cultivation	-	40	50%	40	50%	**80**
	Direct sowing (stubbly) cereal seeder	Shallow stubble cultivation	40	44%	50	56%	**90**
	Direct sowing (stubbly) cereal seeder	-	40	57%	30	43%	**70**
Faba bean	Shallow stubble culivation + Hanged pneumatic cereal seeder	Shallow stubble cultivation	60	46%	70	54%	**130**
	Shallow stubble culivation + Hanged pneumatic cereal seeder	-	60	55%	50	45%	**110**
	Combined cereal seeder with soil cultivation	Shallow stubble cultivation	60	50%	60	50%	**120**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Combined cereal seeder with soil cultivation	-	60	60%	40	40%	**100**
	Direct sowing (stubbly) cereal seeder	Shallow stubble cultivation	60	55%	50	45%	**110**
	Direct sowing (stubbly) cereal seeder	-	60	67%	30	33%	**90**

Total annual unit cost of catch crop establishment and termination in Latvia, EUR/ha/year (2017)

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
White mustard	Shallow stubble cultivation with seed broadcasting	Shallow stubble cultivation	30	43%	40	57%	**70**
	Shallow stubble cultivation with seed broadcasting	-	30	60%	20	40%	**50**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	20	33%	40	67%	**60**
	Direct sowing (stubbly) seeder	-	20	40%	30	60%	**50**
	Combined seeder with soil cultivation	Shallow stubble cultivation	20	25%	60	75%	**80**
	Combined seeder with soil cultivation	-	20	33%	40	67%	**60**
Brown mustard	Shallow stubble cultivation with seed broadcasting	Shallow stubble cultivation	50	56%	40	44%	**90**
	Shallow stubble cultivation with seed broadcasting	-	50	71%	20	29%	**70**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	20	33%	40	67%	**60**
	Direct sowing (stubbly) seeder	-	20	40%	30	60%	**50**
	Combined seeder with soil cultivation	Shallow stubble cultivation	20	25%	60	75%	**80**
	Combined seeder with soil cultivation	-	20	33%	40	67%	**60**
Spring rape	Shallow stubble cultivation with seed broadcasting	Shallow stubble cultivation	10	20%	40	80%	**50**
	Shallow stubble cultivation with seed broadcasting	-	10	33%	20	67%	**30**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	4	8%	40	92%	**44**
	Direct sowing (stubbly) seeder	-	4	10%	30	90%	**34**
	Combined seeder with soil cultivation	Shallow stubble cultivation	4	6%	60	94%	**64**
	Combined seeder with soil cultivation	-	4	8%	40	92%	**44**
Winter rape	Shallow stubble cultivation + Hanged pneumatic seeder	Reversible hanged plough	5	6%	80	94%	**85**
	Shallow stubble cultivation + Hanged pneumatic seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	5	5%	100	95%	**105**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Shallow stubble cultivation + Hanged pneumatic seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	5	4%	110	96%	**115**
	Shallow stubble cultivation + Hanged pneumatic seeder	Rolling + Reversible hanged plough	5	5%	90	95%	**95**
	Direct sowing (stubbly) seeder	Reversible hanged plough	5	7%	70	93%	**75**
	Direct sowing (stubbly) seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	5	5%	100	95%	**105**
	Direct sowing (stubbly) seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	5	5%	100	95%	**105**
	Direct sowing (stubbly) seeder	Rolling + Reversible hanged plough	5	5%	90	95%	**95**
	Combined seeder with soil cultivation	Reversible hanged plough	5	5%	90	95%	**95**
	Combined seeder with soil cultivation	Disc harrowing working width of the machine 3 m + Reversible hanged plough	5	4%	110	96%	**115**
	Combined seeder with soil cultivation	Disc harrowing working width of the machine 5 m + Reversible hanged plough	5	4%	120	96%	**125**
	Combined seeder with soil cultivation	Rolling + Reversible hanged plough	5	5%	100	95%	**105**
Oil radish	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	30	38%	50	63%	**80**
(Forage radish)	Shallow stubble cultivation + Hanged pneumatic seeder	-	30	50%	30	50%	**60**
	Combined seeder with soil cultivation	Shallow stubble cultivation	30	33%	60	67%	**90**
	Combined seeder with soil cultivation	-	30	43%	40	57%	**70**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	30	43%	40	57%	**70**
	Direct sowing (stubbly) seeder	-	30	50%	30	50%	**60**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
Root radish	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	80	62%	50	38%	**130**
	Shallow stubble cultivation + Hanged pneumatic seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	80	57%	60	43%	**140**
	Shallow stubble cultivation + Hanged pneumatic seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	80	57%	60	43%	**140**
	Shallow stubble cultivation + Hanged pneumatic seeder	-	80	73%	30	27%	**110**
	Combined seeder with soil cultivation	Shallow stubble cultivation	80	57%	60	43%	**140**
	Combined seeder with soil cultivation	Disc harrowing working width of the machine 3 m + Reversible hanged plough	80	53%	70	47%	**150**
	Combined seeder with soil cultivation	Disc harrowing working width of the machine 5 m + Reversible hanged plough	80	53%	70	47%	**150**
	Combined seeder with soil cultivation	-	80	67%	40	33%	**120**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	80	67%	40	33%	**120**
	Direct sowing (stubbly) seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	80	62%	50	38%	**130**
	Direct sowing (stubbly) seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	80	57%	60	43%	**140**
