Inventory of available mitigation and BMPs including cost-effectiveness analysis

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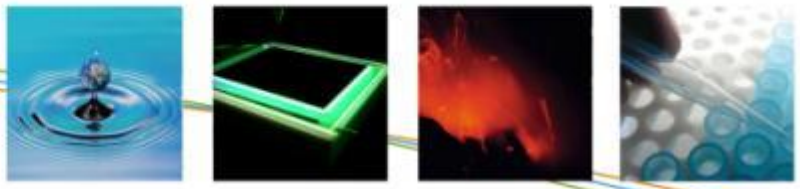

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CHANGE RECORD

Version	Date	Description
V1	30/11/2017	First version
V2	13/03/2018	Second version
V3	10/05/2019	Third version after midterm review; main changes are more extensive introduction, adding a systematic approach to order measures & best practices according to the source/pathway and type of pollutant and an extension of the list from 56 to 81 Best Management Practices and Mitigation Measures

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List of abbreviations & acronyms

BMP	Best Management Practice
PPP	Plant Protection Product
ITP	Instytut Technologiczno- Przyrodniczy (Institute of Technology and Life Sciences)
MM	Mitigation Measure
PIG-PIB	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy (Polish Geological Institute – National Research Institute)
UCSC	Università Cattolica del Sacro Cuore
VITO	Vlaamse Instelling voor Technologisch Onderzoek (Flemish Institute for Technological Research)
CPABLL	Consorci del Parc Agrari del Baix Llobregat

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1 Introduction

High-quality, safe, and sufficient drinking water is essential for life: we use it for drinking, food preparation and cleaning. Agriculture is the biggest source of pesticides and nitrate pollution in European fresh waters. The overarching objective of WATERPROTECT is to contribute to effective uptake and realization of management practices and mitigation measures to protect drinking water resources. Therefore WATERPROTECT will create an integrative multi-actor participatory framework including innovative instruments that enable actors to monitor, to finance and to effectively implement management practices and measures for the protection of water sources.

WP4 in the WATERPROTECT project deals with best management practices and mitigation measures and the first task within this WP is an inventory of available BMPs from the knowledge developed in previous projects.

Nutrient losses are considered as one of the main pollution of water bodies caused by agriculture. Nutrients can be lost in a number of ways. Soluble nutrients like nitrate can be lost in runoff and drainage water, less soluble nutrients like phosphorus are more likely to be lost with runoff water. PPPs can enter surface water through different entry routes. The most important entry route is point pollution (>50%). Besides point sources, diffuse sources (e.g. surface runoff and erosion of PPP, spray drift …) may also cause water pollution by PPP. Task *4.1 Identification of available innovative mitigation measures and Best Management practices (type, applicability, costs)* include a review of available BMPs including example of cost analysis of mitigation measures and BMPs, with assessments of their bottlenecks and strengths. For some BMPs costs are not available. One explanation could be that they relate most to behaviours and knowledge level. The compliance of these BMP is important in order to avoid environmental and health risks but are linked to knowledge and educational systems and operators awareness communication programs.

The report was made using reviews and analyses obtained from previous projects concerning remediation measures against nutrients and pesticides pollution from agricultural sources such as TOPPS, Magpie and Baltic Compass:

- ✓ The TOPPS –Life project (http://www.topps-life.org) was designed as a multi stakeholder project to reduce losses of Plant Protection Products (PPP) to water. The project was funded by EU through the Life program and the ECPA (European Crop Protection Association). The project started November 2005 and ended October 2008 and TOPPS extension program supported by ECPA is still running. In various TOPPS projects a broad range of information, training materials and Best Management Practices (BMPs) recommendations to reduce PPP losses to water has been developed (point sources, spray drift and runoff). Key perspectives are the correct behaviour of the operator, improved equipment and infrastructure.

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- ✓ Magpie (https://www.setac.org/magpie) is a comprehensive view on the state of pesticide risk reduction and pesticide risk mitigation in cultivated landscapes and represent and the result of the extensive discussions that took place over two workshops and 3 years of intensive work and data analysis by 95 experts and regulators from 24 European countries with a common objective: "translating science into applicable solutions to farmers for a safer use of pesticides for the environment. A toolbox of risk mitigation measures with technical recommendations is provided for groundwater, surface water (including the protection of aquatic organisms), off-crop areas and in-crop areas. Each tool is described with regards to its level of implementation, technical description, regulatory status, inclusion in the good farming practices, economical considerations, options to measure its effectiveness.
- ✓ Baltic COMPASS (Comprehensive Policy Actions and Investments in Sustainable Solutions in Agriculture in the Baltic Sea Region) has been launched for the years 2009–2012. The project involved 22 partners from 9 countries in the Baltic Sea Region: Belarus, Denmark, Estonia, Finland, Latvia, Lithuania, Germany, Poland and Sweden. It was designed as (panbaltic) regional platform where participants and stakeholders can develop more efficient agro-environmental policies, share innovations and best practices, create scientific scenarios and facilitate investments. Win-win solutions for agriculture and environment are fostered within the Baltic Compass leading thus to more sustainable rural economies – in effect also friendly to the Baltic Sea. One of the identified challenges was that the competence, technologies, policies and science for developing more sustainable solutions are available, but unevenly distributed in the BSR and thus not efficiently applied. The project aimed at improvement of the stakeholders' capacity to drive the change toward greener agriculture, along with the aim to streamline communication on different policy levels and to mitigate the perceived lack of trust between the environmental and agricultural sectors. Baltic COMPASS project has raised awareness in adaptive governance measures and advanced trustful dialogue between the environmental and agricultural interests. The project outputs highlight win-win solutions in farm measures as well as policy approaches. Overall, the project established new collaboration platforms and networks and produced new integrated knowledge which can be used by policy makers to: (1) balance enforcement and incentives for agri-environment measures; (2) support broader governance and local stakeholder initiatives; (3) understand the importance of transparency in communication to increase trust; (4) prioritize multiple benefit measures as a way to handle current and future uncertainty; (5) utilize the business potential in agrienvironment solutions; and (6) define interventions, adapt management measures and deploy the right platforms for each administrative level: local, national, Baltic Sea and EU.

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2 Methodology

The work consists of two parts: the first part is a comprehensive list of mitigation measures and best management practices with the type of pollutant the measure/practice is suitable for and the second part give you a more detailed description in templates for the each separate mitigation measures (MM) and BMP. For this all partners used a standardized methodology and template made out of the following elements:

1) the name of BMP or MM
2) the type of protected water source, e.g. surface water, groundwater or both;
3) the type of risks mitigated by the measure, e.g. runoff., spray drift;
4) the type of pollutants handled by the measure, e.g. nitrogen, phosphorus, pesticides;
5) the type of benefits and limits of the selected method – economic and environmental benefits and restrictions due to the application of the specific MM or BMP;
6) the costs of application – the costs vary depending on the country so only general information is given about the MM's or BMP's implementation .

Best Management Practices have been divided according to the type of pollutant. Some of them are related to nutrients, while others concern pesticides. However, there are also practices that can be implemented to prevent pesticides pollution as well as nutrient losses. Most often, this applies to contaminants moving with the runoff water.

2.1 Nutrients

A farm is the basic organisational unit in agriculture. The agricultural production involves a large amount of nutrients, which flow dynamically within the farm. The nutrient cycle in the farm includes much internal transfer and transformation of nutrients, because of which some part of them are converted into animal and vegetable products. Nutrients not captured in the food production are likely to be lost to the environment, with impact on water, on land and on the atmosphere.

Nutrients are introduced to the farm in the form of purchased materials like mineral fertilizers, fodder, seeds, straw, as well as atmospheric deposition and biological fixation in soil by non-symbiotic microorganisms. These components circulate on the farm around the loops soil → plant → animal → soil subjected to complex transformations. Because of these changes, some nutrients are transferred to plants and animal products removed from the farm to external recipients (consumers, industry), and some (not used in agricultural production) are dispersed in the environment. The load of unused components called excess, surplus or losses is determined based on the difference between their quantity introduced into and withdrawn from the farm.

In order to limit the negative impact nutrients on water resources, it is necessary to reduce the surpluses of those components generated by agricultural holdings. To achieve this, the farmer should consciously control the flow of nutrients and shape it in the desired direction.

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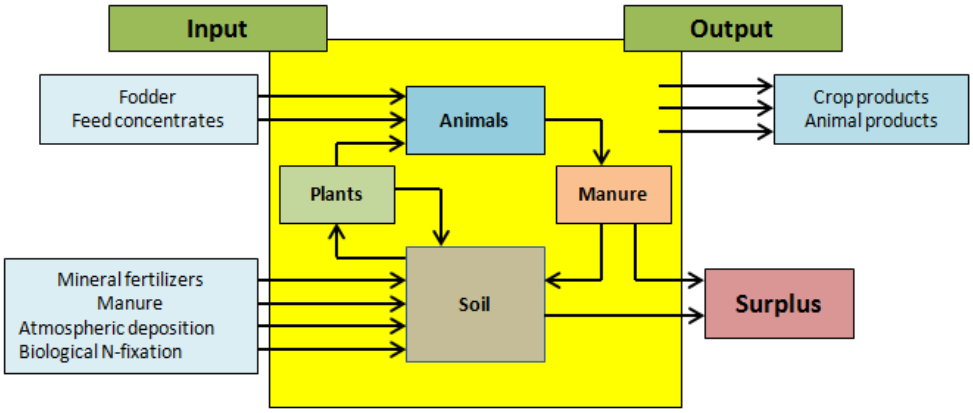

Figure 1: Nitrogen and phosphorus flows at the farm scale (modified based of: Oenema, 1999)

It should be emphasized that in order to maximize the use of fertilizer components (minimize their losses) at the farm level, comprehensive solutions should be applied, including optimization of the agricultural production process in all its segments (optimization of plant fertilization and soil management, animal feeding, management of fodders and natural fertilizers); fragmentary solutions are not as effective. The starting point for activities in this field should be assessment of factors affecting the amount of nutrient losses at the farm level. Such an approach allows the selection of adequate measures in specific conditions (economic, social, and environmental) counteracting those losses. The catalogue of measures to be used in this field is very rich, as exemplified in Table 1.

2.2 Pesticides

PPPs can enter surface water and groundwater through different entry rout. The most important entry route is point pollution. Besides point sources, diffuse sources such as spray drift and surface runoff may also cause water pollution by PPPs.

Point sources are related to the handling on PPPs on the farm. Proper storage of PPPs as well as safe filling and cleaning sprayers is a key factor to prevent water contamination. Point sources mitigation is addresses farmers' behavior directly. Main diffuse source entry risks of PPPs are related to spray drift and field runoff and soil erosion. Spray drift can occur during application PPPs. Spray drift mitigation is related to behaviours and knowledge level, e.g. avoiding spraying during windy weather, as well as using appropriate technologies and devices. Special attention is required in relation to treatment planning, spray technologies used and calibration and an adapted management of the application is necessary. Diffuse source such as surface runoff and soil erosion depends on weather conditions and landscape. It is linked to a water catchment area and individual farms. Best Management Practices need to be implemented at a farm scale and catchment scale.

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In the report several Best Management Practices or measures to reduce water pollution of PPP are listed. These include BMPs to reduce point pollution, BMPs to reduce drift and BMPs to reduce runoff and erosion. Reducing water pollution by PPP can be obtained by changes in behaviour, which can usually be applied cheaply. Other BMPs are new or improved technology or infrastructure, which is more expensive. The BMPs and measures to reduce water pollution by PPP are mainly based on the BMPs developed in the TOPPS projects (TOPPS-life project, TOPPS prowadis and TOPPS water protection – more information on www.TOPPS-life.org) and Magpie project.

3 List of available BMPs and MMs

The selection of available BMPs and mitigating measures was based upon the experiences of our project partners that resulted from implementations of projects concerning water protection (Baltic COMPASS, TOPPS and Magpie) and their overall knowledge about the agricultural conditions within the catchment area. The list contains measures to reduce nutrient losses from agriculture and water pollution of PPP. In total, a list of a of 77 available BMPs and mitigating measures was developed and is presented in table 1. BMPs and mitigation measures listed in this registry have been systemized according to their functionality use type of pollutant combated by the measure.

Table 1: List of best management practices and mitigation measures

	Nº	Name of Best Management Practice or mitigation measure	Type of pollutant combated by the measure
Animal production & Manure management	6	Avoiding the application of chemical fertilizers and manure during high-risk periods	Nutrients
	4	Incorporating manures immediately after application on cultivated land	Nutrients
	5	Injection, trailing shoe or band spreader used for slurry	Nutrients
	63	Estimation of nutrient content of organic manures (hydrometer for slurry)	Nutrients
	62	Spreading slurry in early growing season to maximize crop uptake	Nutrients
	16	Slurry bags	Nutrients
	61	Manure store with tank	Nutrients
	15	Covered manure storage system	Nutrients
	71	Directing manure towards special ponds (for sedimentation of organic substances for extraction of nutrients)	Nutrients

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		72	Temporary depositing of organic manure on the agricultural field	Nutrients
		74	Use of impermeable folia under the pile of solid manure deposited on field	Nutrients
		73	Precaution measures (solid manure distance from rivers, well etc deposited on field) for preventing pollution of water	Nutrients
		13	Separation of pastures from water courses and reservoirs	Nutrients
		17	Adopting phase feeding of livestock	Nutrients
		18	Phytase supplementation	Nutrients
		19	Reducing dietary nitrogen and phosphorus intake	Nutrients
Soil management & Plant production		1	Nutrient balance on farm and/or field level	Nutrients
		2	Fertilizer program	Nutrients
		7	Use treated urea (with urease inhibitor)	Nutrients
		3	Liming	Nutrients
		64	Soil analysis for pH, nutrients or organic matter	Nutrients
		9	Crop rotation and its role in rebuilding and preservation soil organic matter	Nutrients
		78	Set-aside	Nutrients
		79	Afforestation	Nutrients
		77	Energy crops	Nutrients
		14	Controlled drainage	
		59	Use of Global Positioning System to manage inter field variability in crops	Nutrients
	PPP runoff	60	Use Decision Supporting Systems or Forecasting Systems	Nutrients, pesticides
		56	Optimize irrigation timing and rate	Nutrients, pesticides
		49	Improved soil management to increase the water holding capacity of the soil	Nutrients, pesticides
		11	Grass buffer zones	Nutrients, pesticides
		12	Constructed wetlands	Nutrients, pesticides
		10	Plant cover in autumn and winter	Nutrients, pesticides

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		8	Conservation tillage	Nutrients, pesticides
		50	Inter-ridge bunding	Nutrients, pesticides
		51	Enlarge headlands	Nutrients, pesticides
		52	Double sowing	Nutrients, pesticides
		53	Manage field access areas	Nutrients, pesticides
		54	Avoid accelerated run-off of water and PPP by tramlines or short cuts	Nutrients, pesticides
		55	Establish retention structures (fascines, edge of the field bunds, vegetative ditches, …)	Nutrients, pesticides
		65	Vegetated filter strip (VFS) at edge-of-field	Nutrients, pesticides
		66	In field vegetative filter strips (VFS) as talwegs	Nutrients, pesticides
		67	Inter-row processing and weeding on the row	Pesticides
		68	Permanent grassing in the inter row and weeding on the row	Pesticides
		75	Alternatives systems to chemical fights to pest control	Pesticides
PPP point source		24	Do store sprayers safely	Pesticides
		25	Use inspected sprayers	Pesticides
		26	Calibrate sprayer for the appropriate and optimized application of PPP	Pesticides
		27	Safe transport of PPP	Pesticides
		28	Store PPP within lockable rooms/containers or cupboards	Pesticides
		29	Dispose obsolete PPP by an authorized waste collection company	Pesticides
		30	Choose a safe filling and cleaning place for the spraying equipment	Pesticides
		31	Be prepared for and manage spills safely	Pesticides
		32	Prevent overflow and foam escape during filling	Pesticides
		33	Rectify/Adjust any equipment problem immediately	Pesticides
		34	Adequate cleaning of sprayers to minimize the amount of spray remnants	Pesticides
		35	Clean and safely manage empty containers/packages, seals and caps	Pesticides

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	36	Seal and secure partly used containers/packages immediately after use	Pesticides
	37	Safe disposal of spraying liquid residues	Pesticides
	81	Anti- drip devices	Pesticides
PPP spray drift	38	Use drift reducing nozzles	Pesticides
	39	Use sprayer types allowing spray-drift reduction	Pesticides
	40	Use application techniques allowing PPP reduction if appropriate	Pesticides
	41	Use the lowest effective distance between nozzles/atomizers and the spray target	Pesticides
	42	Use the lowest effective sprayer forward speed	Pesticides
	43	Use the lowest effective pressure	Pesticides
	44	Do not spray no spray zones and other non-target areas	Pesticides
	45	Adjust sprayer settings according to application conditions, crop density and canopy to minimize spray drift	Pesticides
	46	Do not use cannon sprayers next to sensitive areas	Pesticides
	47	Keep existing vegetation or establish windbreaks/retention structures between sensitive areas and fields being sprayed	Pesticides
	48	Use new technologies to apply PPP more precisely	Pesticides
	69	Anti-hail net	Pesticides
General measures	57	Professional support in selection of appropriate PPP	Pesticides
	20	Ensure the sprayer operator is adequately trained and prepared for Plant Protection Product use	Pesticides
	21	Always plan and organize your spray activities.	Pesticides
	22	Only spray when weather and field conditions allow safe and effective PPP use	Pesticides
	23	Only use approved PPP and comply with all their conditions of Use	Pesticides

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4 Best Management Practices and Mitigation Measures

1. Nutrient balance on farm and/or field level	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Subsurface flow, Runoff
Type of pollutant combated by the measure:	Nutrients
Description	The nitrogen (N) and phosphorus (P) balance is calculated as the difference between the amount of elements brought to the farm and removed from it (farm gate balance) or between the input and output from agricultural land (on the surface of the field). The difference represents the surplus of N and P [Pietrzak, 2012].
Benefits and limitations of use	Results of the N and P balance calculation can provide a background for practical solutions for reduction of the environmental impact of agriculture as well as for improvement in the farming economy. The latter aspect results from the fact that more efficient use of nutrients means lower costs of chemical fertilizers or feeds.
Costs of application	Calculating N and P balances at farm and field level does not require external funding and therefore does not generate additional costs on the farm.

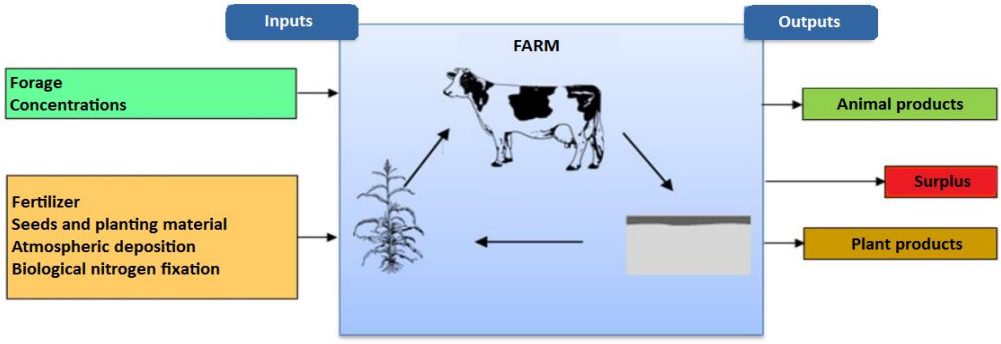

Figure 2: Schematic nutrient balance "at the farm's gate" with selected nutrient circulation within the farm [Pietrzak, 2012]

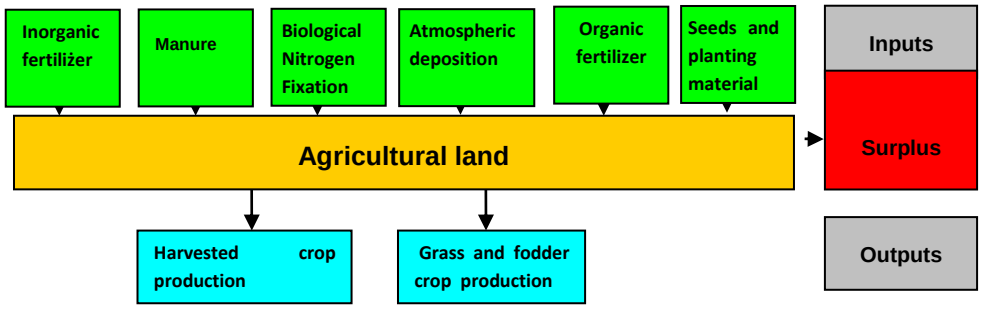

Figure 3: Balance "on the surface of the field" [OECD, 2001]

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2. Fertilizer program	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Runoff, nitrogen spray drift
Type of pollutant combated by the measure:	Nutrients

Description

A fertilizer plan is a conceptual design that shows farmers how they can, in environmentally and economically justified ways, manage mineral and natural fertilizers. It can be prepared using a variety of methods, such as developed Excel tables and spreadsheets or appropriate computer programs.

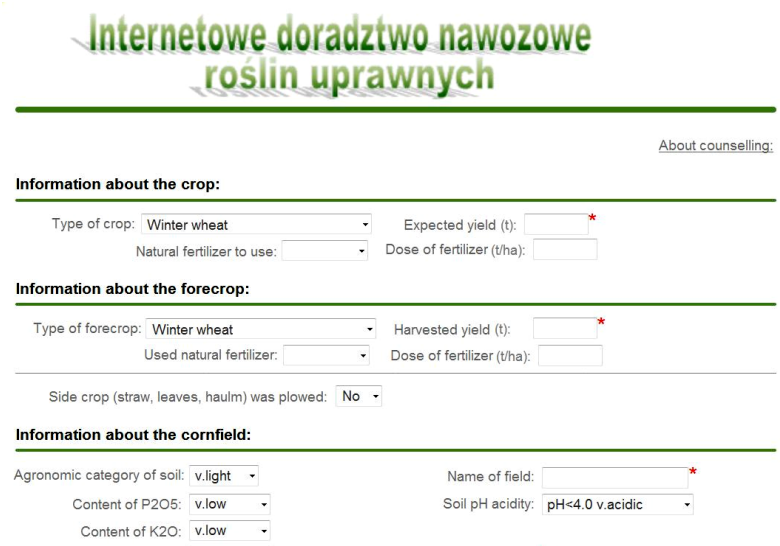

Figure 4: Screen-shot of website displaying the crop and field data for calculating dosage of fertilizer components in the "Fertilizer program on-line" [Krajowa Stacja Chemiczno-Rolnicza w Warszawie; translated from Polish]

Benefits and limitations of use

Fertilizer plan brings savings, resulting from the purchase of fewer fertilizers and the reduction in the number of applications. Efficient use of nutrients significantly reduces their losses to the environment and therefore reduces eutrophication and improves the quality of surface and groundwater. This can be achieved when fertilization of crops takes place under favourable weather conditions and application techniques do not cause additional losses of fertilizer components, especially nitrogen

Costs of application

The cost of preparing a fertilizer plan for a farm varies and depends on the type of computer program. An individual purchase of a computer program such as NawSald offered by IUNG PIB in Puławy costs 250 EUR. It is possible to order a complete fertilizer program from a specialized company.

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3. Liming

Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff, release of heavy metals
Type of pollutant combated by the measure:	Nutrients

Description

Soil acidification effectively inhibits the growth of crops. The obtained yields are unsatisfactory and unused fertilizers are dispersed into the environment. Low soil pH and anaerobic conditions block the nitrification process, cause the loss of gas and leaching of nitrates that can also be also transformed into molecular nitrogen. The need for liming results from the pH of soil. The lime dosage depends on the agronomic category of the soil and its pH [Jadczyszyn, 2015].

Table 2: Recommended doses of lime fertilizer (mg CaO· ha-1) [IUNG – PIB]

Agronomic category of the soil	Level of soil pH				
	< 4,5	4,5 – 5,1	5,2 – 5,6	5,7 – 6,1	6,2 – 6,6
Very light	2,5	1,0	-	-	-
Light	5,0	3,0	1,0	-	-
Medium	6,0	4,0	2,0	1,0	-
Heavy	6,0	5,0	3,0	1,5	1,0

Liming treatment is done every 3-4 years. After this period, pH of soil should be tested to verify if liming treatment brought the intended effect. If the soil has improved, it is sufficient to use less conservative lime, which will offset the acidification of mineral fertilizers and supplement the annual loss of calcium and magnesium cations from the soil by leaching.

Benefits and limitations of use

Liming has a positive influence on the physical and chemical properties of soil and the efficiency of nutrient uptake from fertilizers and soil, including N and P. This indirectly leads to increased yields and profits for the farmer, while at the same time protecting water resources from pollution. Liming treatment is usually carried out in post-harvest and pre-sowing tillage. Liming with use of carbonates occurs in light and very light soils while calcium and magnesium oxides and hydroxides are used for medium and heavy soils. The condition for achieving the desired liming effect is to use lime on relatively dry soil and evenly apply it.

Costs of application

The costs of spreading lime vary widely and depend on the type and dose of lime as well as on the type of machine used for application.

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4. Incorporating organic manures immediately after application on cultivated land		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Nutrients runoff
Type of pollutant combated by the measure:		Nutrients
Description	Natural and mineral fertilizers should be completely covered with soil to maximize uptake of nutrients by plants. Ploughs or disc and spring-tine cultivators can be used to cover fertilizers. With liquid manure, incorporation should take place quickly after spreading or within 6 hours after application. This effectively reduces the potential for ammonia emissions. This benefit is also similar with the technique of soil injections. Also, in the case of solid manures, immediate mixing with soil by ploughing, is the most effective way to reduce losses of ammonia from fertilizer [Pietrzak 2012].	 Figure 5: Rapid slurry incorporation into the soil [Frandsen et al., 2011]
Benefits and limitations of use	The applied fertilizer should be immediately incorporated into the soil through tillage also to prevent nutrient loss through runoff, erosion or volatilization. Due to incorporation, nutrients are mixed into the surface soil layer where roots are able to intercept them. In some cases, however, in areas where natural fertilizers are covered with soil by ploughing, larger soil losses associated with erosion have been observed than in non-treated fields. It is recommended to incorporate applied fertilizer into the soil in such a way as to keep plant residues on the soil surface by applying tillage methods such as knifing or injection (in the case of liquid manure).	
Costs of application	Mixing of fertilizers with soil is a part of routine farming practices related to soil and plant cultivation and therefore does not generate additional costs on the farm.	

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5. Injection, trailing shoe or band spreader used for slurry	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Subsurface flow, runoff
Type of pollutant combated by the measure:	Nutrients
Description	Liquid animal manure can be applied by a variety of methods including land surface spreading, subsurface injection and spray irrigation. Direct injection, e.g. shallow injection can reduce nutrient emission through direct introduction of manure beneath the soil surface, decreasing the manure exposure to the air and increasing its infiltration into the soil. Use of band spreaders can also reduce nutrient emissions from slurry and liquid manure through decreasing the manure exposure to the air and the flow of air over it. Modern spreaders are also equipped with an automatic application control system guaranteeing its lateral and longitudinal distribution [Pietrzak, 2012]. The liquid fertilizer system is also important for reducing odours.
	 *Figure 6: Manure spreader applicator for shallow injection of liquid manure [photo: P. Nawalany]*
Benefits and limitations of use	Use of band spreading technology effectively limits the emission of ammonia to the atmosphere and its deposition into surface water and natural areas. Ammonia losses resulting from use of deep soil applicators are approximately 90% lower than losses resulting from use of traditional spray application techniques. Band application techniques reduce ammonia losses by ca. 10 to 20%. The farmer is able to reduce the costs of purchase of mineral fertilizers as well as the costs of application. In Poland, investment in manure spreader applicators and suitable equipment can be returned after approximately 5 or 10 years [Wojtczak, 2015].
Costs of application	Depending on the brand and type of manure spreader applicator (cultivator or disc), purchase price ranges from approximately ten to several tens of thousands of EUR.

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6. Avoiding the application of chemical fertilizers and manure during high-risk periods	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrient runoff, subsurface flow
Type of pollutant combated by the measure:	Nutrients
Description	Fertilizers should not be used in times and conditions when the mineral nutrients, especially nitrogen, are vulnerable to leaching to groundwater or to runoff to surface water. This applies especially to the winter period but also to other periods, depending on soil type, rainfall intensity and soil cover. The weather can vary and therefore fertilizers should not be applied when the soil is frozen and covered with snow – even during a periodic of warming. Nitrogen uptake is rapid in spring and summer periods. In case of correct estimation of fertilizer inputs, the concentrations of nitrate are small by late summer. However, once the growth of plants slows and then stops (in July for cereal crops), subsequent nitrate originating from natural soil processes is no longer balanced by plant uptake, and thereby the concentrations of nitrate increase. If some or all of the nitrates present in soils are not taken up by plants they will be leached during the autumn [ADAS, 2007].
Benefits and limitations of use	The timing of chemical fertilizer and manure application is a key factor in achieving high efficiency of nutrient use. This ultimately affects the yield and, indirectly, the economic and ecological efficiency of farm production.
Costs of application	The activity does not generate additional costs on the farm.

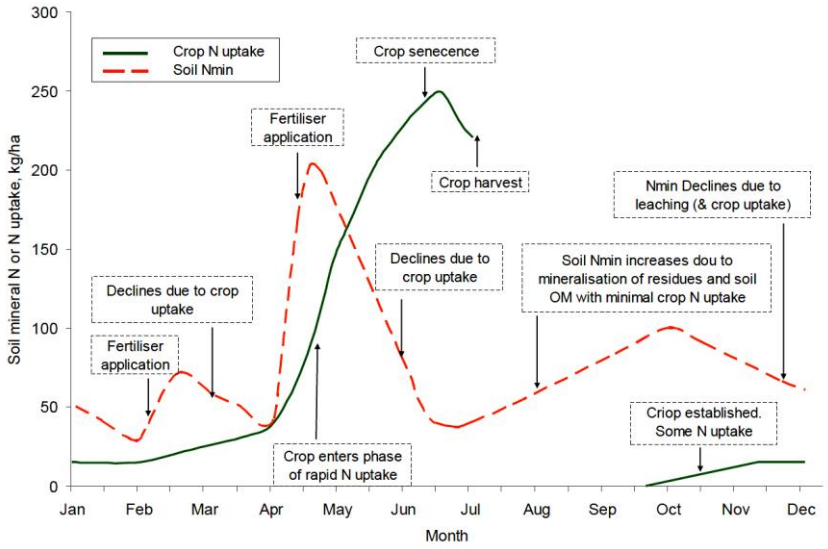

Figure 7: Exemplary nitrogen dynamics showing the risk of N leaching and the synchronicity between N supply from the soil and N uptake by crop [ADAS, 2007]

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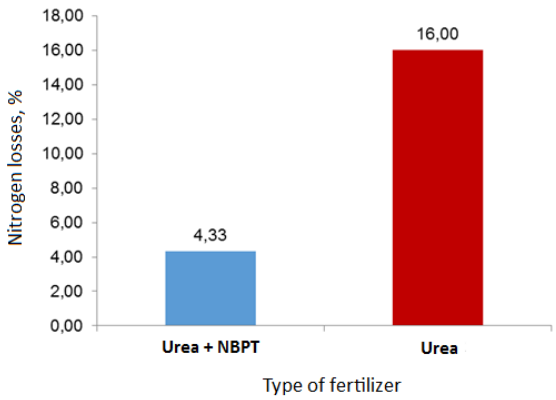
7. Use treated urea (with urease inhibitor)		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Nutrients runoff, acidification of water and soil, eutrophication
Type of pollutant combated by the measure:		Nutrients
Description	Restriction of the release of ammonia from urea and UAN (Urea-Ammonium Nitrate Solution) solutions during the first week after use can be effectively achieved by using substances that inhibit urease enzymatic activity (which are responsible for hydrolysis of urea). These are called urease inhibitors. One of these inhibitors is NBPT (N-(n-butyl) thiophosphoric triamide), which is approved for use in all EU countries. Under field conditions, it has been shown that fertilization of stable grassland with urea stabilized with NBPT inhibitor reduces ammonia loss by approximately 70% in relation to urea without inhibitor [Marcinkowski and Kierończyk]. Increasingly used in the mineral nutrition ofcrops, liquid nitrogen fertilizers (including UAN solutions) should be enriched with such additives that reduce nutrient losses to the aquatic ecosystems.	 *Figure 8: Nitrogen losses in the form of ammonia from urea stabilized with inhibitor of urease NBPT and from urea without inhibitor, immediately after application to grassland in a dose of 60 kg N□ha-1 [Marcinkowski, Kieronczyk, 2015]*
Benefits and limitations of use	Concentrating on environmental and economic considerations, the application of urea to fertilize plants in solid and liquid form without urease inhibitor should not be recommended. It is now known that, due to using the NBPT inhibitor, its hydrolysis susceptibility to ammonia, at least for a few days after application of the fertilizer, may be limited. Therefore, increasing the efficiency of this form of nitrogen in mineral nutrition is highly probable and the ecological benefit is unquestionable.	
Costs of application	The purchase of urea or UAN stabilized with NBPT inhibitor causes an increase in the cost of fertilization by approximately 10 to 20%.	