	Direct sowing (stubbly) seeder	-	80	73%	30	27%	**110**
Turnip	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	50	50%	50	50%	**100**
	Combined seeder with soil cultivation	Shallow stubble cultivation	50	45%	60	55%	**110**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	50	56%	40	44%	**90**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
Winter rye	Shallow stubble cultivation + Hanged pneumatic seeder	Reversible hanged plough	10	11%	80	89%	**90**
	Shallow stubble cultivation + Hanged pneumatic seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	10	9%	100	91%	**110**
	Shallow stubble cultivation + Hanged pneumatic seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	10	8%	110	92%	**120**
	Shallow stubble cultivation + Hanged pneumatic seeder	Rolling + Reversible hanged plough	10	10%	90	90%	**100**
	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	10	17%	50	83%	**60**
	Direct sowing (stubbly) seeder	Reversible hanged plough	10	13%	70	88%	**80**
	Direct sowing (stubbly) seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	10	9%	100	91%	**110**
	Direct sowing (stubbly) seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	10	9%	100	91%	**110**
	Direct sowing (stubbly) seeder	Rolling + Reversible hanged plough	10	10%	90	90%	**100**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	10	20%	40	80%	**50**
	Combined seeder with soil cultivation	Reversible hanged plough	10	10%	90	90%	**100**
	Combined seeder with soil cultivation	Disc harrowing working width of the machine 3 m + Reversible hanged plough	10	8%	110	92%	**120**
	Combined seeder with soil cultivation	Disc harrowing working width of the machine 5 m + Reversible hanged plough	10	8%	120	92%	**130**
	Combined seeder with soil cultivation	Rolling + Reversible hanged plough	10	9%	100	91%	**110**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Combined seeder with soil cultivation	Shallow stubble cultivation	10	14%	60	86%	**70**
White clover	Shallow stubble cultivation + Hanged pneumatic seeder	Reversible hanged plough	60	43%	80	57%	**140**
Red clover	Shallow stubble cultivation + Hanged pneumatic seeder	Reversible hanged plough	50	38%	80	62%	**130**
White melilot	Shallow stubble cultivation + Hanged pneumatic seeder	Reversible hanged plough	60	43%	80	57%	**140**
Italian ryegrass	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	40	44%	50	56%	**90**
	Shallow stubble cultivation + Hanged pneumatic seeder	Reversible hanged plough	40	33%	80	67%	**120**
Perrenial ryegrass	Shallow stubble cultivation + Hanged pneumatic seeder	Reversible hanged plough	40	33%	80	67%	**120**
Phacelia	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	30	38%	50	63%	**80**
	Shallow stubble cultivation + Hanged pneumatic seeder	-	30	50%	30	50%	**60**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	30	43%	40	57%	**70**
	Direct sowing (stubbly) seeder	-	30	50%	30	50%	**60**
	Combined seeder with soil cultivation	Shallow stubble cultivation	30	33%	60	67%	**90**
	Combined seeder with soil cultivation	-	30	43%	40	57%	**70**
Cock's foot	Shallow stubble cultivation + Hanged pneumatic seeder	Reversible hanged plough	40	33%	80	67%	**120**
	Shallow stubble cultivation + Hanged pneumatic seeder	Disc harrowing working width of the machine 3 m + Reversible hanged plough	40	29%	100	71%	**140**
	Shallow stubble cultivation + Hanged pneumatic seeder	Disc harrowing working width of the machine 5 m + Reversible hanged plough	40	27%	110	73%	**150**
Oat & Black oat	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	20	29%	50	71%	**70**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
	Shallow stubble cultivation + Hanged pneumatic seeder	-	20	40%	30	60%	**50**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	20	33%	40	67%	**60**
	Direct sowing (stubbly) seeder	-	20	40%	30	60%	**50**
	Combined seeder with soil cultivation	Shallow stubble cultivation	20	25%	60	75%	**80**
	Combined seeder with soil cultivation	-	20	33%	40	67%	**60**
Buckwheat	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	10	17%	50	83%	**60**
	Shallow stubble cultivation + Hanged pneumatic seeder	-	10	25%	30	75%	**40**
	Combined seeder with soil cultivation	Shallow stubble cultivation	10	14%	60	86%	**70**
	Combined seeder with soil cultivation	-	10	20%	40	80%	**50**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	10	20%	40	80%	**50**
	Direct sowing (stubbly) seeder	-	10	25%	30	75%	**40**
Winter vetch	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	50	50%	50	50%	**100**
	Shallow stubble cultivation + Hanged pneumatic seeder	-	500	38%	80	62%	**130**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	50	56%	40	44%	**90**
	Direct sowing (stubbly) seeder	-	50	42%	70	58%	**120**
	Combined seeder with soil cultivation	Shallow stubble cultivation	50	45%	60	55%	**110**
	Combined seeder with soil cultivation	-	500	36%	90	64%	**140**
Pea	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	50	50%	50	50%	**100**
	Shallow stubble cultivation + Hanged pneumatic seeder	-	50	63%	30	38%	**80**
	Combined seeder with soil cultivation	Shallow stubble cultivation	50	45%	60	55%	**110**
	Combined seeder with soil cultivation	-	50	56%	40	44%	**90**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	50	56	40	44%	**90**
	Direct sowing (stubbly) seeder	-	50	63%	30	38%	**80**