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8. Conservation tillage	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients and PPP runoff, wind and water erosion
Type of pollutant combated by the measure:	Nutrients, pesticides
Description	In addition to traditional systems of soil cultivation based on ploughing and other mechanical treatments, a conservation tillage system (ploughless) can be considered. It is a tillage system without the use of a plough (to a depth of 10–12 cm) or tillage with deeper soil loosening (up to 25 cm). It conserves soil, water and energy resources through the reduction of tillage intensity and retention of crop residue. Tillage of the soil stimulates microbial decomposition of soil organic matter, which results in emissions of CO_2 to the atmosphere. Therefore, minimizing the amount of tillage promotes sequestration of carbon in the soil. It also limits wind and water erosion and runoff of nutrients and pesticides. The no-tillage system is also known to be similarly beneficial. This is seed sowing to the untreated soil after harvest of the previous crop using special drills for direct seeding [Ulen B. et al., 2013]. The basic machines used in this system are drills of different construction, harrows, rotary cultivators and combined systems.
Benefits and limitations of use	Once the system has stabilized, the conservation tillage system brings a number of benefits, mainly to reduce soil degradation. The amount of labour and energy used to prepare land for cultivation and fertilizer needs are decreasing. A significant disadvantage of this measure is long, multi-stage processes of stabilization of the system, calculated for 5-7 years, transient yield reduction and increase of N_2O emissions and soil fungi.
Costs of application	The costs are primarily the purchase of specialized equipment including direct seeding drills. Price of the equipment depends on the type and manufacturer and chemicals for the transient control of more weeds and harmful organisms.

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9. Crop rotation and its role in rebuilding and preservation soil organic matter

Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff, PPP runoff
Type of pollutant combated by the measure:	Nutrients, pesticides

Description

The rebuilding and preservation of organic matter in soils is largely a result of the farmer's conscious decisions based on the proper selection and sequence of crop rotation. Cultivation of legume crops, their mixtures with grasses or grass crops only, and the use of natural and organic fertilizers, promote reproduction of organic soil. The cultivation of root crops, maize, cereals and *oilseeds*, however, contributes to soil impoverishment. IUNG-PIB studies clearly show that in sequences of crop rotation in which organic growth-promoting plants (aftercrops and legume crop mixtures with grasses) were present, the organic matter content in the soil was from about 10 to more than 20% higher than the sequences, in which these crops did not occur (Tab. 3). Organic matter supports soil structure, soil aggregates and has a high water-holding capacity. It also increases the microbiological activity and therefore the degradation and adsorption of pesticides.

Table 3:The content of humus in the soil after three rotations (12 years) of different sequences of crop rotation [Jończyk, 2008]

The sequence of crop rotation		The content of humus in the soil (%)
A	potato + solid manure[1)] – sugar beet – maize – spring barley	1,25
B	sugar beet + solid manure [1)] – spring barley + aftercrop – potato – spring barley	1,39
C	oats + solid manure[1)] – clover with grass – maize – spring barley	1,51

1) dose of solid manure: 30 t · ha^{-1}

Benefits and limitations of use

These activities stimulate and rebuild the soil fauna and flora responsible for the reproduction of humus and fertility of soil. It has a significant impact on crop yields and the economic effects of the farm. Proper crop rotation through the sequence of plants reduces the need for nutrients and therefore reduces the need for additional fertilizers, so the costs associated with their purchase and application are decreasing. Intercrops with a large number of legume plants may increase the risk of nitrate runoff and potentially increase the risk of nitrogen oxide emissions following agronomic treatment.

Costs of application

There are likely to be small costs associated with increasing labour consumption on the farm connected with agrotechnical activities, e.g. sowing and ploughing of intercrops.

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10. Plant cover in autumn and winter	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff, PPP runoff
Type of pollutant combated by the measure:	Nutrients, pesticides
Description	An efficient way of reducing nutrient and pesticides loss from arable land during autumn and winter is to keep the land under vegetative cover (green land) during these periods, particularly in areas with light soils and mild climates. At the same time, annual winter crops, such as winter wheat or winter rape, can provide a vegetative cover that actively takes up available N and P from soil more efficiently than annual spring crops in a seasonal period with high precipitation and cool climate. Similar functions can be used for intercropping, which can be under-sown in the main crop simultaneously or just after sowing of that main crop. When the main crop is harvested, the catch crop has already an established root system ready to take up nitrogen from soil during late summer and autumn. Nitrogen that otherwise could have been leached is then taken up and incorporated into plant biomass. The immobilized nitrogen will be released to the soil again, at the moment of termination of the catch crop growth e.g. by tillage. The catch crop is ploughed as late as possible in autumn, or in spring. The selection of plant species used as a catch crop depends on climatic and soil conditions [Pietrzak, 2012].
Benefits and limitations of use	Plant cover of arable land during autumn and winter effectively limits the runoff and flow of fertilizer components and pesticides. Nitrate leaching is reduced relative to the time the soil is covered by vegetation. The effect of the catch crop on N leaching depends also on precipitation and drainage conditions. It also affects the amount of available N in soil and influences how successfully the catch crop may establish. Catch crops, apart from reducing nitrate leaching, may also retain and recycle available P in the root zone, increase the amount of organic matter in the soil and improve the soil structure.
Costs of application	It is a relatively easy method to implement requiring only purchasing and sowing the seeds, and finishing the catch crop, which is compensated for by increasing primary crops.

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11. Grass buffer zones		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Runoff, subsurface flow, drift and runoff of PPP
Type of pollutant combated by the measure:		Nutrients, pesticides
Description	Buffer zones are strips of land covered with permanent vegetation located between agricultural land and watercourses and reservoirs. Buffer zones are a particularly important measure in areas where erosion is a problem (reduces inflow of surface water; stops eroded soil material, pesticides, P and other soil contamination). The buffer zones are the most effective mitigation measure to reduce pollution from agriculture on the area characterized by sandy and silty soils, located on slopes of more than 7° inclined towards watercourses reservoirs [DEFRA, 2009].	 *Figure 9: Grassy buffer zone [Z. Miatkowski]*
Benefits and limitations of use	Buffer zones reduce the risk of soil material, N, P and other nutrient and pesticides losses from agricultural fields to surface waters. The ability to retain pollutants through the buffer zones depends on many factors such as: width of the zone, slope of the terrain, plant species composition, soil type, land cover, hydrological and meteorological conditions. It has been found that buffer zones, depending on their plant cover, can hold from 4 to 95% of nitrogen and 24 to 85% of P migrating from cultivated fields to surface water [Hawes and Smith, 2005]. A grass buffer zone of 5m, 10m or 20m reduces pesticides runoff respectively 50%, 90% and 97,5% [ECPA, 2009]. Moreover, buffer zones have a beneficial effect on biodiversity (they are a refuge for plant and animal species, enrich the agricultural landscape and improve the microclimate). The adverse consequence of buffer zone applications is the exclusion of strips of cultivated fields from agricultural use. The potential of agricultural production and revenue is reduced.	
Costs of application	The average cost of establishment of a grass buffer zone differs in the different EU countries. Moreover, establishment of buffer zone decreases the direct surplus from plant production (annual production value from 1 hectare).	

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12. Constructed wetlands		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Nutrients and PPP runoff
Type of pollutant combated by the measure:		Nutrients, pesticides
Description	Wetlands fulfil many useful functions. One of them is the removal of N, P, pesticides and other pollutants from runoff water through sedimentation, biological and chemical transformation and degradation as well as to plant uptake. Nitrogen is reduced due to nitrification of ammonium, in shallow areas, and anaerobic denitrification in deeper areas. Phosphorus is removed in the process of sedimentation. Soil particles with bonded P settle at the bottom of the pond. Constructed wetlands are established, or re-established, to receive water from large runoff areas in arable and agricultural lands. The runoff area should be covered by at least 50% intensive agricultural land use, with the constructed wetland of an area approximately 0.5–4% of the total runoff area [Pietrzak, 2012].	 *Figure 10: Constructed wetlands ITP Falenty [P.Nawalany]*  *Figure 11: Constructed wetlands ITP Falenty [P. Nawalany]*
Benefits and limitations of use	Constructed wetlands, as well as natural ponds and marshes, can capture runoff, clean it, and stop eroded sediments. Wetlands have additional benefits, i.e. improved biodiversity, water storage capacity, resource recovery, irrigation possibilities and production of crop biomass. It is generally accepted that constructed wetlands retain 20 to 90% N and 25 to 100% of P introduced to them with runoff [Owenius and van der Nat, 2009]. The retention efficacy for weakly and moderately adsorbed compounds is estimated to be lower (approx. 50%), while for strongly adsorbed compounds efficacy can reach up to >90% [TOPPS prowadis, 2012].	
Costs of application	The cost of earthworks associated with construction of artificial wetland is similar to the cost of land elevations, digging of shallow tanks or ditches and depends on the size of the wetland.	

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13. Separation of pastures from water courses and reservoirs	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Water eutrophication and acidification
Type of pollutant combated by the measure:	Nutrients
Description	Pastures situated in the immediate vicinity of reservoirs and water courses should be restricted along the waterline. The watercourse should be separated from the pasture and the bank adequately protected. A preferred solution in the vicinity of watercourses and reservoirs is to use a mown and grazed system of grassland management that effectively limits the migration of biogenic substances to water bodies [Ulen B. et al.2013].
Benefits and limitations of use	Isolating watercourses and reservoirs from pastures prevents contamination of water with animal waste, which directly affects the reduction of eutrophication and acidification of surface water. Livestock that has no direct access to watercourses and reservoirs do not damage the edges, banks or slopes. There are no occurrences which have negative impacts on the soil, e.g. "trampled soil" susceptible to water erosion.
Costs of application	The cost of the measure depends on price of fences for cattle. The average cost of a typical 100 m fence for cattle in Poland is around 250 EUR. Alternatively, the costs of electric fencing can be refunded under the "Modernization of Farms", Rural Development Program 2014-2020.

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14. Controlled drainage

Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff
Type of pollutant combated by the measure:	Nutrients

Description

Intensive plant production causes a periodic increase of nitrate concentration in drainage water flowing from agricultural areas. The major part of the outgoing N load occurs during the winter and early spring [Rafałowska, 2008]. It is caused by the outflow of N and P (partly) along with water from thaw and precipitation in the post- vegetative period. It is therefore advisable to partially reduce the flow of water during this period, especially after reaching the appropriate level of groundwater. Water-rising devices can be located in drainage wells or in drainage ditches receiving drainage water. The height of water-raising and the way of using these devices depends on local habitat conditions, type of soil and crops.

Figure 12: Flow-gate on drainage ditch [source: wikidelta.pl]

Benefits and limitations of use

Regulating the outflow of water from the drainage network allows for limiting the load of N and P flowing to surface and groundwater. In addition, plants can use the collected water during the growing season which can have a positive impact on the yield. However, drainage systems with controlled outflow work well in flat areas. In more diverse landscapes it is recommended to build small retention reservoirs on outflows from drainage systems and drainage ditches [Naturalna mała retencja… 2016], where water can be treated and used for irrigation or other economic purposes.

Costs of application

On the assumption that plant production takes place on previously reclaimed agricultural land, regulating the outflow of water from the drainage network does not generate significant external costs.

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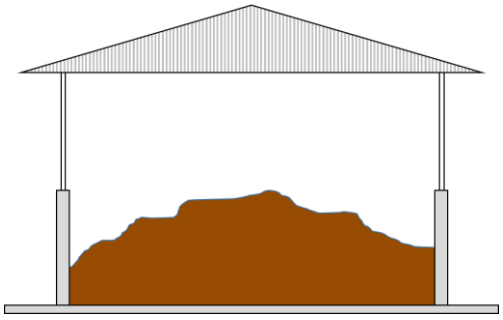
15. Covered manure storage system		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Nutrients runoff, subsurface flow
Type of pollutant combated by the measure:		Nutrients
Description	Ammonia emission and leaching from solid manure increases the loss of nutrients, especially in those farms where the fertilizer is stored directly on the ground. Manure should be stored in tight manure pits with side walls on the discharge channel and a reservoir to collect leachates. The loss of ammonia from storages with solid manure, especially if composting proceeds at high temperatures, could be high. Peat included in the bedding material will reduce NH_3 loss during storage. Roofs on solid manure storages could be an effective measure to reduce ammonia losses from solid manure. Additionally, a roof keeps rainwater away, which could prevent nutrient leakage from the manure pad if it has insufficient or lacking drainage leading to a collection pit [Pietrzak, 2012]. A good method of reducing ammonia losses from manure is plastic film cover with a thickness of at least 0.15 mm. The film should be loaded with weights to prevent blowing through the wind.	 *Figure 13: Covered solid manure storage reduces ammonia emission and nutrients runoff*
Benefits and limitations of use	The solid manure that is covered by the roof effectively reduces N losses in the form of ammonia as well as runoff of N and P through atmospheric precipitation. The farm can potentially save on the purchase of mineral fertilizers which increases its economic efficiency. Also groundwater and surface water resources located on the farm and its immediate surroundings are not degraded.	
Costs of application	The costs of building a roof over solid manure is determined by the type of construction (steel, wooden).	

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16. Slurry bags		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Nutrients runoff, subsurface flow
Type of pollutant combated by the measure:		Nutrients
Description	The needs of farms for the storage of slurry can be realized on the basis of very light and functional slurry bags. In an emergency situation where liquid manures need to be stored for the short term, slurry bags are the only rational way to increase the storage capacity of the fertilizer on the farm. Bag installation does not require a building permit. It is sufficient to place a bag on a flat surface, without sharp material and sand or gravel substrate. Slurry bags are equipped with connectors that facilitate the filling of liquid manure and its later distribution. The bag construction is completely sealed and safe and does not allow the spread of any odours.	 *Figure 14: Slurry bags [Exflo s. z o.o., 2017]*
Benefits and limitations of use	Flexible bags for liquid manure completely eliminates the problem of loss of nutrients during storage of liquid manure and slurry on the farm. Installation takes about 30 minutes and the bags are stabile – for at least 10 years. The farm saves on the purchase of mineral fertilizers, which increases its economic efficiency, while ground and surface water in the farm and its surroundings are not exposed to N and P pollution. In Poland, however, this is a high financial burden, especially for small and medium sized farms.	
Cost of application	The cost of buying Exflo Farmer bag with the capacity of 200 m^3 in Poland is about 10000 EUR.	

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17. Adopting phase feeding of livestock

Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff, subsurface flow
Type of pollutant combated by the measure:	Nutrients

Description

Livestock at different growth stages or stages of the reproductive cycle have different optimum nutritional requirements. Greater division and grouping of livestock on the basis of their feed requirements allows more precise formulation of individual rations. This increases the animal's nutrient use efficiency and results in reduced excretion of N and P in fresh animal faeces and urine [Pietrzak, 2012]. In pig feeding the fattening period can be divided into consecutive sub-periods (feeding phases). In any of these periods the level of protein in feed is closely adapted to the needs of the porker and decreases with the animal's growth. In growing pigs the percentage of protein in the feed should be reduced together with their growth due to the decreasing animal demand for protein. At the same time, an addition of lysine should be used to improve the quality of protein. According to some studies, 4-phase fattening and supplementation of protein with lysine (primary limiting amino acid for pigs) can reduce N excretion by pigs to 66% when the addition of lysine is 7%.

Table 4: Reduction of nitrogen excretion by the use of phase feeding and improving the quality of protein, in kg N per porker [Potkański 1997 after Krichgessner et al., 1994]

Specification	1-phase feeding	4-phase feeding			
	Lysine in the protein,%				
	5,0	5,0	5,5	6,0	6,5	7,0
Nitrogen uptake	6,3	5,66	5,14	4,72	4,35	4,04
Retention of nitrogen	2,29	2,26	2,26	2,26	2,26	2,26
Nitrogen excretion	4,01	3,4	2,88	2,45	2,09	1,78
In %	100	85	72	61	52	44

Benefits and limitations of use

Adopting phase feeding of livestock increase nutrient use efficiency from feed and results in reduced excretion of N and P. Changing the traditional feeding system to phase feeding to reduce animal feed costs, provide better nutrition for animals, reduces the cost of animal production, provides better nutrition for animals and reduces the negative impact on the environment.
A helpful tool for reducing N and P in the diet of animals, and for reducing the amount of excreted components is computer feeding programmes. They enable balancing and optimising the feed formulations for farmed animals according to their living and productive needs.

Costs of application

Costs are related to increased labour intensity due to the preparation of several types of compound feed.

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18. Phytase supplementation

Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff
Type of pollutant combated by the measure:	Nutrients

Description

The foundation of pig feed is fodders of plant origin of different abundance and accessibility of P (in the range between 3 and 12 g/kg dry feed). Phosphorus is present in them in two forms: phytic (not absorbable) and non-phytic (absorbable). The largest amounts of phytates are present in cereal grains (from 55 to 77%), oil seeds and pulses. Monogastric animals (pigs and poultry) have no bacterial microflora and cannot produce phytase by themselves. A consequence is that P fixed in the form of phytic compounds is unavailable for them. The content of digestible forms of P varies considerably in different types of feed. Supplementation with synthetic phytase to pig feed reduces the need for additional mineral phosphate.

Table 5: Total phosphorus content and share of digestible and excreted phosphorus in selected pig fodders [Ulen et al., 2013]

Fodder	P [%]	Digestible forms of P in fodder [%]	Share of excreted P (%) in relation to P in fodder
Barley	0,5	0,1	72
Fishmeal	39,1	32,8	16
Lupine	3,8	1,1	70
Lucerne	22,4	4,7	79
Maize	0,1	0,3	72
Beet molasses	5,4	0,9	84
Oat	0,8	0,2	69
Pea	0,9	0,4	61
Rapeseed meal	9,6	7,0	37
Rye	0,5	0,2	64
Triticale	0,5	0,2	63

Benefits and limitations of use

Phytase increases the availability of P in the feed and allows total P content to be reduced without affecting productivity. With the addition of phytase, the P content of pig feed can be reduced by up to 30%. Furthermore, a large number of studies show that the addition of phytase improves digestion and use efficiency of protein and fat, resulting in reduced excretion of P and N.

Costs of application

The cost of additional phytase to fodder is associated with the purchase of suitable mineral-vitamin mixtures.

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19. Reducing dietary nitrogen and phosphorus intake	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff, subsurface flow
Type of pollutant combated by the measure:	Nutrients
Description	In order to improve the low efficiency of the use of N and P all feed components from purchase and production process require proper management and balancing. The balanced nutrition of animals will enable their on-farm requirements while reducing the negative impact of animal production on the environment. The efficiency of using N from feed depends on the type, age and species of the animal and ranges from 4 to 28%, with P being slightly higher, up to 39%. A helpful tool for reducing N, P in the diet of animals, and for reducing the amount of excreted components is computer feeding programs. They enable the balancing and optimizing of the feed formulations for farmed animals according to their living and productive needs.
Benefits and limitations of use	Changing diets to reduce adverse environmental impacts affects the cost of livestock production. Purchased feeds are often based on the least costly components that contribute excess nutrients, because cheaper raw materials often have worse amino-acid balances and are less digestible. In some farms, mixtures of plant-based feeds with residues of other crops or waste from the agricultural and food industry often form an important part of the animal diet. These feed ingredients also require balanced management – balancing of nutrients and nutritional values make it possible to improve the efficiency of feed utilization.
Costs of application	The costs of buying feedstuffs by-products and by-products of the agricultural and food industry are relatively small and, often in Polish conditions, are reduced to transport costs.

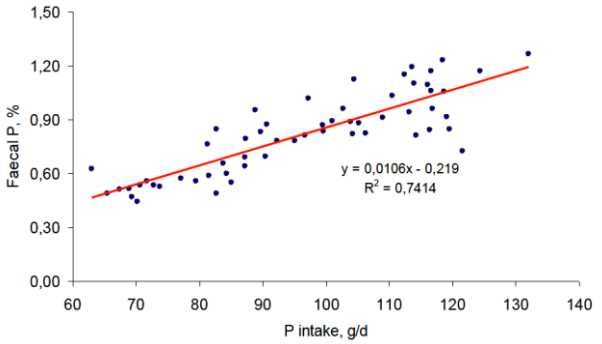

Figure 15: Relationship between P intake and faecal P in lactating dairy cows [Wu et al., 2001]

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20. Ensure the sprayer operator is adequately trained and prepared for PPP use	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point sources pollution, spray drift, runoff
Type of pollutant combated by the measure:	Pesticides
Description	The EU Directive 2009/128/EC on sustainable use of pesticides says that professional pesticide users, distributors and advisors of its Member States must receive a proper training on the safe use and handling of using Plant Protection Products (PPP). Guidance on training schemes, certificates of competence is available from your local authorities. (Source: TOPPS)
Benefits and limitations of use	Trained operators know how to use the PPP and the spraying sprayer equipment in order to safely use and handle PPP. They are aware of possible water pollution by PPP and know how to prevent water pollution by PPP. They also know better how to act and react in case of accidents with PPP.
Costs of application	Check the local authorities for the actual cost of training schemes in your country. For example in Belgium: - Professional users of PPP need a spraying licence type II (P2), advisors and distributors need a spraying licence type III (P3). To prolong/extend their spraying licence, they need to follow 4 (P2) or 6 (P3) courses of 3 hours during the following 6 years after date of issue. These lessons are for free. - To obtain a P2 spraying licence, you need to follow 60h training, to obtain a P3 spraying licence, you need to follow 120h training. Courses to obtain a spraying licence cost approximately 150 EUR.

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21. Always plan and organize your spray activities	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point sources pollution, spray drift, runoff
Type of pollutant combated by the measure:	Pesticides
Description	Spraying starts with careful planning of the application. Planning means to do a series of preliminary actions concerning the equipment and their check, the definition of the operating parameters, the correct handling of Plant Protection Products (PPP) and the assessment of mitigation measures to be adopted in the presence for example of sensitive areas or water bodies to be respected. This begins by marking the fields to be treated and the selection of the PPP. When possible, try to cluster the fields that need to be spread with the same PPPs, in order to minimize the amount of opened packs and spray remnants. Identify the location of all sensitive zones on the farm and the fields such as adjacent waters or sources, neigbours, adjacent crops, vegetative buffer zones and no spray zones and take appropriate mitigation measures. In case of employment of spray contractors a detailed briefing is required. Invest time to adjust the sprayer for an optimal use according the particular conditions. Select the most adequate working parameters to obtain an uniform and precise distribution of the intended amount of pesticide over the target. Use the on-line tools available for sprayers calibration such as: http://prototype.topps-eos.org Assess predicted weather and soil conditions for the region at the timing of the planned application. Check during the preparation of your spraying application the product labels carefully to calculate precisely the amount of PPP and water needed. Select and use the least risky road to the field, in order to minimize the risk of accidents [TOPPS].
Benefits and limitations of use	A good planning and preparation may prevent accidents and spraying of sensitive zones, which may cause point pollution. Planning before spraying results in time benefits and a more efficient use of PPP used.
Costs of application	No extra cost.

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22. Only spray when weather and field conditions allow safe and effective PPP use	
Type of protected water:	Groundwater and surface water
Type of risk mitigated by the measure:	Spray drift, runoff
Type of pollutant combated by the measure:	Pesticides
Description	Weather can influence the risk of Plant Protection Product (PPP) losses through spray drift and runoff. Check the following weather parameters before starting to spray: wind direction, wind velocity, air temperature, air humidity. Spray low wind velocity, at low air temperatures and high relative humidity (morning or evening). If no legal requirements about wind velocity are specified, preferably spray at low and medium wind (0,5 - 3,0 m/s) at spray dispersion height. In case of high wind (3.1–5.0 m/s) stop spraying until the wind speed decreases. Never spray at very high wind speed (>5.0 m/s). Spray in stable atmospheric conditions: avoid spray loss at high temperatures (>25 °C) or low air humidity due to potential thermal drift. Do not spray PPP onto frozen or snow covered ground or on water logged soils (High risk for runoff). (Source: TOPPS)
Benefits and limitations of use	The particularly environmental benefits of a spray application at good conditions are the better and optimized use of the PPP, less spray drift and less runoff.
Costs of application	No cost on this BMP.

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23. Only use approved PPP and comply with all their Conditions of use	
Type of protected water:	Groundwater and surface water
Type of risk mitigated by the measure:	Point sources pollution, spray drift, runoff
Type of pollutant combated by the measure:	Pesticides
Description	A plant protection product can be used exclusively on crops, for the adversity, with the methods and doses reported on the label. Any other use, other than those listed on the label, is illegal. Also the use of unauthorized mixtures or between incompatible products can be illegal and can cause chemical-physical reactions that hinder their distribution in safe conditions. Make sure that the Plant Protection Products (PPP) and the PPP mixes You intend to use are approved and permitted by the local authorities for the crop and location you intend to use it for. Read the product labels and relevant Safety Data Sheet carefully. Ensure that all its conditions of use are understood and can be fully implemented in the farm management. Use the correct dose and precisely calculate the total amount of PPP and water needed. If necessary, seek extra guidance. PPP must never be loaded into an empty spray tank. The spray tank should be at least be half filled with water. Follow the PPP label advice for the correct dilution of the product. Seek guidance when mixing contrasting formulations. If no advice is available, consider the following sequence: water soluble bags, water dispersible granules, wettable (soluble) powders, suspension concentrates, emulsifiable concentrates and adjuvants. Follow any specific guidance for the loading of Water-Dispersible Granules (WG), powders and water soluble sachets. Non-approved or counterfeit products/mixes may cause chemical/physical reactions that enhance the risk for issues such as sedimentation/blockage within equipment and need for hazardous waste disposal. (Source: TOPPS)
Benefits and limitations of use	Using approved Plant Protection Products and complied with all their conditions of use results in correct use and good efficacity, which results in a reduction of the water pollution.
Costs of application	No costs.

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24. Do store sprayers in safe places	
Type of protected water:	Groundwater and surface water
Type of risk mitigated by the measure:	Direct losses
Type of pollutant combated by the measure:	Pesticides
Description	When sprayers are not used, they must be parked in a secure area. (Preferably cleaned) sprayers must be stored in a covered place to protect it from rain washing off any remaining PPP and protected from frost and rain damage. (Source: TOPPS)
Benefits and limitations of use	Economic benefits of application: Good storage of the sprayer prevents damage costs and ensures better operation of the sprayer. Environmental benefits of application: Better stored sprayers prevents less damages and leakages, which may end up in the surface water.
Costs of application	Perhaps some extra cost in order to build or provide a covered place to store the sprayer. No cost calculation present at the moment.

25. Use inspected sprayers	
Type of protected water:	Groundwater and surface water
Type of risk mitigated by the measure:	Point source pollution, spray drift
Type of pollutant combated by the measure:	Pesticides
Description	The implementation of the Sustainable Use Directive for pesticides (EU Directive 128/2009) requires the regular inspections of sprayers in all countries to be established (ref.: ISO16122). Information on inspection and schemes is available from your local authorities.
Benefits and limitations of use	An inspection of application equipment (handheld excluded) is necessary to make sure the spraying equipment works well. Well maintained spraying equipment ensures the correct functioning of the sprayer and avoid leakages. Malfunctioning sprayers will cause an over or under dosage of the PPP. An overdose can lead to residues on the crops and may be hazardous for the environment. A too low dosage will result in poor treatment and the need of extra treatment to achieve the biological effect, which is uneconomical for the grower. An insufficient pesticide level may also induce resistance. So inspection of the sprayer equipment results in reduction of potential point source pollution and reduction of spray drift.
Costs of application	Check the local authorities for the actual cost of sprayer inspections in your country. For example in Belgium, the price for inspection of a field sprayer of 12 m work width is 83,5 EUR, for a field sprayer of 21 m work width it is 153 EUR. For orchard/vineyard sprayers, total amount of nozzles on the spray crown is parted in two in order to become the equivalent work width.

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26. Calibrate the sprayer for the appropriate and optimized application of PPP	
Type of protected water:	Groundwater and surface water
Type of risk mitigated by the measure:	Point source pollution, spray drift
Type of pollutant combated by the measure:	Pesticides
Description	Sprayer calibration is necessary to ensure a correct flow rate (l/ha). Therefore some parameters needs to be checked such as forward speed, flow meter, wear of the nozzles, spray output at the nozzles … For air-assisted sprayers, also check and adjust direction, volume and speed of the air. Before you start calibration, you need to check if your sprayer is operating properly, without leaks, plugged filters, kinked lines or other problems and adjust the sprayer to optimise spraying conditions and consider drift reduction.Calibrate before every spraying application or whenever appropriate (f.e. new nozzles, new tractor tyres, changes in sprayers computer, after spraying liquid fertilizer, …) Calibrate and maintain sprayers on an biologically active area or on washing surface with a collection system for liquids without risk of ground/surface water pollution. Sprayers must be calibrated only with clear water. Ensure full safety to the operator, bystanders and the environment when calibrating. Do note that operators will make direct contact with surfaces such as nozzles that may have been contaminated from earlier PPP use. Especially in vineyards/orchards, check the calibration visually in action by spraying clear water and evaluate the spray penetration and distribution by visual assessment of coverage on water-sensitive paper located inside, under and over the crop canopies. Always monitor sprayer performance whilst applying Plant Protection Product solution over the intended treatment zone [TOPPS].
Benefits and limitations of use	Calibration of the sprayer is necessary to establish a good spraying, minimize residual volume remaining in the sprayer after application and minimize spray drift.
Costs of application	No cost calculation available

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27. Safe transport of Plant Protection Products	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides
Description	Transport PPP safely. During loading, transport and unloading all precautions must be taken to avoid accidental losses that may contaminate the vehicle and the environment. Be aware that national regulations on transport of PPP may vary across EU and therefore needs to be checked locally. The transport of PPPs from suppliers to the farm is the first step in a series of processes where there may be risks for point source contamination. Transport from retailer to farm: Make use of your supplier's delivery service for the transport of PPP to the farm whenever possible. When transporting PPPs on your own, use lockable boxes which can contain spills in case of an accident and stow and secure your load safely. PPPs must be transported in their original and intact containers with original labels. From farm to field: Follow the local transport rules if you carry PPP concentrate or spray liquid on your sprayer. Travel carefully with the spraying equipment and/or PPP and ensure the vehicle stability. Choose roads to the field which have the lowest risks of accidents to occur and always know where you are. Ensure that no accidental or unintended losses of PPP can occur, such as leakage of hoses and nozzles or overflow of the tank. Secure all valves against accidental opening during transport and ensure that the tank closures, couplings and valves are tight. If the spray tank fill level display is visible from the cabin, you can detect losses while on the way. Do not drive through or in water courses. Do not transport PPPs together with food or feed. Keep emergency numbers with you in case of emergencies [TOPPS].
Benefits and limitations of use	Safe transport has many benefits: - Enhanced safety for the driver, passengers and all other road users. - Reduced risk of prosecution and fines from regulators - Risk reduction in environmental & water contamination - Enhanced public relations Be aware that transport of hazardous goods on public roads is strictly regulated in most countries. The law limits the maximum PPP loads you can carry as a farmer. Check the load limits and local conditions of exception in your region.
Costs of application	No cost.

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28. Store Plant Protection Products within lockable rooms/containers or cupboards

Type of protected water:	Surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides

Description

A storage specifically designated to store Plant Protection Products (PPPs) is essential at the farm. This store is exclusively for PPPs and, if local legislation allows, for intermediate storage of residual fractions such as empty containers. Only authorized persons may have access to PPP stores. Appropriate safety and hazard signs should be displayed at the store entrance. Keep instructions on hazards and emergency procedures at store entrance.