Catch crop	Sowing method	Termination method	Seed cost per hectare	Percentage of seed cost in total cost	Sowing and termination cost per hectare	Percentage of sowing and termination cost in total cost	Total cost of catch crop application
Faba bean	Shallow stubble cultivation + Hanged pneumatic seeder	Shallow stubble cultivation	40	44%	50	56%	**90**
	Shallow stubble cultivation + Hanged pneumatic seeder	-	40	57%	30	43%	**70**
	Combined seeder with soil cultivation	Shallow stubble cultivation	40	40%	60	60%	**100**
	Combined seeder with soil cultivation	-	40	50%	40	50%	**80**
	Direct sowing (stubbly) seeder	Shallow stubble cultivation	40	50%	40	50%	**80**
	Direct sowing (stubbly) seeder	-	40	57%	30	43%	**70**

Annex 3. Description of results of monetary valuation studies in Lithuania and Latvia

3.1. The Baltic Drainage Basin Project

This was the first project which attempted to assess socio-economic benefits of nutrient reduction strategies in monetary terms in the Baltic Sea region. The project involved three countries around the Baltic Sea - Sweden, Lithuania and Poland (Turner et al., 1995).

The survey, which examined reduction of the entry of phosphorus and nitrogen into the sea by 50%, covered both use and non-use values. 44% of the Lithuanian pilot sample positively answered the question, i.e. were willing to pay for the improvement of the Baltic Sea environment, meanwhile 42% of respondents said that they would not support the proposed action.

The annual amount in LTL of 1994 which one resident would agree to pay totalled approximately LTL 28 (or 2.3 EUR/month). In current prices (as of 2017), taking the inflation into account, the annual WTP equals 29.9 EUR/year.

The amount which respondents would be willing to pay in all Baltic Sea countries was calculated using the so-called 'benefit transfer' method. Consequently, the study showed that the Baltic Sea is 'worth' about 5 billion EUR per year.

3.2. Baltic Coast Study

This was one of pioneering economic evaluation studies in Lithuania (Povilanskas et al., 1998). The environmental focus of the study was the valuation of 'nature' in the surveyed coastal regions in Lithuania and Estonia in order to test whether economic valuation methods can assist in optimising coastal conservation policy decisions.

The following biotopes were examined: bare sand dunes of the Curonian Spit, dry pine forests, dry meadows, wetlands of the Nemunas delta, wet alder forests of the Nemunas delta. The sample respondents were asked various 'willingness to pay' questions.

1683 respondents were interviewed in Lithuania applying three economic valuation methods: contingent valuation, hedonic price analysis and travel cost analysis. The contingent valuation method was recognized as the most appropriate method for this kind of assessment in Lithuania.

Tables below allow to compare values provided by the respondents for Nemunas delta and other valued areas using contingent valuation and travel cost analysis.