Figure 16: Storage room [E. Pauwelyn]

The place should have enough light so that the labels are easy to read. Ensure stores keep PPP dry and protected from frost, excess heat (> 40°C) and direct sunlight. Surfaces must be impervious to liquid and solid PPPs and stores must be bunded. Storages (capacity < 1 ton) areas should be designed as such that a spillage of 10% of the liquids stored could be contained. Seal and disconnect any drain, gully or channel in the flooring, safe the one leading to a dedicated tank to contain spillages. The floor must be secure, not slippery and easy to clean. The shelves should be made of non-absorbent material and be easy to clean. Dry products should always belocatedonthe top shelves and liquid products on the low shelves.

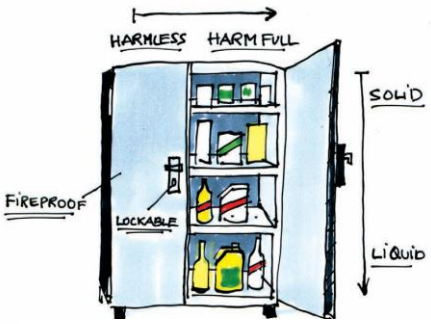

Figure 17: Storage shelves [TOPPS]

Store PPP in original packages with their labels intact and readable. When packs are leaking or been damaged, isolate them from the other PPP, repack them and minimize the storage time by using them first.

Appropriate and dedicated measuring facilities for PPP should be available attached to or within the store and located within a bunded area. Distance between the store, mixing and loading should be limited, as it enhances the safety and labour efficiency.

Equip the storage room with facilities to safely manage spills if they occur. Therefore, foresee containers with absorbent inert material such as sand or sawdust, together with a floor broom, dustpan and plastic bags. Foresee personal protective equipment [PPE] too.

Check and follow the local requirements for storage of PPPs.

Benefits and limitations of use

Benefits:

- enhanced safety for operators and farm dwellers
- reduced pollution risk and reduced insurance fees
- reduced risk of prosecution and fines from regulators
- enhanced cross compliance & trade certification approval risk reduction in environmental & water contamination

Costs of application

The average cost of establishment of a storage room depends on how much PPP must be stored. You can use a lockable cupboard if you only have a small amount of PPP or you can build a big storage room if you have many different PPP.

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29. Dispose obsolete Plant Protection Product by an authorized waste collection company	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Point sources pollution
Type of pollutant combated by the measure:	Pesticides
Description	Obsolete Plant Protection Products (PPP) should be disposed by collecting them by the supplier or an authorised waste disposal contractor. Keep the PPP for collection in their original containers and/or packaging with intact labels, so recycling is possible on the correct way. In case You do not need a specific PPP as planned, bring the unused product back to the retailer/distributor so You don't store unnecessary products. (Source: TOPPS)
Benefits and limitations of use	When collecting the obsolete PPP and sending back unused PPP to the waste collection company or retailer, it results in an environmental benefit, as there are no chances of leakages or accidents anymore. The waste collection company destroys the product on an environmental correct way. (Source: TOPPS)
Costs of application	No costs available.

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30. Choose a safe filling and cleaning place for the spraying equipment	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides
Description	You can fill or clean your sprayer safely on the field, on the farm on a dedicated area or in biological active area/soil close to the farmyard. If the filling or cleaning is done in the field, alternate the filling place and keep a distance to water of at least 10 m during filling, at least 100 m from any borehole and do not take place on compacted soil and keep more distance to water during washing. In farm mixing, handling and cleaning should happens on an impermeable surface with a sealed drainage system. All run off from the pesticide handling / washdown area must drain to a secure temporary storage. Filling and cleaning on a hard surface at the farmyard is only allowed only if the site is planned to collect remnant in dedicated water tank, all spillings, potential tank overflow and washing water, containing PPP. Carefully check and calculate the litres stored at anyone time and that there is no risk of liquids leaking. On an outdoor filling and cleaning place a separation between rain water and remnant water is necessary. Ensure that spray liquid cannot contaminate your water source when filling the sprayer with water (e.g. backflow valve, intermediate water tank, air gaps between water sources supply pipes and spray solution different pump for clear water and spray sollution, …). Treat collected contaminated washing water with appropriate techniques: biological, physical and chemical solutions are available (e.g. biofilter, osmofilm, heliosec, etc.) (see BMP “Safe disposal of spraying liquid residues”) [TOPPS].
Benefits and limitations of use	The environmental benefits of application of the agricultural best management practice is the reduction of point sources and protection of the surface water.
Costs of application	Filling on a permeable bioactive surface such as field/soil has no additional costs. Building of an impermeable filling and cleaning place with collection of remnant water cost in Belgium 1000 – 10 000 EUR.A subvention of 15% is available in Belgium for a filling and cleaning place.

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31. Be prepared for and manage spills safely	
Type of protected water:	Groundwater and surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides
Description	Be prepared and avoid spills during the handling with PPP by careful handling of PPP. Choose to work with PPP on safe sites, which are capable of retaining all spills. It can be a biological active area (soil/field) or a hard surface, which allows the collection of spray remnant. Use technical tools which reduce the risk of spills, e.g. low level induction hoppers or closed transfer systems with integrated container rinse facility. Place damaged containers/packs separately within a sealable container/sack. If spills happen, manage them safely by absorbing them. Therefore, make sure you have absorbent inert material such as sand or sawdust, together with a floor boom, dustpan and plastic bags by hand. Sweep up bound contaminants and place them within sealable containers/sacks to be managed as remnants. Never wash Plant Protection Product spills into drains or public sewage systems. Think about wearing personal protective equipment [PPE] by managing spills as defined on label and/or Safety Data Sheet. (Source: TOPPS)
Benefits and limitations of use	This best management practice has an important environmental benefit, as spills are an important source of point pollution. Therefore, preventing spills and managing them safely is necessary.
Costs of application	Cost to provide the PPE and absorbent inert material.

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32. Prevent overflow and foam escape during filling	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides
Description	Do not leave sprayers unattended during filling and loading with Plant Protection Products to prevent overflow. Check if the volume indicator at the sprayer tank is correct or use a flow meter with automatic water shut-off valve to measure the exact water volume. Use the tank scale only for checking if the sprayer is filled on a levelled area. Do not fill up the spray tank completely. Respect the over volume to ensure excess capacity [typically a further 10%]. This minimises the risk of spills, overflow and foam escape. Be prepared to take emergency actions. (Source: TOPPS)
Benefits and limitations of use	When applying this BMP, point source pollution can be prevented during loading of the sprayer. If you do not leave the sprayer unattended during spraying, you can prevent accidents and can keep unauthorized persons away. (Source: TOPPS)
Costs of application	No costs for this application.

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33. Rectify/Adjust any equipment problem immediately	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides
Description	When an spraying equipment problem emerges, immediately stop spraying and repair the problem. Mark the field location where the spraying was interrupted. Avoid the buffer zones or environmentally sensitive areas or public roads to conduct any necessary repairs on the sprayer. Protect yourself by wearing personal protective equipment and be prepared to clean PPP spills in a correct way (see BMP 31: Be prepared for and manage spills safely) [TOPPS].
Benefits and limitations of use	A bad working sprayer can cause point pollution f.e. by leakage of the spraying equipment. These can also result in over- or under-dosage of plant protection products, with economic and environmental impacts, reduced efficacy or increased risk of damage to the crop, exceeding the MRLs and resistance.
Costs of application	Cost of the reparation of the spraying equipment.

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34. Adequate cleaning of sprayers to minimize the amount of spray remnants	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides
Description	Clean/rinse your sprayer carefully in the field or biological active surface if possible also from the outside. Cleaning in het field reduces the amount of remnant water. A sprayer may also be cleaned on a secure washing place with collection of contaminated liquids. Never clean sprayers in areas with connection to sewage, groundwater or surface water or near to the surface water. Minimise the amount of spraying solution remaining after spraying by using callibrated sprayers with a low technical residual volume (non-sprayable and non-rinseable PPP solutions, which is influenced by the design of the sprayer) and by a precise calculation of the necessary spray sollution.Rinse your sprayer internally in the last treated field using the internal rinsing nozzles and clean water tank, if available. Multiple rinsing (triple rinsing, continuous rinsing or automatic rinsing) achieves better dilution of the residual volume. **Internal rinsing procedures:** **a)** Manual 3 step rinsing With the three-step rinsing method clear water is filled 3 times into the main spray tank (3 x 1/3 of the clean water tank content). The water is mixed with the residual volume (dilution) and after each cleaning/rinsing the diluted residual volume is applied on the last treated field. The three step rinsing is necessary to reach dilution factors of 50 to 100 based on the original spray concentration. **b)** Continuous rinsing method With the continuous rinsing method, a separate pump fills clear water into the spray tank via cleaning nozzles. The regular sprayer pump then presses the rinsing water out through the regular sprayer pipe network. **c)** Automated rinsing Newer and larger sprayers offer automatic rinsing systems, which steer the procedure either through continuous rinsing systems or through multiple step rinsing procedures. **External cleaning:** Spray residues can accumulate on the outer surfaces of the sprayer and tractor. Therefore, external cleaning of the sprayer is necessary. The cleaning should, if possible, take place in or nearby the field that was last treated. An attached spray lance for external cleaning for sprayer cleaning in the field is handy. Use high-pressure devices and/or recommended equipment for the external cleaning. Follow the instructions of the consultant/supplier regarding the use of any cleansing agents.
Benefits and limitations of use	Cleaning on the field in triple rinsing/cleaning reduces the risk of point source pollution. The following crops to be treated will not be damaged by PPP residues when good internal cleaning was applied. Limitation of use of the best management practice: a clean water tank and cleaning equipment should be available on the spray
Costs of application	Cost of providing cleaning equipment on the sprayer.

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35. Clean and safely manage empty containers/packages, seals and caps	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point sources pollution
Type of pollutant combated by the measure:	Pesticides
Description	Clean the empty Plant Protection Product (PPP) containers and packages properly, using a container rinse facility, which may be integrated in the induction hopper or filling device. If not available, clean the containers and packages manually. Wash the empty containers in three steps and throw the rinse water into the spray tank/induction hopper. Store your rinsed PPP containers straight up so they can dry out or store them in a way that no residual liquid may leak. Keep empty PPP containers / packages in securely closed and covered areas. Be aware that empty containers/sacks may still be contaminated with PPP. Puncture or crash the container to prevent re-use. Use the local recycling/disposal service for empty containers of PPPs and follow the recommendation of storage (special containers/sacks) and collection. Pay attention to the seals and caps of the PPP containers too. Wash container caps and seals carefully as they may carry remnants of PPP concentrate. Make sure they do not fall on the ground. Check with waste collecting company for guidance on collection and disposal of seals and caps.
Benefits and limitations of use	Implementation of this BMP provides a correct cleaning and collection of the PPP containers and packages, seals and caps. By doing this, point pollution can be prevented. Limitation of use of this BMP: not in every EU Country a recycling/disposal service of empty containers is present.
Costs of application	Collection of the empty PPP containers and packages f.e. in Belgium a recycling/disposal service is set up by the industry of PPP. The recycling costs of the empty PPP bags and packages is borne by the industry of PPP.

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36. Seal and secure partly used containers/packages immediately after use	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides
Description	Replace seals securely immediately after use. Partly used containers must be returned to the store, kept upright, stable and secure to avoid leaks, spills and unauthorised use. (Source: TOPPS)
Benefits and limitations of use	The economic and environmental benefits of application of the agricultural best management practice are most found in the prevention of point source pollution by avoiding leaks and spills.
Costs of application	No costs.

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37. Safe disposal of spraying liquid residues	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Point source pollution
Type of pollutant combated by the measure:	Pesticides
Description	Contaminated remnant water, collected from filling and cleaning of the sprayer, must be treated by means of appropriate techniques. There are three methods for treating remnants: a. Biological methods: f.e. biofilter/biobed and phytobac b. Physical/chemical methods: f.e. the Sentinel c. Physical method: f.e. Heliosec. The biological methods work on the principle of microbiological degradation of PPPs in a bioactive matrix. The biofilter/biobed/phytobac is filled with organic materials. Contaminated liquids are applied onto these organic materials and percolate through the organic material. Microorganisms in the system degradate the PPP. Water evaporates from the system. Physical/chemical cleaning system exist too. Chemical treatments and activated carbon, which work on the basis of absorbing PPP residues, are used to remove PPP from remnant water. Waste from the chemical treatments and the carbon, if it has lost its absorbing capacity, has to be treated as hazardous waste. With the physical methods, contaminated liquids are collected in a protected basin in order to separate the PPPs in the remnants from water by evaporation, e.g. Heliosec, or by Osmofilm. Such systems are protected against outside influences such as rainfall and preventing bystanders or wildlife from damaging the construction. The remaining dry residue is collected and disposed of as hazardous waste and incinerated. Please check the local recommendations for the approved purification systems in your country. (Source: TOPPS)
Benefits and limitations of use	The environmental benefit of this BMP is definitely the reduce of point source pollution of PPP in the surface water.
Costs of application	Cost of this application is depending on the amount of remnant to purify, the choice of the purification system and the choice of materials used to build the system. For example in Belgium, four systems are approved: a. Biofilter with capacity up to 5000 L/year: ± 750 – 1 500 EUR b. Phytobac: depending of its capacity: ± 2000-15 000 EUR c. Sentinel (chemical system): capacity 900 L in 6h: ± 30 000 EUR (installation price) without consumables. d. Heliosec: capacity up to 2500 L/year. System of (2x3)m^2: ± 5 000 EUR. Plastic layer has to be replaced every year. It costs ± 50 EUR.

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38. Use drift reducing nozzles

Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides

Description

Drift reducing nozzles produces coars and very coars droplets to prevent drift onto fields nearby, surface water around the field and roads.Therefore, use drift-reducing nozzles with low amount of fine droplets (<100µm) and use low pressure.

Most countries classify drift-reducing nozzles by comparing them to a standard nozzle. Select nozzles according to your local classifications. If a nozzle classification is not available/implemented in the country, use following indications:

Nozzle type		Working parameters	Potential drift reduction vs. reference nozzle
Flat fan or hollow cone with size > 03		1 – 4 bar	10 – 20% at low pressure
Flat fan pre-orifice		2 – 5 bar	30 – 50%
Flat fan air induction		2 – 8 bar	70 – 90%
Air induction end boom		1 – 1,5 bar 2 – 2,5 bar 4 – 8 bar	90 % 75% 50%
Air induction hollow cone		3 – 10 bar 10 – 15 bar	75% 50%

Figure 18: Nozzle classification [TOPPS]

The classification may differs by country, it is not yet harmonized. The use of driftreducing nozzles may influence PPP buffer zone distance requirements. (Source: TOPPS)

Benefits and limitations of use

Using drift-reducing nozzles has an important environmental benefit, as less PPP will drift to sensitive areas such as the surface water.

Limitation of use of this best management practice is that not in every country in the EU a classification of drift-reducing nozzles already exists. Check in that case the recommendations mentioned above.

Costs of application

Cost of the drift-reducing nozzles, depending on the country or region. For example in Belgium, an air induction nozzle costs nearly double compared to the flat fan nozzle.

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39. Use sprayer types allowing spray-drift reduction	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides
Description	Some countries have started to classify sprayers according to their spray drift-reduction potential (known as Spray Drift-Reducing Technology (SDRT)). The sprayers are divided into spray drift mitigation classes, e.g. 25%, 50%,75%, 90%, 95% or 99% (see ISO 22369-1). SDRTs are classified separately for different crop types, e.g. arable crop, fruit crop, hops, vineyard and nursery. Check the national SDRT classifications and the local recommendations and purchase a sprayer which is classified as SDRT. For field sprayers: - Use drift reducing nozzles (BMP 38) producing coarser droplets. - Use Air-assisted field crop sprayers. Air-assisted field crop sprayers or air-curtain sprayers have a spray boom equipped with fan and air sleeve producing a downward air flow of 1 400 to 2 000 m^3/h/m supporting the transport of the droplets to the target. The air assistance counteracts the effects of windy conditions and wind generated from driving. Air-assisted field crop sprayers have a drift reduction potential. - Use shielded field crop sprayers. These sprayers are provided with covers to contain the dispersion of droplets around the nozzles/atomizers. For orchard sprayers: - Use drift reducing nozzles (BMP 38) producing coarser droplets; - Use sprayers that allow easy adjustement and safe use (BMP 46: Adjust sprayer settings according to application conditions, crop density and canopy to minimize spray drift) - Use sprayer types with adjustable air-jet direction, which can be oriented to the target. Two examples are the cross-flow sprayers with air deflectors or towers with air spouts and the directed air-jet sprayers with flexible air ducts and adjustable air spouts - Use sprayers with adjustable air-flow velocity. - Use sprayers equipped with a system to close the air flow on either side - Use shielded orchard sprayers with a recycling system (tunnel sprayers) - Use row-covering sprayers in order to achieve uniform deposition and reduce drift. - Use new technologies to apply PPP more precisely (BMP 48)
Benefits and limitations of use	The environmental benefits of this best management practice is that less PPP end up in the surface water due to drift. Economic benefit: drift is reduced and the used PPP end up more specifically to the crop, which will result in a more efficient use of PPP.
Costs of application	No cost available at the moment.

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40. Use application techniques allowing PPP reduction if appropriate	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides
Description	Consider if it is possible to reduce the PPP use and drift, by adopting the application technique (e.g. spot treatment, band spraying, sensor spraying, weed wiper, etc.) Spot treatment is the application of a pesticide to a small, distinct area where the pest is present. A band sprayer applies the spray liquid in bands or rows (ISO 5681). Typically used on row crops or to apply herbicides under the vineyard/orchard rows. They minimize the rate/area of a pesticide. When a sensor sprayer is used, the sprayer is equipped with target identification systems, which can detect target plants/area with leaves. The sensors open the spray nozzles individually only if leaf area is detected. A weed wiper can be used for selective weed control if the weeds are taller than the crop. The weed-wiper eliminates drift, as droplets are not generated. (Source: TOPPS)
Benefits and limitations of use	Environmental benefits: when less PPP are used less PPP can end up in the surface water. The economic benefits are reduction of the PPP cost. Limitation of use: These application techniques cannot be used in every crop.
Costs of application	No cost calculation available at the moment.

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41. Use the lowest effective distance between nozzles/atomizers and the spray target	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides
Description	Field crop sprayers: For flat fan nozzles the optimal distance is where the spray fan generated exactly covers the entire width with full overlap. The closer the nozzles are spaced on the boom, the shorter the effective distance to the target. Use the lowest effective distance between nozzles and spray target. Distance to the target depends on angle of the spray fan produced by the nozzle: for 110-degree nozzles, the optimum distance to target is 50 cm, for 80-degree nozzles the optimum distance to target is 70 cm. Check the distance of the boom to the target before and during spraying by means of indicators (as it is difficult to judge the boom height from the driver's seat) or use automatic height controllers. Use sprayers with effective boom stabilization systems (shock absorbers, movement dampers or antiyaw systems) to maintain the optimal distance to the crop and prevent swinging of the spray boom. For band and row crop sprayers, adjust nozzles to cover the band/row while at the same time maintaining the lowest possible distance to target. Orchard/vineyard sprayers: Reduce as much as possible the distance between the nozzles/spouts and the target by using specific and optimized settings. For each treatment, the settings have to be adapted and optimized in order to suit crop development characteristics. (Source: TOPPS)
Benefits and limitations of use	Using this BMP induces important environmental benefit, as less PPP end up in the surface water by spray drift and a more effective spraying can be done. Limitation of use: boom stabilization is sometimes difficult to keep up the correct distance to the target.
Costs of application	No cost available at the moment.

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42. Use the lowest effective sprayer forward speed	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides
Description	At higher forward speed, the effective distance of the spray droplets to the targets increases (droplets are exposed to wind for a longer time). Increasing speed also increases the head wind and turbulence around the sprayer. This will leave more droplets in the air behind the sprayer and can be observed as a plume of "spray mist". Always aim for the smallest possible plume f.e. by slower driving. If it is desired to increase the speed, the negative effects must be counteracted by other drift reducing measures. (Source: TOPPS)
Benefits and limitations of use	The environmental benefit is less spray drift as the "spray mist" can be reduced by driving slower.
Costs of application	No costs on this application.

43. Use the lowest effective pressure	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides
Description	Higher pressures yield smaller drops and lower pressures yield larger drops, very fine droplets are minimized and hence risk of drift is reduced. Therefore, use the lowest pressure possible within the recommended operation pressure. So read the recommendations of the nozzle manufacturer for correct use.
Benefits and limitations of use	The environmental benefits of application of the agricultural best management practice is the reduce of spray drift.
Costs of application	No costs.

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44. Do not spray no spray zones and other non-target areas	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift, point source pollution
Type of pollutant combated by the measure:	Nitrogen, pesticides
Description	Check the Plant Protection Product (PPP) label for required distance to water bodiesand other sensitive areas (no spray zone). Do never spray no spray zones. Never spray non-target areas: • Stop spraying when turning at headlands • Never start spraying on the headlands when the sprayer is stationary. Only start spraying when the sprayer is moving at the calibrated speed. Consider the use of a boom re-cirulation system for the spray liquid. That way, the spray liquid is at the correct dose at the complete length of the spray boom at the start of application. • Do not spray or fertilize over surface water • For field crop sprayers switch off the boom sections applying PPP outside the target area • For vineyard/orchard sprayers, especially for multi-row sprayers, a number of sections should be adaptable to the shape of the spray profile delivered by the sprayer (by shutting down sections) and should fit the size of the field (for instance triangle shape) • Be careful at the field margins and use drift-reducing technology • In orchards/vineyards when spraying the outer row, close the nozzles and the airflow blowing on the side of the sprayer without canopy. Consider the adaption of automatic systems to manage the air flow rate independently on the two sprayer sides (closed/unclosed). • Adjust air-flow velocity/direction when approaching field boundaries or sensitive areas. (Source: TOPPS)
Benefits and limitations of use	The environmental benefits are the prevention of PPP and fertilizers in the surface water. Economic benefit: less PPP and fertilizers needed, so less cost. Limitations of the use of this agricultural best management practice: Alternative crop protection strategies are necessary to maintain the no spray zones and non-target areas.
Costs of application	No cost

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45. Adjust sprayer settings according to application conditions, crop density and canopy	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides
Description	Depending on the crop density and canopy, the sprayer should be adjusted. Adjustment is especially complex in Bush and Tree crops where sprayers need to be adjusted to changes in canopy structure, and multiple adjustments during a season. Adjustments concentrate on the liquid volume output rate, the spray profile and the air support (often visible spray drift is a result of sprayers that are not correctly adjusted). Therefore, use sprayers that allow easy adjustment. Adjust following settings: - Use sprayers with individually controllable nozzles to adjust sprayer settings to canopy development (especially for early stages) by adapting the number of active nozzles. Shut off the nozzles which are not oriented to the crop. Consider that shutting off nozzles changes the volume rate applied and requires new measurements and/or calculation to prepare the correct PPP concentration of spray mixture. - Multi-nozzle holders make it easy to change nozzles. - Adjust the nozzle position and orientation to achieve uniform spray distribution along the canopy profile. - Use sprayer types featuring the target-oriented properties (Cross-flow sprayers with air deflectors or towers with air spouts or Directed air-jet sprayers with flexible air ducts and adjustable air spouts). Make use of devices and adjustment features of the sprayer to apply spray precisely according to the canopy size, geometry and density. - Adjust air flow velocity according to target size, geometry and crop stage. This can be done by an appropriate angling of blades of the fan propeller or adjustment of the rotation speed of the propeller by the appropriate gearbox setting. Avoid excessive air flow and speed causing high drift risks in crops with little leaf cover/early stages. When spraying plants at early growth stages (no leaves), consider the option of switching off air support. - Adjust air flow direction according to application conditions. Change the angling of the blades on axial fan sprayers and correctly orient the air deflectors, so that the air flux matches the canopy profile. - Make a visual assessment of the air-flow adjustment in the plantation with clean water prior to the PPP application to check penetration. - Try to obtain a spray profile matching as much as possible the vegetation profile. Therefore, use Water Sensitive Paper (WSP) to get indications on inside, outside and vertical profile spray penetration of the canopy with certain adjustments or use the vertical patternator the select/adjust the most appropriate spray profile.
Benefits and limitations of use	When adjusting the sprayer settings according to the application conditions, crop density and canopy, spray drift can be seriously reduced.
Costs of application	No cost available at the moment.

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46. Do not use cannon sprayers next to sensitive areas	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides
Description	Cannon sprayers produce an uncontrollable spray cloud exposed to wind, and hence pose a high risk of drift. Do not use cannon sprayers. Should the use of this kind of sprayer be unavoidable, be aware of sensitive areas close to the sprayed field and take all precautionary measures into account to reduce spray drift. (Source: TOPPS)
Benefits and limitations of use	The environmental benefits of application of this agricultural best management practice is the reduction of spray drift and pollution of surface water by Plant Protection Products.
Costs of application	No cost available at the moment

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47. Keep existing vegetation or establish windbreaks/retention structures between sensitive areas and fields being sprayed	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift
Type of pollutant combated by the measure:	Pesticides
Description	To prevent drift, preserve and maintain existing vegetation/windbreaks or establish buffer vegetation/windbreaks. Depending on the crops the establishment requires different vegetation. Main aspects: height of "catch structure" – for orchards: 6 to 8 m, for field crops: 2 to 3,5 m; Density of canopy – conifers' permanent density or leafy structure which then need to develop earlier than the crop. Artificial spray retention structures (e.g. plastic structures or hail nets) can also be established to prevent spray drift. Consult local expertise for technical legal and funding advice before establishing a buffer. (Source: TOPPS)
Benefits and limitations of use	The environmental benefits of application of this agricultural best management practice is the reduction of spray drift. Limitations of use: losing land to establish windbreaks/retention structures. Good maintenance of the windbreak/retention structures is necessary to limit the possible negative effects of the structures. Possible limitations are the shadow, shelter for rabbits, more difficult passage for the tractor through tilting branches, …
Costs of application	No cost of application available at the moment.

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48. Use new technologies to applied PPP more precisely	
Type of protected water:	Surface water
Type of risk mitigated by the measure:	Spray drift, point source pollution
Type of pollutant combated by the measure:	pesticides
Description	By the use of new technologies, Plant Protection Products (PPP) can be applied more precisely. Some examples are GPS controlled sprayers or sensor controlled sprayers. GPS controlled sprayers automaticly shut-off nozzles at headlands when turning and automaticly adjust of specific sprayer settings (e.g. pressure, type of nozzle, number of active nozzles, air flow rate) on the basis of sprayer position in the field (e.g. in the proximity of sensitive areas or to prevent overlap) Sensor controlled spraying (presence/absence of leaf area) prevents spraying in the gaps, exposing the spray cloud to the wind. Sophisticated sensors identifying canopy geometry and density allow for even further drift reduction, by adjusting the spray volume to the actual canopy structure. (Source: TOPPS)
Benefits and limitations of use	Moreover, using new technologies to apply PPP more precisely results in less PPP use, reduction of point source pollution and spray drift. Limitation of use of innovative mitigation measure or best management practice: These new technologies need considerable investment and some older sprayers cannot be improved by such technologies.
Costs of application	Cost analysis of application of agricultural best management practice depends on the cost of the new technology which will differ per country.

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49. Improved soil management to increase the water holding capacity of the soil	
Type of protected water:	Groundwater, Surface water
Type of risk mitigated by the measure:	Runoff
Type of pollutant combated by the measure:	Nitrogen, phosphorus, pesticides
Description	Soil management has an influence on the water infiltration capacity of the soil. Key elements to increase the infiltration capacity include: - Breaking of soil compactions (soil surface and subsoil) - Increasing the soil porosity (water-holding pores, aggregation) The aim of these measures is to keep the water in the field and to avoid runoff at the source. Examples of improved soil management are: - Preparation of a rough seedbed - Avoiding surface soil compaction - Avoiding subsoil compaction - Reduced tillage intensity (BMP 8: Conservation tillage) - Cover crops (BMP 10: Plant cover in autumn and winter) In order to create a rough seedbed, reduce tillage to a minimum when preparing the seedbed and don't roll over after drilling. This way coarse aggregates are preserved. Mainly soils with high silt content (> 30%) are prone to capping (also termed crusting) after rains. Soil crusts reduce the infiltration capacity of the soil and therefore represent a high-risk situation for runoff and erosion. Maintenance of high organic matter content in topsoil improves aggregation and thus reduces the tendency of soils to crusts. Break a capping layer mechanically by hoeing or harrowing. Subsoil compaction (e.g. plough pan) can be a barrier for water infiltration and a reason for subsurface runoff (lateral seepage or runoff by saturation). Soil compaction can best be observed in winter by monitoring the fields for areas with standing water. Avoid ploughing or harvesting when the soil is too moist. Use low-pressure tyres or twin tyres to prevent soil compaction to a minimum level. Break subsoil compaction mechanically (e.g. ripping) or by growing plants with taproots. (Source: TOPPS)
Benefits and limitations of use	Environmental benefits: A higher water holding capacity implicates a higher uptake of water and pesticides and fertilizers in the soil and thus less runoff and erosion of pesticides and fertilizers. In this way, pesticides can perform their work and will be degraded by the biological organisms in soil. Fertilizers can be captured by the crop. Limitations: It takes time for tillage modifications to have a significant impact on the movement and storage of water in soil. In some cases, tilling will still be necessary to reduce the amount of soil cracks formed during summer (especially on clay soils) and to avoid soil compaction. Changing tillage practices may have technical and economic issues (time and cost), which need to be considered.
Costs of application	No cost available at the moment

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50. Inter-ridge bunding	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Runoff
Type of **pollutant combated** by the measure:	Nitrogen, phosphorus, pesticides
Description	A bund is a barrier/small dam in the field which retains water in the field and slows down the water flow in order to allow more water infiltration. In row crops like potatoes, bunds between the ridges have shown good effects to mitigate run-off of PPP [Goffart et al. 2013]. investigated the effects of inter-ridge bunds in potato fields and found that a reduction of runoff water from 70 to 98% was obtained. Erosion was reduced by 90% with inter-ridge bunds. Total pesticide losses through runoff were reduced with 96% using inter-ridge bunding. Research is currently also being conducted on bunding in vegetables grown on ridges such as leek or chichory [Vanden Nest et al., 2017]. Inter-ridge bunds can be made with special machines such as the Dycker from Grimme, the barbutte from Cotard and the Erosion Stop by Miedema.
Benefits and limitations of use	Different environmental benefits for this agricultural best management practice: - Improvement of the water holding capacity of the soil - Reduction of run-off and thereby reduction of surface water pollution by Plant Protection Products (PPP) and fertilizers. Economic benefits: More effective use of water, PPP and fertilizers. Limitation of use of best management practice: - Especially for crops cultivated on ridges such as potatoes, carrots, leek, chicory. - Availability of machine for inter-ridge bunding.
Costs of application	No cost available at the moment.

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51. Enlarge headlands	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Runoff
Type of pollutant combated by the measure:	Nitrogen, phosphorus, pesticides
Description	Often, the dominant cultivation direction of fields runs in the down slope direction and sometimes this cannot be changed due to various reasons. As the headland is usually cultivated in a perpendicular direction to the rest of the field, this area may serve as a cropped barrier for water running downslope. If necessary and possible, the headland can be enlarged or double sowed to further increase the mitigation effect of the headland. (Source: TOPPS)
Benefits and limitations of use	Environmental benefits: The headland may serve as a cropped barrier for runoff water (containing PPP and fertilizers).
Costs of application	No cost.

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52. Double sowing	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Runoff
Type of pollutant combated by the measure:	Nitrogen, phosphorus, pesticides
Description	Usually the optimal density of crop is adapted to local conditions, but when diffuse runoff is observed on a field, a strip with a higher plant density of a crop can reduce the volume of surface runoff water, without implementing a non-crop buffer strip (works like an annual grass buffer strip). Example: When sowing cereals in a talweg then double the sowing density to normal, which will reduce the flow of water strongly and will be less susceptible to erosion. The double-sowing is done in a strip across the slope or in a talweg in addition to the first sowing process. The placement of the double-sowed strip follows in principle the same methodology as in-field vegetated buffer strips. (Source: TOPPS) Gyssels investigated the impact of sowing density of small grains on rill and ephemeral gully erosion in concentrated flow zones. Doubling the root mass in the topsoil by double or multiple sowing of winter triticale resulted on average in a reduction of soil loss by 42% for the whole growing season. For the winter period, soil loss reduction, mainly attributed to the triticale roots, amounted even to 53%, showing the tremendous impact of seedling roots on soil erosion by concentrated overland flow in the early stages of vegetation growth.
Benefits and limitations of use	Environmental benefits: Double sowing reduces the volume of the surface runoff water and thereby reduces the potential of runoff Plant Protection Products or fertilizers. Limitations: Grain size of the cereals can be smaller [Gyssels et al., 2002].
Costs of application	Cost of the extra seed to sow.