Table 39. Values of different nature elements in Curonian Spit and Nemunas delta, contingent valuation method, EUR of 2017 per person per year

Contingent valuation format	Referendum		Discrete Choice		Payment card		Open end	
Biotope/landscape	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Curonian Spit								
General nature	13.5	25	13.5	1.44-4.8	35	17.3	22.5	5.7
Dry meadows			5.7	1.44-4.8			9.6	3.85
Wandering dunes			13.5	1.44-4.8			13.5	11.6
Sandy beaches			7.7	0-1.4			7.7	1.9
Pine forests			19.3	1.44-4.8			40.4	11.6
Mountain pine plantations			11.5	1.44-4.8			9.6	3.9
Nemunas delta								
General nature	7.7	23.1	9.6	1.44-4.8	55.8	19.3	23.1	7.7
Wetlands			13.5	1.44-4.8			15.4	5.8
Floodplains			13.5	1.44-4.8			9.6	1.9
Wet alder forests			17.3				23.1	7.7

Source: Povilanskas et al., 1998

Note: values of 1996 recalculated taking inflation into account

Table 40. Total estimated consumer surplus (benefit) for the Curonian Spit and Nemunas delta, EUR of 2017

Area	Consumer surplus (benefit) for total marginal visit costs	Separational consumer surplus (benefit)
Curonian Spit	18,180,000	1,820,000
Nemunas delta	370,000	Not estimated

Source: Povilanskas et al., 1998

Note: values of 1996 recalculated taking inflation into account

The following table presents the comparison of results of two economic valuation methods used in the Baltic Coast Study.

Table 41. Results of two economic valuation methods used in Baltic Coast Study, EUR of 2017

Method	Value of nature	
	Curonian Spit	Nemunas Delta
WTP, contingent valuation, referendum format	3,700,000	2,100,000
Consumer surplus (benefit), travel cost analysis	1,800,000	370,000

Source: Povilanskas et al., 1998

Note: values of 1996 recalculated taking inflation into account

3.3. UKMERGĖ willingness to pay study

To illustrate some of the challenges municipalities faced in developing and implementing environmental investments prior accession to the EU, in the frame of the development of the Lithuanian Environmental Financing Strategy, a case study was prepared for the municipality of Ukmergė in 1999.

The project team designed a survey to gauge perceptions of Ukmergė residents about the quality of their municipal services and willingness-to-pay for system improvements focused principally on meeting EU requirements. The survey focused mainly on extension of sewerage lines, improved drinking water quality, and solid waste.

The purpose of this study was to estimate the magnitudes of the willingness to pay for the environmental benefits associated with the following directives in the town of Ukmergė:

- 80/778/EEC (Drinking Water) – upgrading of pipes only
- 91/271/EEC (Urban Wastewater Treatment) – extension of sewerage only
- 99/31/EC (Landfills)
  - Landfill upgrading
  - Organic waste recovery and reuse components.
- 94/62/EEC (Packaging Waste)

The method used for estimating the willingness to pay was contingent valuation and relied on the use of a highly structured survey to infer willingness to pay.

A description of the change in services was prepared which detailed the benefits respondents would enjoy if the measures stipulated in the respective directives were implemented. The original resulting willingness to pay in LTL in 1999, also adjusted for CPI sums in EUR for 2017 are presented in the table below.

Table 42. The willingness to pay for water and sewerage services, adjusted for inflation, LTL and EUR per person per month

Willingness to pay – 1999, LTL	Willingness to pay, adjusted for 2017, EUR	Estimated percentage of population that would support the drinking water / sewerage extension programme
Drinking water		
0.24	0.10	20%
0.12	0.05	50%
0.06	0,03	80%
Sewerage extension		
1.75	0.76	20%
0.64	0.28	50%
0.24	0.10	80%

Numbers in shaded column are calculated by the authors of this report, using inflation in Lithuania and exchanging LTL to EUR before EUR became the currency of Lithuania (2015).

It was found that household willingness to pay was substantial for upgraded landfill management and expanded sewerage service, but virtually zero for the two recycling programmes considered. Relative to costs, households were willing to pay approximately 80–90 per cent of costs for landfill improvement, but less than 10 per cent for upgraded sewerage service and recycling programmes.

This study is quite old, and its results are only indirectly interesting to the purpose of the evaluating economic benefits because of environmental changes. Nevertheless, it shows that wastewater collection problems are being evaluated at quite a high level in comparison to other environmental programmes.

3.4. Valuation of Land as a pollutant sink study (Gren, 1999)

Studies of Soderqvist (1996) and Markowska and Zylicz (1996) were used to transfer estimates of benefits from nitrogen reductions to the Baltic Sea to other countries around the Baltic Sea.

The paper analyzes values of marginal change in the area of particular types of land as a pollutant sink under different decision-making policies (including catch crops):

- maximization of international net benefits (IB),
- maximization of national net benefits (NB),
- minimization of international costs for a 50% total N reduction (IC),
- minimization of costs for a 50% national N reduction (NCs)

The estimated marginal values of increased area of land types in Lithuania are shown in Table 43.

Table 43. Estimated original marginal values of increased area of land types in Lithuania and adjusted for inflation in EUR

Policy context	Optimal N reduction	Net benefit		Wetlands		Catch crops		Wetlands, if current area is doubled	
		m SEK	m EUR	SEK/ha	EUR/ha	SEK/ha	EUR/ha	SEK/ha	EUR/ha
IB	37%	897	200	590	130	0	0	640	142
NB	38%	142	32	130	29	0	0	140	31
IC	56 %	1781	396	692	154	30	6.7	2230	495
NICs	50 %	761	170	1120	250	20	4.4	270	60

The marginal value of energy forest and ley grass were 0 SEK / ha.

The calculated values in EUR are based on the exchange rate 1 USD = SEK 7,99 of 17.12.1998, exchange rate between USD and LTL at that time, exchange rate between EUR and LTL and Lithuanian inflation change.

Table 44. Marginal costs and benefits from nitrogen reductions to the Baltic Sea in Lithuania according to Gren, 1999. Adjusted for inflation.

Drainage basin area, thousand km2	Nitrogen load, thousand tonnes N/year	Marginal costs, SEK, kg N		Marginal benefits, SEK, kg N	Marginal benefits, EUR2017, kg N
		Land as sinks	Others		
66	**45**	**36 - 283**	**0.1 - 500**	**12.4**	**2.76**

Note: The last column is added and numbers calculated by the authors of this report

3.5. NEVĖŽIS willingness to pay study

Study on willingness to pay for water quality improvement in the Nevėžis Basin was conducted in 2007 and funded by the Government of the Netherlands. The Nevėžis Basin belongs to the Nemunas RBD, the rivers of which affect the quality of the Baltic Sea, at least in the Lithuanian part.

The good – water quality improvement – was chosen because water quality problems are characteristic to many Lithuanian rivers, and theoretically these results might be indicative of willingness to pay (WTP) values for other rivers in Lithuania. Nevėžis river basin was selected for the study due to the fact that a large number of water bodies at risk of not reaching good status by 2015 exist in the basin, and therefore it was important to assess the benefits that can be brought by the costly programme of measures. The environmental change described in the scenario of the survey was related to the increase of surface water quality in all water bodies of Nevėžis river basin from the current status up to the good ecological status required by the Water Framework Directive.

512 inhabitants were surveyed during the Nevėžis Basin Study on willingness to pay for water quality improvement. The same study was also conducted in the other two Baltic States.

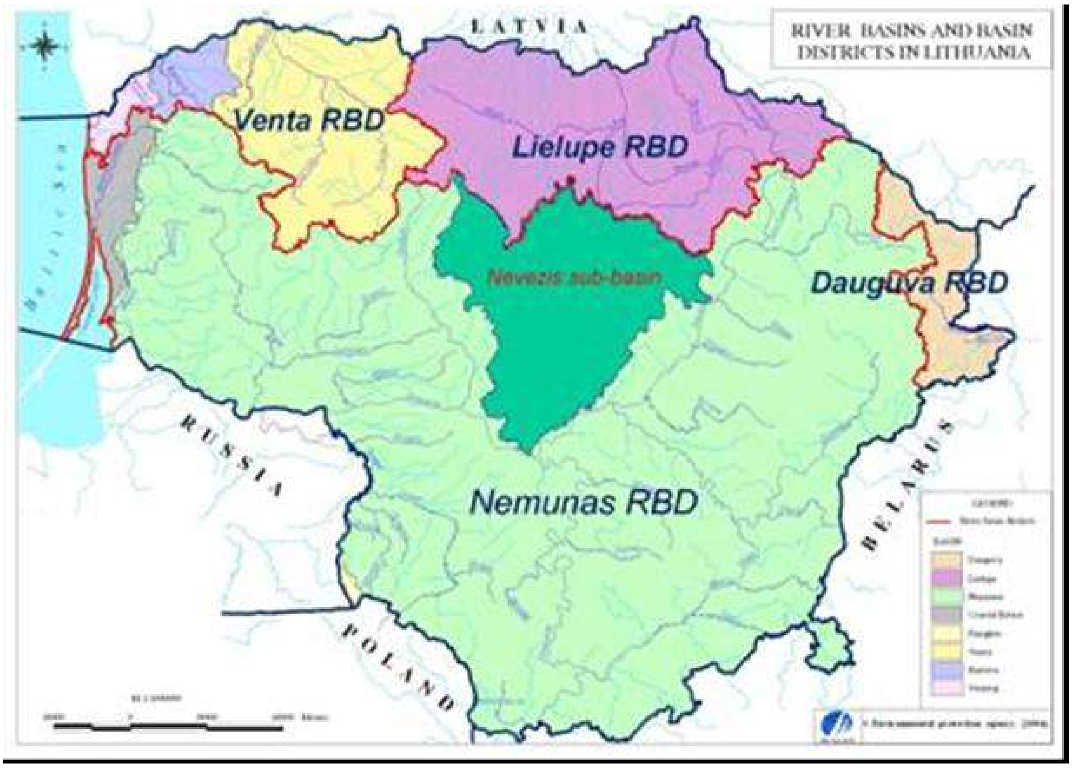

Figure 2. Nevėžis river basin in the central part of the territory of Lithuania.