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53. Manage field access areas	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Runoff
Type of pollutant combated by the measure:	Nitrogen, phosphorus, pesticides
Description	Field access areas are potential water pathways in a catchment or are areas where concentrated water flow may start to form. Especially in the down slope position of a field, they need to be managed carefully to prevent formation of linear runoff. In the area of direct wheel traffic, soil compaction may be reduced by using a layer of coarse gravel on the top of the soil. The field access areas should be grassed, using a robust grass species. (Source: TOPPS)
Benefits and limitations of use	Environmental benefits: reduction of the linear runoff and reduction of surface water pollution by Plant Protection Products or fertilizers. Economic benefit: Field access is more optimized for modern machinery.
Costs of application	Cost to fortify the access areas.

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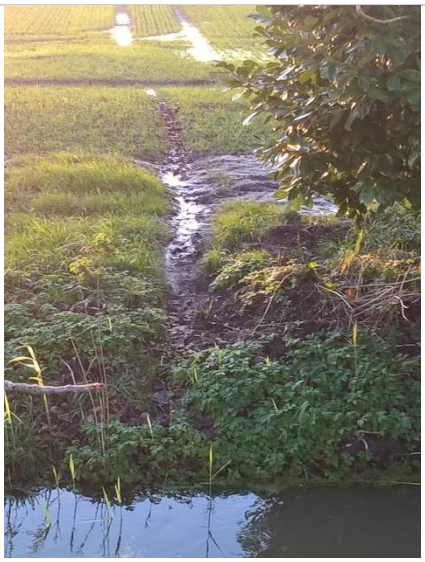
54. Avoid accelerated run-off of water and PPP by tramlines or short cuts		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Runoff
Type of pollutant combated by the measure:		Nitrogen, phosphorus, pesticides
Description	Tramlines are crop-free areas in the field, where the tractor drives to spray and to fertilize the crop. If the tramlines are oriented in the direction of the slope they work like channels for run-off water and soil erosion. If possible, orient the tramlines with the contour lines instead of in the direction of the slope and reoriented them after each cropping season if possible. However, sometimes this is difficult if there is more than one slope direction in the field or slope creates a risk for machinery overturns. (Source: TOPPS) Shortcuts to drain water from the field after heavy rainfall are direct channels for water polluted with Plant Protection Products (PPP) and/or fertilizers. They must be avoid.	 *Figure 19: Short cut for drainage of excess water on field [E. Dupon]*
Benefits and limitations of use	Different environmental benefits for this agricultural best management practice: - Improvement of water retention in the field - Reduction of run-off and thereby reduction of surface water pollution by Plant Protection Products (PPP) and fertilizers. Limitation of use of best management practice: Short cuts sometimes can't be prevented especially after heavy rainfall when the excess water can cause damage to the crops.	
Costs of application	No additional cost.	

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55. Establish retention structures (fascines, edge of the field bunds, vegetative ditches,…)	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Runoff
Type of pollutant combated by the measure:	Nitrogen, phosphorus, pesticides
Description	Retention and dispersion structures are constructed in the catchment to mitigate concentrated flow runoff. If mitigation of runoff at source is unlikely to be achieved, the construction of retention structures may be an option to keep the water in the catchment. Possible retention structures are vegetative ditches, edge-of-field bunds and dispersive constructions. Before establishing retention structures, recommendations of location and sizing need to be based on a thorough diagnosis. Vegetative ditches are retention structures that are created in the catchment to protect downstream areas by retaining runoff water and sediments, as well as water discharged from artificially drained areas. These vegetative ditches must be disconnected from the surface water (ditch with dead ends). Edge of field bunding is a small embankment or dam of soil at the lower edges of the field to keep runoff and erosion in the field. Essentially, bunding works by halting the movement of runoff and its sediment load, which enables runoff to infiltrate and eroded soil to deposit. Bunding is also used as a critical component in rice paddy systems for water and soil management. Dispersive constructions include fascines and mini-dams. They are artificial structures of logs/branches/stones that are erected in catchments to disperse concentrated surface runoff in catchments. Fascines limit erosion and capture sand and silt transported in runoff water. (Source: TOPPS)
Benefits and limitations of use	Environmental benefits: retention structures prevent run-off of Plant Protection Products and fertilizers and thus pollution of the surface water. Limitations of use: - Check the local recommendations or authorities if retention structures do not interfere with other legislation (f.e. protection of ecosystems/habitats etc.) - Dispersive constructions may be labour-intensive and need considerable investment to build and to maintain them. In some countries, subventions are available for the establishment of retentions structures. Check with your local authorities.
Costs of application	Cost of application depends on the type of retention structure.

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56. Optimize irrigation timing and rate	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Runoff
Type of pollutant combated by the measure:	Nitrogen, phosphorus, pesticides
Description	Key to reduce the risk of runoff is the correct irrigation management considering soil water content, soil water holding capacity and crop requirements in relation to evapotranspiration. Most important is to monitor, estimate and manage the correct amount of water needed by the crop. Key indicators are soil moisture content, soil moisture tension and consideration of possible rainfalls forecasted. There are IT-based decision support systems available for planning of irrigation. If less controllable systems (flood irrigation) are used, furrow irrigation may help to save water and to reduce runoff. Such practice may also be helpful to infiltrate more water in case of rainfalls. (Source: TOPPS)
Benefits and limitations of use	The economic and environmental benefits : optimal use of irrigation water will safe costs and prevents Plant Protection Products and fertilizers runoff.
Costs of application	No costs on this application.

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57. Professional support in selection of appropriate PPP	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point sources pollution, spray drift, runoff
Type of pollutant combated by the measure:	Nutrients, pesticides
Description	Important element in making decisions about the necessity of performing arochemical treatment is systematic survey of plantation. It is aimed to determine presence and type of threats, such as pest infestations, occurrence of diseases or weeds, and finally, selection of appropriate plant protection products for their elimination. In case of difficulties in this area, it is necessary to immediately contact and consult with an advisor from Agricultural Advisory Center. Decision support system, intended for producers or advisors, contain a series of helpful instructions to facilitate the decision-making process. The components of this system are plant protection products database and pests database, agrotechnical factors, field history, weather information in the form of meteorological data monitoring or weather forecasting, the current situation on the plantation and environmental factors. The end result are specific recommendations regarding treatments and plant protection products.
Benefits and limitations of use	Currently, modern agriculture requires the use of various chemical plant protection products, including herbicides, insecticides and fungicides. Their proper selection for specific cultivation and natural conditions brings a number of benefits, such as increases the amount and quality of crops, limiting the amount of weeds, pests and fungal diseases, which significantly reduce the cost of cultivation. Therefore, professional support in selection of PPP is economically justified.
Costs of application	The activity does not require any additional costs.

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59. Use of Global Positioning System (GPS) to manage inter field variability in crops	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff, subsurface flow
Type of pollutant combated by the measure:	Nutrients
Description	The idea of precision fertilization is based on observing, measuring and responding to the *field variability in crops.* In all fertilizer applications, the use of Global Positioning System to determine the current location of equipment on the earth's surface can improve the possibilities for control and proper distribution of manure. GPS combined with steering systems means that a fertilizer can be spread with a minimum of bare spots and overlaps. Precise nitrogen fertilization is based on sensing of growing plants to determine nitrogen requirements. It involves the application of a variable nitrogen rate, varying depending on the degree of plant nutrition. While driving the tractor, a sensor scans the plant cover and measures the light reflected from the crop canopies. That allows to measure crop nitrogen requirement as the spreader passes across the field and variably adjusts the fertilizer application rate.
Benefits and limitations of use	The GPS system is used to collect samples, apply fertilizers and register vehicle location on the field. The implementation of the precision fertilization system allows for significant reduction of fertilizer consumption, increase the efficiency of fertilizer use by plants, reduction the risk of nitrogen and phosphorus losses and improve the profitability of fertilization. Use of the precision fertilization system on a farm allows for adjusting the rate of nutrients delivered to the soil, which reduces the purchase costs of fertilizers and gives better yields than in traditional agriculture.
Costs of application	The cost of precision agriculture per one hectare decreases with the growth of the farm, because a large share in the overall implementation of the system is due to the costs of a single purchase of specialized equipment.

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60. Use Decision Supporting Systems or Forecasting Systems	
Type of protected water:	Surface water, groundwater
Type of risk mitigated by the measure:	Nutrients and PPP runoff, subsurface flow
Type of pollutant combated by the measure:	Nutrients, pesticides
Description	Weather and climate are the main drivers of variability in agricultural production. Extreme weather events, such as droughts or heavy rains, whose frequency and intensity are constantly increasing, can have serious consequences for crops around the world. Currently, crop monitoring and forecasting systems have become an important element of decision supporting systems in agriculture, enabling optimization of production. Thanks to such systems it is possible to adjust the dates of sowing, fertilization or agrochemical treatments to meteorological conditions. The timing of chemical fertilizer and manure application is a key factor in achieving high efficiency of nutrient use. Fertilizers should not be applied in times and conditions when the mineral nutrients, especially nitrogen, are vulnerable to leaching to groundwater or to runoff to surface water. This applies especially to the winter period but also to other periods, depending on soil type, rainfall intensity or wind. Plant Protection Products should be applied in an optimal temperature. Inadequate temperature can cause reduced absorption of the pesticide by plants, and as a result its elution. Also important are air and soil humidity, rainfall before and after the treatment, and wind strength. The use of DSS in irrigation management could improve the efficiency of irrigation systems and contribute to the preservation of water resources. To be able to make the best use of the water it is necessary to know the moments in which the crop has the most need of this element and to irrigate if the environmental conditions do not allow the right supply.
Benefits and limitations of use	Adaptation of agrochemical treatments, fertilization or sowing to meteorological conditions is a key factor in achieving high efficiency of the use of fertilizer components and PPP by plants.This ultimately affects the amount and quality of yield and, indirectly, the economic and ecological efficiency of farm product. Advantage of good irrigation management are less compaction and an optimal relationship between water and air in the soil, less percolation of water and nutrients in depth and prevention of runoff, which may cause pollution.
Costs of application	Currently, there are many models, websites or applications that provide agrometeorological data available for free.

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61. Manure storage with tank	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	concentrated runoff
Type of pollutant combated by the measure:	Nutrients
Description	The storage of liquids is used by many larger dairy farms or pigs. Liquid manure and slurry should be stored in an environmentally safe manner, preventing leachates from entering the ground and water. Farmers must ensure the possibility of environmentally safe storage of natural fertilizers. This requires providing adequate capacity of sealed areas. Liquid manure storage volume size depends on the amount of time in a year that is not available for land application (at least 6 months) or other manure utilization strategies. Land application time depends on growing season of the target crops and local weather. Liquid manure on farms is typically stored in one of the following types of structures: • deep pits under the building floor housing the animals, • outside below ground earthen pits or concrete storages, • outside above ground tank storages, • treatment lagoons, • holding ponds. Storage of fertilizer in the tank made of impermeable material provides protection against leaks to water and soil. It also allows, due to the smaller surface in relation to the lagoon, to cover the stored liquid.
Benefits and limitations of use	During storage, biological activity occurs in the manure. The release of gases has environmental consequences, associated with odour as well as loss of nutrients, which causes a decrease in the nutrient content of the fertilizer. Cover of storage facilities for manure in order to be protected from rain or other precipitation and be able to reduce nutrient loss is a good practice.
Costs of application	The cost of building a tank made of impermeable material with depends on the capacity needed, but it is rather high

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62. Spreading slurry in early growing season to maximize crop uptake		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Nutrients runoff, subsurface flow
Type of pollutant combated by the measure:		Nutrients
Description	In terms of absorption of nutrients, the properties of liquid natural fertilizers, including slurry, are very similar to mineral fertilizers. Therefore, it is justified to use them shortly before sowing or in the early vegetation period. This increases the efficiency of the absorption of nutrients by plants and at the same time limits the possibility of their dissipation into the environment. In the early vegetation period of plants it is not possible to incorporate slurry with soil and therefore acceptable ways of its application are limited only to the use of the method of hoses (acceptable but not recommended) or for direct soil injection (preferred method).	 *Figure 20: Application of slurry in early growing season. source: [Zabost 2017]*
Benefits and limitations of use	The use of slurry in the early vegetation period using soil application techniques is the most effective way to use liquid manure in crop production. The nutrients contained in the slurry go directly to the root zone of crop plants, which means that their use in the case of nitrogen can reach up to 90%. This ultimately translates into an improvement in the economic efficiency of the farm as well as significantly reduces the leaching of nitrogen and phosphorus to water resources. Significant restrictions in the application of the proposed method are mainly related to the farm's technical capabilities.	
Costs of application	This activity does not generate any additional costs (if we assume that equipment for the application of liquid manure is available on the farm).	

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63. Estimation of nutrient content of organic manures (hydrometer for slurry)	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff, subsurface flow
Type of pollutant combated by the measure:	Nutrients
Description	Natural fertilizers such as solid manure and slurry are a rich source of nutrients for plants. However, if used improperly, they pose a great threat to the environment, especially to local water resources [Pietrzak 2013]. The chemical composition of natural fertilizers is variable and depends on many factors, including the type of animals, their age, maintenance system and the method of storage of fertilizers. The content of nutrients can be accessed on the basis of appropriate results of chemical analyzes carried out in agrochemical laboratories. Another method of estimating their fertilizer potential is a hydrometer method for slurry. The hydrometer method was created to indirectly measure the nutrient contents, i.e. total nitrogen N, and total phosphorus. Estimation of nutrient contents in slurry to determine safe and effective application rates is the part of agricultural management. The basis of this method is that there is a correlation between the total solids contents and nutrient elements in slurry. Using a hydrometer to measure the specific gravity of slurry and relate it to the nutrient contents in the slurry is one of the simplest methods.
Benefits and limitations of use	In accordance with the current legal regulations, including the Nitrate Directive, to rationally use natural fertilizers on the farm, it is necessary to know about the content of basic nutrients. This will allow the use of optimal and acceptable doses of these fertilizers, adapted to the current soil abundance and nutritional requirements of arable crops. The permissible nitrogen dose from natural fertilizers may not exceed 170 kg N / ha. Also, when using high-frequency natural fertilizers, particular attention should be paid to the abundance of soils in phosphorus, which excessive accumulation may pose a threat to the aquatic environment.
Costs of application	The activity includes the costs of chemical analyzes in the laboratory. The purchase price of the hydrometer is small, around a dozen or so euros.

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64. Soil analysis for pH, nutrients or organic matter	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nutrients runoff, subsurface flow
Type of pollutant combated by the measure:	Nutrients
Description	Proper soil fertility, pH and soil organic matter content are of great importance for crop production and environment. Excess nutrients may run-off or leach through the soil to enter waterways, contributing groundwater and surface water pollution. It is important to keep soil fertility at optimum level. Research on the content of available forms of phosphorus, magnesium and potassium should be ordered at 4-6-year intervals. Nitrogen should be tested annually in early spring. Plant nutrients become available or unavailable according to the soil's pH level. A soil pH of 5,0 to 7,0 provides optimum conditions for most agricultural plants. The soil pH test should be carried out regularly every 4-6 years. Soil organic matter improves soil structure and thereby water- holding capacity. The accumulation of soil organic matter is favored by the use of natural and organic fertilizers or plowing of straw. Conservation tillage and regular liming favor the preservation of organic matter.
Benefits and limitations of use	The deficiency of one of the components limits plant growth, even if other components are present in sufficient quantities. With the excess of nutrients, risk of nutrients loss increases, which is also disadvantageous from an economic point of view. Soil pH has indirect yet far-reaching effects on plants. Under conditions of unregulated soil pH, especially acidification, productivity of agricultural lands is reduced. This leads to a reduction in yields and poses a risk of nutrients loss, including nitrates. To reduce the risk of losses and maintain optimum fertility of arable soils, they should be periodically limed. Organic matter has a positive effect on soils. Soil structure improves, water capacity and mineral content increase. Organic matter also protects soil from erosion.
Costs of application	The cost of soil analysis vary depending on the component being tested, as well as on the size of area under cultivation.

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65. Vegetated Filter Strip (VFS) at edge of the field	
Type of protected water:	surface water
Type of risk mitigated by the measure:	runoff and erosion
Type of pollutant combated by the measure:	Pesticides, nutrients
Description	VFS are vegetated surfaces designed to protect receiving water bodies from sediments, pesticides, and nutrients that are transported from adjacent agricultural surfaces (Source: Munoz-Carpena & Parsons, 2004[1]). Are designed to intercept the transfer path of water run-off and sediment. These are densely vegetated strips of land, often located at the downslope field border. The VFS acts as a physical impediment to surface runoff, reducing the kinetic energy of the flowing water and reducing passage of water, sediment and diffuse pollutants across the strip through infiltration of water and trapping of sediment. VFS are a readily accessible measure for farmers which are cheap to install and maintain The effectiveness of VFSs in terms of run-off and sediment trapping vary greatly in the field and mainly depends on the vegetation and the width. The correct positioning of the buffer in the landscape is usually more important than its width for its effectiveness to reduce runoff. (Source: Colin Brown et al, 2012[2])
Benefits and limitations of use	Depending on the width of the strip and vegetation, a well designed VFS could lead to the reduction in pesticide concentrations in surface water from 40% for a minimum width of 5 meters VFS, 65% for 10 meters VFS and 80% for 20 meters VFS (Source MAGPie: proposals for average effectiveness derived from available literature data and experts judgment)
Costs of Application	Generally VFS are a readily accessible measure for farmers which are cheap to install but need manteinance and care to assure their effectiveness.

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66. In Field Vegetative Filter Strips (VFS) as talwegs	
Type of protected water:	surface water
Type of risk mitigated by the measure:	concentrated runoff
Type of pollutant combated by the measure:	Pesticides
Description	Run off could tends to concentrate into discrete flow channels due to converging water flow in the larger landscape, following so-called talwegs (or waterways) downslope. Concentrated flow is one of the main reasons for cases of low effectiveness of vegetated buffer strips under field conditions. Any concentrated runoff and erosion channels in-fields effectively extend the river and stream network into agricultural fields and are potentially the greatest cause of adverse diffuse pollution of surface water by pesticides (Source: MAGPie)
Benefits and limitations of use	Grassed waterways in talwegs reduces levels of pesticide in surface water.
Costs of application	Not quantifiable. Necessity of a local diagnosis.

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67 Inter-row processing and weeding on the row 68 Permanent grassing in the inter row and weeding on the row	
Type of protected water:	surface water
Type of risk mitigated by the measure:	runoff
Type of pollutant combated by the measure:	Pesticides
Description	Weed control is an important practice in vineyard management Inter-row processing and weeding on the row and Permanent grassing in the inter row are management techniques leading to reduce the amount of pesticide, favour the presence of beneficial insect and soil improvement. In hilly vineyard this management techniques favour the slowing of water flow with the reduction of runoff.
Benefits and limitations of use	Reduction of pesticide used for weeding treatment.
Costs of application	Not quantifiable.

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69. Anti-hail net	
Type of protected water:	surface water
Type of risk mitigated by the measure:	spray drift
Type of pollutant combated by the measure:	Pesticides
Description	Anti-hail nets offers an optimal defence against frost and showers of hail. Are not designed for pest management purposes, otherwise their use could lead to a reduction and control of spray drift. In this case the net act as a barrier.  *Figure 21: Photo by International Centre of Pesticide (ICPS) Drift Mitigation measure*
Benefits and limitations of use	The net hinders the dispersion of the drops and allows to reduce the drift by 50-95% depending on the type of atomizer and the operating conditions. Could changes the amount and quality of the light supplied to the crops (Source: Commissione Consultiva Fitofamaci, 2017).
Costs of application	Netting involves very high capital cost.

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71. Directing manure towards special ponds/containers (for sedimentation of organic substances for extraction of nutrients)	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nitrates leaching and runoff
Type of pollutant combated by the measure:	Nutrients
Description	No storage facilities are to be constructed in following locations/conditions: • in areas with flood risk and in areas with ground water abundance of less than 2 m; • less than 100 m away from the water protection area; • at a distance of less than 5 m from the water banks (for water courses with a width of less than 10 m); • less than 50 m away from drinking water sources (wells, springs); • less than 100 m from the water courses; • less than 250 m of water wells. Traditional households produce small amounts of manure that can be stored and composting alongside household waste in mini-containers. This container type has a reduced capacity of 1m ^{3} (or less). The number of containers may be increased as required.
Benefits and limitations of use	**Benefits:** • quick and easy construction; • cheap and locally available materials; • are aesthetic and can be designed according to the preferences of the owner; • reduces the risk of organic water bodies; • good for sedimentation of organic substances; **Limitations:** • reduced capacity (about 1m^3); • unpleasant odor; • discomfort, stinging insects and vectors of pathogens; • pollution risk; • difficult public oversight; • requires frequent repairings.
Costs of application	The type of storage can be tailored to individual needs and possibilities.

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72. Temporary depositing of organic manure on the agricultural field	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nitrates leaching and runoff
Type of pollutant combated by the measure:	Nutrients
Description	Solid manures should be stored in an environmentally safe way, preventing leachates from entering the water and soil. The surface of storage places for natural fertilizers should allow their storage for a period of several months when the manure cannot be applied to the field. It is possible to store the manure in temporary field heaps if they are solid enough to be stacked in a freestanding heap and not give rise to free drainage from within the stacked material. It is necessary to keep distance from any surface water (such as a river, pond or ditch) and slopes. Move the field heap at least every 12 months and leave at least a two years gap before returning to the same site (unless otherwise provided by local low). Identify the location of field sites on the map. It is not allowed to store a poultry litter directly on the ground.
Benefits and limitations of use	When fertilizers are stored directly on the ground, excessive amounts of nutrients get into the soil. The high concentration of compounds, instead of favorably affecting the growth and development of plants, can cause the death of plants. In addition, manure storage directly on the ground is uneconomically for farmers, because of occurring nutrient losses.
Costs of application	If the farm does not have adequate storage space for manure, it is necessary to pay the cost of building a manure pad - from several dozen to several hundred euros per square meter.

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73. Precaution measures (solid manure distance from rivers, well etc deposited on field) for preventing pollution of water	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Nitrates leaching and runoff
Type of pollutant combated by the measure:	Nutrients
Description	There are several major reasons for depositing manure: • Prevention of pollution of water and soil; • Prevention of loss of nutrients, a loss that causes higher costs for farmers in land use; • Compliance with agri-environmental measures. According to legislation special measures for depositing and application of organic fertilizers are imposed on the land near watercourses, lakes, drinking water points because they are at risk of nitrate pollution (and in some cases with phosphates) transported with drainage and surface leakage. No manure depositing is to be placed in: • areas with flood risk and in areas with ground water that are less than 2 m depth; • at a distance of less than 100 m away from the water protection area; • at a distance of less than 5 m from the water banks (for water courses with a width of less than 10 m); • at a distance of less than 50 m away from drinking water sources (wells, springs); • at a distance of less than 100 m from the water courses; • at a distance of less than 250 m distance from water forages/wells designed for drinking water.
Benefits and limitations of use	**Benefits:** • no risk of contamination of water resources with organic pollutants; • easy to plan and apply if land conformation is known; • useful in case no space for depositing of manure in the proximity of the household. **Limitation:** • manure can not be stored on temporary basis for more than one year, being stored in each year in different locations; • will only be stored on the land on which it will be scattered
Costs of application	Theoretically there are no costs associatied to the implementation of this best management measure. A good knowledge of the field and good planning ensures success and no contamination of water resources.

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74. Use of impermeable foil under the pile of solid manure deposited on field		
Type of protected water:		Groundwater, surface water
Type of risk mitigated by the measure:		Nitrates leaching and runoff
Type of pollutant combated by the measure:		Nutrients
Description	A direct threat to the quality of the environment and public health is the improper management of manure from livestock in individual households. Thus, the risk of nitrogen loss in the form of nitrates via surface spills (percolation of water) occurs. As a result, a diffuse environmental pollution may occur in the area. In order to comply with the national and European rules related to manure management and in accordance with the principles of sustainable development, it is recommended that to store the manure piles on plastic, impermeable folia.	 *Figure 22: Temporary depositing of manure on plastic folia*
Benefits and limitations of use	**Benefits:** • The most simple and cheapest method of storing and composting manure; • Provides superior protection against leakage of nutrients; • Represents an efficient solution for the management of manure in an individual system; • Allows handling of manure when there are no optimal storage platforms; • Can be applied in farms / households where no other method is applied due to economic and technical reasons. **Limitation:** • The degree of protection depends on the quality of the folia; • Temporary storage method; • Plastic materials are fragile and will deteriorate over time; • Only small quantities of manure may be stored; • Cannot be applied to floodplains.	
Costs of application	Impermeable foil has a rather low cost. Good quality sheets, which offer better protection and longer lifespan, are relatively more costly.	

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75. Alternatives systems to chemical fights to pest control	
Type of protected water:	Groundwater and surface water
Type of risk mitigated by the measure:	Point source pollution, spray drift, runoff
Type of pollutant combated by the measure:	Pesticides
Description	The use of alternative systems to the chemical struggle to pest control and weeds is considered a strategy to be followed to reduce the PPP use: • Biological pest control: massive capture traps and sexual confusion traps. • Useful fauna Introduction: predators and / or parasites against ages, trips, white flies, miners and lepidoptera • Promote the presence of useful fauna by means of the maintenance and / or implantation of margins with reservoirs of auxiliary fauna. Ex. Calendula officinalis and lobularia maritima (Alyssun maritimun) • Promote the presence of beneficial species for the pest control such as rats and insectivorous birds, providing shelter sites with the installation of nest boxes. • Solarization and biofumigation for the control of nematodes and fungal phytopathogens of the earth. • Tools for mechanical tearing in fruit trees and orchard, such as the fingers, coupled to the tractor and the motocultor. • Crops Rotation.
Benefits and limitations of use	The objective and therefore the benefit, is the reduction of the application of chemical products throw the promotion of the application of alternative systems to the chemical fight against pests and illnesses in crops and fruit trees. The limitation is the difficulty in changing the work habits of farmers in the management of their crops and in the change of management strategy of their exploitation. ADVs (farmer advisers) play an important role as they give this necessary support for the implementation of these new strategies.
Costs of application	The Department of Agriculture in Spain has a subsidy for the promotion of some of these agricultural practices. Farmers can access it at same time they register their Farming Declaration (DUN). The amount of the grants will vary depending on the method they wish to implement. For example : a) in horticultural crops • Contribution of useful fauna: predators and / or parasitops against thighs, trips, whitefly, miners and lepidoptera: € 400 / ha • Solarization for the control of nematodes and terrestrial phytopathogenic fungi: € 150 / ha • Implantation of margins with auxiliary fauna reservoir plants: € 515 / ha b) Cherry trees • Massive capture against Drosophila suzuki: € 121 / ha

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77. Energy crops	
Type of protected water:	Groundwater
Type of risk mitigated by the measure:	Runoff, nitrates leaching
Type of pollutant combated by the measure:	Nitrates
Description	Energy crops are introduced mainly for environmental reasons to reduce greenhouse gas emissions. Another important aspect of growing energy crops is the loss of nutrients from the production systems to the environment. Energy crops with significantly lower nutrient losses than conventional agricultural crops can be used to protect drinking water supplies as a riparian buffer strips. Perennial crops are usually efficient at taking up nitrate due to their long growing season, the permanent and deep root system and the absence of tillage. As a result, nitrate leaching is limited. Additionally, the permanent soil cover in perennial crops can reduce surface run-off of soil, nutrients and organic material.
Benefits and limitations of use	It is important to efficiently use nutrients in the production of energy crops. The high content of nutrients in energy crops is a negative quality parameter in the combustion process because they increase the quantity of ash, reduces the biomass energy content and can cause harmful emissions, e.g. NOx. In some cases, it is possible to cultivate energy crops with a low nutrient use efficiency value.
Costs of application	The costs of introducing energy crops on the farm are associated with exclusion of lands from direct agricultural production.

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78. Set-aside	
Type of protected water:	Groundwater
Type of risk mitigated by the measure:	Runoff, nitrates leaching
Type of pollutant combated by the measure:	Nitrates
Description	Set-Aside Land Option was introduced as part of the Common Agricultural Policy in the countries of the European Union. The main reason to create the new agricultural policy of the EU was surplus in agricultural production. However, the set-aside process may have a positive impact on agroecosystems, including improving soil conditions and increasing biodiversity in areas of intensive agriculture. It should also be emphasized that land set-aside programs contribute to a significant reduction of emissions of diffuse pollution originating from agricultural lands (mainly nitrogen and phosphorus compounds). Increasing the area of set-aside land in agricultural catchments may contribute to the reduction of nitrate content in rivers.
Benefits and limitations of use	Set-aside has a positive effect on the soil, surface water and physicochemical processes occurring in the environment, such as: • reduction of soil erosion; • improvement of soil properties; • increase of biological activity and amount of organic matter soils; • improvement of water and air properties of soils; • limitation elution of elements (nitrogen and phosphorus) responsible for water eutrophication Increasing the area of set-aside land in agricultural catchments may contribute to the reduction of nitrate content in rivers.
Costs of application	The costs of set-aside on the farm are associated with exclusion of lands from direct agricultural production.

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79. Afforestation	
Type of protected water:	Groundwater
Type of risk mitigated by the measure:	Runoff, nitrates leaching
Type of pollutant combated by the measure:	Nutrients
Description	The forests have an important function in increasing of biological diversity and the ecological cycles, in particular those of nutrients, water and carbon. Several of the environmental advantages are associated with forest cover, for instance groundwater protection and carbon sequestration. In Denmark afforestation of agricultural land is part of a strategy to improve water quality.
Benefits and limitations of use	Forest cover is the most effective way to protect soil from water and wind erosion. Moreover, afforestation of former arable land contributes to lower nitrate leaching than during the use of this land for agricultural production. Therefore, the nitrite concentration in water is reduced below the value for groundwater to be utilized as drinking water. The relatively extensive management regimes in the forests as compared to agriculture, with limited use of fertilisers and pesticides, also means that they protect groundwater reserves.
Costs of application	Danish National Forest Programme provides economic incentives aiming at management regime changes.

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81. Use anti-drip devices to prevent dripping of the nozzles	
Type of protected water:	Groundwater, surface water
Type of risk mitigated by the measure:	Point sources pollution
Type of pollutant combated by the measure:	Pesticides
Description	With anti-drip devices on the nozzles, loss of spray liquid from the spray boom and dripping after spraying will be prevented after closing the main valve or the section valves. Depending on the size of the sprayer, 5 to 15 litres of spraying solution could easily be lost without anti-drip devices on the nozzles.
Benefits and limitations of use	By using an anti-drip system, you avoid a local over dose of the spraying sollution on the crop and significant spillage into the environment.
Costs of application	In Belgium, cost of that system includes cost of new set of nozzle holders, which varies from 40 till 60 EUR per nozzle holder, depending on the number of nozzles that it can hold (f.e. 1 nozzle: 40 EUR; 3 nozzles on one nozzle holder: 60EUR).

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5 Summary

Task 4.1 *Identification of available innovative mitigation measures and Best Management practices (type, applicability, costs)* was focused on a review of available mitigation measures and BMPs that combat water pollution resulting from leakage of nitrogen, phosphorus and plant protection products used in agricultural practices.

The review was based on previous EU funded projects, specifically TOPPS projects (TOPPS-life project, TOPPS prowadis and TOPPS water protection), the MAGPIE and the Baltic COMPASS projects.

Overall 77 measures have been identified and described in a structured way, with a special focus on their bottlenecks and strengths. Where it was possible, analysis of costs was also provided. The main criterion for selection of BMPs was relatively low cost of application. Many of these measures are well known in EU countries but are not fully implemented.

While some of measures can provide solution for a wide range of pollution problems, such as grass buffer zones or constructed wetland, other are more problem specific such as phytase supplementation or urease inhibitor. Within 77 measures selected within this project, some BMPs are related to nutrients, while others concern pesticides. There are also practices that can be implemented to prevent pesticides pollution as well as nutrient losses. Measures that reduce water pollution of PPPs include BMPs that can reduce pollution from either point sources, drift, runoff or erosion. Often reduction of water pollution can be obtained by changes in behaviour of operators, which can usually be applied cheaply. Other BMPs require new or improved technology or infrastructure, which is more expensive.

Dissemination and practical implementation of knowledge gathered in this report can significantly reduce pesticides pollution, as well as nitrogen and phosphorus losses generated by agriculture.

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