RBD – river basin district (according to the Water Framework Directive)

Forty eight percent of the survey population answered that in principle they would agree to contribute financially to water quality restoration in the rivers of Nevėžis basin and 52% of respondents said that they disagree to pay for water quality improvement.

Majority of people who were not against the financial contribution for achieving better water quality (28.7%) stated that they would be ready to pay for water quality change because they would like children and grandchildren to have better quality water. Approximately the same number of respondents (26.6%) was willing to pay because they expected to do recreational activities at the water bodies.

A statistically reliable amount which the respondents would be willing to pay for the improved water quality in the Nevėžis Basin was LTL 3.82 per household per month (including those households who were willing to pay LTL 0), or about LTL 18 per household member per year in 2007. Aso f 2018, this figure would amount to **7 EUR**/person/year.

Several methodological lessons were obtained from this study which can be important for our purpose. For example, the good selected for the valuation has to be easy to describe and present for the public. If the good is marginal, people experience difficulties in understanding of what they are asked to give value for. For instance, in Nevėžis case it was extremely difficult to explain the good (water quality improvement) because actual change in the river (removal of nutrients) is hardly visible from the perspective of an inhabitant. Also, a high level of co-operation with ecologists is needed in order to assess the hypothetical situation after the implementation of the measures. It is especially important when applying economic models for WFD purposes. The good to value is good water quality and it is also a task of ecologists to explain what a good quality is in terms of human use and non-use values.

3.6. Impact of changes of the Baltic Sea environment on tourism (2008)

The project did not intend to determine the monetised value. Its goal was to find out whether the quality of the Baltic Sea environment affects industries related to the Baltic Sea, and if so – to identify the impacts. Interviews were conducted with representatives of 12 various companies in April 2008:

- organisation of recreational activities (4 companies);
- accommodation (3 companies);
- yachting and sailing (3 companies);
- fishing (3 companies);
- rent and sale of real estate (1);

The main conclusions of the survey were as follows

- businesses have rather simple understanding of environmental protection and climate change;
- Baltic Sea environmental protection factors have not affected business yet;
- the majority of the respondents assessed the current state of the marine environment as good;
- only very large changes in the state of the marine environment, as compared to the current state, would affect the tourism business;
- the key factors which have influenced the marine tourism activities up to now are related to weather conditions and recreational infrastructure;
- it was acknowledged that there is a lack of assessments of the state of the marine environment and marine tourism, therefore there is no data on the relationship between environmental quality and tourism business.

3.7. Study on willingness to pay for water quality improvement in the Neris Basin

Like the Nevėžis Basin, the Neris Basin belongs to the Nemunas RBD, the rivers of which affect the quality of the Baltic Sea. The said two basins are situated in the Nemunas RBD so the benefit derived therein may be directly transferred into other sub-basins of the Nemunas RBD due to highly similar geographical and social conditions all over the country.

The valuation in the Neris Basin was carried out within the framework of the so-called AquaMoney project funded by the European Commission, along with 15 other EU countries in 2010. The project goal was to develop and test a practical guide for the estimation of costs and benefits of environmental protection and resources, as required by the Water Framework Directive (WFD).

Four scenarios were identified during the study on the valuation of the Neris water quality improvement to achieve good status:

1) Willingness to pay for the improvement of all water bodies in the Neris *Basin* to achieve good ecological status
2) Willingness to pay for the improvement of all water bodies in the Neris Sub-basin to achieve good ecological status and also for remeandering of straightened rivers
3) Willingness to pay for the improvement of the water quality of Lake Riešės to achieve good ecological status
4) Willingness to pay for the improvement of the water quality of Lake Riešės and Lake Didžiulis to achieve good ecological status.

In this way statistically reliable figures illustrating willingness to pay both for individual water bodies and for the improvement of all bodies of water in the Neris Basin were derived.

In the Neris Basin, the amount agreed to be paid by one household was LTL 40.51 per year (as of 2018, 13.2 EUR/year) only for the improvement of the water quality, and LTL 48.18 per year (as of 2018, 15.7 EUR/year) both for the improvement of the water quality and remeandering of rivers. In the first case, the amount totals about 0.29% and in the second case –0.36% of the income of the surveyed households. The WTP figures per person would respectively amount to **5.5 EUR**/person/year and **6.5 EUR**/person/year.

3.8. Study of the general public about usage, attitudes and measures for improving marine environment (attitude of the Baltic region population to the Baltic Sea) (2010)

This survey was carried out in April – June 2010, 1000 respondents were interviewed. Lithuania was one of the nine countries around the Baltic Sea that participated in this study. Questions about the respondents' relationship with the Baltic Sea, their leisure time at the sea, awareness of the quality of the marine environment and key issues, agents of the improvement of the marine environment, ways of financing environmental improvement actions, and their own role in the improvement of the marine environment enabled to figure out the Baltic Sea region population's understanding of the sea and their sea use habits.

The majority of the population in all countries consider both the quality of the coastal area and the entire sea neither good not bad, the sea quality does not affect the quality of recreational activities. About 42% of the respondents in Poland, Germany and Lithuania are concerned about the Baltic Sea environment. The greatest threats to the Baltic Sea are deemed to be as follows:

1. Large oil spills (8 countries),
2. Small daily oil spills (all countries),
3. Littering (all countries),
4. Damage to the marine flora and fauna (8 countries),
5. Heavy metals and other hazardous substances (8 countries),
6. Unexploded mines and chemical weapons at the sea bottom (5 countries).

Lithuanian inhabitants recognize that their actions have an impact on the quality of the Baltic Sea environment, however, they do not take responsibility saying that they cannot participate in the improvement of the Baltic Sea state. Lithuania was the country with the largest number of people saying that it would not be acceptable to them to contribute financially to the addressing of the Baltic Sea environmental problems.

3.9. Benefits of meeting the Baltic Sea nutrient reduction targets - Combining ecological modelling and contingent valuation in the nine littoral states

Eutrophication is one of the most serious threats to the Baltic Sea. The value of eutrophication is best demonstrated in a study on the assessment of the reduction of nutrients in the Baltic Sea which was conducted in 2011-2012 in all nine Baltic Sea countries.

For the first time, people in nine Baltic littoral countries were simultaneously surveyed on the annual amount they would be willing to pay to reduce eutrophication. In total, 10 500 were interviewed (Hasselstrom et al, 2012).

The questionnaire described the state of the Baltic Sea in 2050 if no additional measures are taken and the state in case the HELCOM Action Plan is implemented. The results showed that the majority of the respondents would be in favour of the additional measures and the annual willingness to pay value in all countries would total EUR 4.5 billion.

The results of this study, especially the willingness to pay amounts, were very similar to those obtained during the earlier studies on water quality improvement in the Nevėžis and Neris sub-basins (described above). The results of this study are directly related to the assessment of the quality of the Baltic Sea.

The study showed (Table 45) that the average annual willingness to pay amount to reduce eutrophication in the Baltic Sea in Lithuania and Latvia totalled respectively EUR 6.32 and EUR 4.23 per household member; which, after inflation is taken into consideration, means **EUR 7.1**/person/year in Lithuania and **EUR 4.69**/person/year in Latvia in euros of 2018.

Having multiplied this amount by the number of the population whose age corresponds to that of the survey sample, the amount obtained would reflect the extent to which the Lithuanian and Latvian inhabitants value the decrease of eutrophication - the annual national benefit for the reduction of eutrophication in Lithuania would be around EUR 17.86 million and in Latvia EUR 7.87 million in euros of 2018.

Table 45. Results of the survey related to the assessment of the quality of the marine environment conducted in Lithuania and Latvia, EUR of 2018

Study	Annual willingness to pay amount per household member	Monthly willingness to pay amount per household member	Number of population reflecting the survey sample	National annual willingness to pay amount
Reduction of nutrients in the Baltic Sea, 2012, Lithuania	7.1	0.59	15-74-year-old: 2 516 420	17 860 000
Reduction of nutrients in the Baltic Sea, 2012, Latvia	4.69	0.39	15-74-year-old: 1 690 000	7 870 000

Source: Ahtiainen, H. et al. (2012). Benefits of meeting nutrient reduction targets for the Baltic Sea – combining ecological modelling and contingent valuation in the nine coastal states and Consultant calculations

3.10. Benefits of restoration of the Tyruliai bog

Project „Demonstrative restoration of the Tyruliai bog as a part of the initiative of the re-wetting of Lithuanian peatlands" (LIFE12 NAT/LT/001186) is an example of a bit different than described above monetary assessment of nature elements. Among other activities carried out in the Tyruliai bog, 18 relevant ecosystem services have been monetised.

Ecosystem services in Tyruliai project area were classified according to the Common International Classification of Ecosystem Services (CICES, v4.3) framework and based on proposals developed by the Mapping and Assessment of Ecosystems and Their Services (MAES) project working group for the implementation of Action 5 of the European Biodiversity Strategy 2020. Market Prices based, Cost based, Benefit (value) Transfer and Travel Cost methods were applied to arrive at monetisation of 1 ha of restored Tyruliai bog.

The following ecosystem services were selected for the assessment: provision of wild plants (mushrooms, berries) and animals (game and fish); filtration/decomposition/detoxification of waste and wastewater, air quality regulation, erosion control, hydrological cycle and water flow maintenance, pollination and pest control, habitat and shelter provision for breeding and migrating species, climate regulation; potential for recreation, nature tourism, leisure fishing and hunting, science and education.

The preliminary economic value of the Project Area ecosystem services potential is about 940 EUR per hectare per year, or at least 3.26 million EUR annually. The value of habitat and shelter provision for breeding and migrating species, hydrological cycle and water flow maintenance, erosion control, climate regulation, filtration of waste and wastewater represents up to 86 % of above mentioned total value of the ecosystem services.

Table 46. Distribution of value of ecosystem services assessed in Tyruliai bog, EUR of 2018

Ecosystem service	Share of total value, %	Value, EUR/ha/year
Provision of wild animals and leisure hunting	3,5%	34
Provision of fish and leisure fishing	0,2%	2
Provision of mushrooms	2,6%	26
Provision of berries	1,1%	11
Filtration/decomposition/detoxification of waste and wastewater; regulation of fresh water chemical status	3,8%	37
Air quality regulation	3,0%	29
Erosion control	15,4%	151
Hydrological cycle and water flow maintenance	27,6%	270
Pollination	0,5%	5
Pest control	0,5%	5
Habitat and shelter provision for breeding and migrating species	27,6%	270
Climate regulation	12,0%	118
Potential for recreation, nature tourism, science and education	2,1%	21
Total	100,0%	978

Source: Final report on the Assessment of Ecosystem Services of Tyruliai bog (2017). Project „Demonstrative restoration of the Tyruliai bog as a part of the initiative of the re-wetting of Lithuanian peatlands" (LIFE12 NAT/LT/001186) (in Lith.) and calculation of the Author.

3.11. Marine Environmental Assessment - Economic and Social Analysis (2018)

The object of the study is to characterize the benefits to society and to the economy of the use of marine waters and the pressures and impacts of marine use activities on the marine environment. The study includes an economic and social analysis of the use of marine waters and an analysis of the costs of marine degradation. An ecosystem services approach is used in assessing the economic value of loss to the community and evaluation is monetised where possible, based on previous economic studies in relation to Latvian water environment. In all studies, used in this evaluation as the source of information, data are derived from national public surveys and shows society willingness to pay for certain improvements in the quality of the marine environment.

The study does not estimate the cost of degradation of the marine environment caused by agriculture, but mentions the role of agriculture in diffuse pollution. Thus, it can be assumed that the negative impacts of agriculture are taken into account when estimating the cost of degradation of the marine environment due to eutrophication.

The average value of "willingness to pay" for reducing the impact of eutrophication on water quality is estimated at 5.3 - 7.2 EUR/capita/year (Pakalniete et al., 2017). However, it should be considered that benefit assessment covers only the effects of eutrophication on water quality for recreational purposes (not including other impacts of eutrophication on the marine environment) and the data were collected quite a long time ago (for 2013).

Source: Marine Environmental Assessment (2018) Economic and Social Analysis. (2019). Available at: https://drive.google.com/file/d/1-LIzI4AhfZx3ebv7lEW_OAIz53Kib-8s/view

Pakalniete K., Aigars J., Czajkowski M., Strake S., Zawojska E., Hanley N. (2017), "Understanding the distribution of economic benefits from improving coastal and marine ecosystems". // Science of the Total Environment, Vol 584-585 (2017), pp 29-40.

3.12. Assessment of possibilities to implement results-based agri-environment measures (2018)

The object of the study was to assess the possibility of implementation of results-based agri-environment measures in Latvia on the basis of ecosystem services approach; providing the basic and voluntary agri-environmental practices and contributing to biodiversity conservation, soil and water quality improvement, climate change mitigation.

The study evaluates the environmental situation, focusing on the main pressures from agriculture, and assesses the potential of using an ecosystem services approach in planning of agri-environmental support measures. The measure for catch crop growing is among proposed support agri-environmental measures, mentioned being measure with multifunctional influence for several ecosystem services such as biological biodiversity, quality of water and soil and reduction of SEG emissions.

Source: Baltic Environment Forum (2018) Assessment of the possibilities of implementing results-based agri-environment measures. Unpublished.