FAIRWAY REPORT series

Recommendations of the most promising package(s) of measures, policies, governance models and tools at national and EU level

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www.fairway-project.eu

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SUMMARY

The aim of Task 7.3 is to provide recommendations of the most promising package(s) of measures, policies, governance models and tools at national and EU level using the results of WP2-WP6 and assessments with integrated assessment tools at national and EU level, such as MITERRA-EUROPE and GeoPEARL.

An assessment of the main key messages of the FAIRWAY project was made, including the origin (work package or case study), the exchange of information between work packages and case studies, and the target audience. The main key messages of FAIRWAY are:

- Multi-actor platforms are valuable in building networks and creating a common understanding about complex issues in the agriculture-water governance interface. While they are important for setting joint strategies, they might not be sufficient to achieve desired impacts.
- During all phases of Water Safety Planning, engagement of stakeholders in the development of the methodology and content is essential. Establishing cooperation between large and small suppliers contributes to overcoming barriers for effective risk assessment and management for small suppliers.
- Water and nitrate transfer through geological material is not instantaneous. There is a lag time between agricultural nitrogen leaching from the fields and its impact on water quality in aquifers. This time lag should be taken into account when developing drinking water projection strategies.
- Nitrogen surplus at the farm or regional level is a useful agri-environmental indicator. However, because Member States apply different calculation methods, comparisons at the European level are ambiguous.
- Monitoring groundwater quality, detecting pollution sources and evaluating mitigation measures are necessary topics to ensure sustainable drinking water supply for citizens. For this purpose, it is necessary to rely on a consistent database, which enables scientists to link pollution and mitigation measures to water quality.
- Implementation of measures to reduce nitrate losses should not only consider the effectiveness, and costs, but also the likelihood of (unwanted) side-effects such as pollution swapping to emissions of ammonia, nitrous oxide and phosphate.
- For measures to reduce nitrate losses, there is a discrepancy between the type of field- or trial-based measures tested and reported in literature and real-world farm-level management options that are used or reported in the case studies.
- Reduction of pesticide pollution of drinking water resources demands a combination of input reduction, farm system redesign and point source mitigation.
- Decision support tools are helpful in advising farmers about best practices in the application of fertilizers and pesticides, in order to both optimize crop yield and prevent water pollution problems.
- Many farm management tools promoting smart nutrient and/or pesticide use are available, but only a few explicitly consider the impact of mitigation methods on water quality.
- Although most EU countries already have comparable decision support tools, designed to address similar problems, there are obstacles to exchanging the tools between countries.
- Good drinking water quality delivery requires sufficient capacity at the local level to ensure that implementation of policies and law results in effective local action. This includes feedback mechanisms and intersectoral learning.
- Improving correlations between directives, policies, objectives and requirements, including cross-referencing them, will strengthen the overall policy framework towards protection of drinking water resources from agricultural pressures.

- Economic pressures in agriculture severely limits farmers' room to maneuver. The effect of local optimization processes is only a fraction of what can be achieved with more structural policy choices that reduce inputs and pressures at their source.
- Barriers to protection of water quality in the EU are mostly observed at the national or regional levels and relate to lack of political will, and scarce instruction on the process of legislation implementation. Project clustering is a strategy to make science more connected to policy challenges and stakeholder needs.
- There are potential synergies for evidence-based practices for reducing nitrate and pesticide pollution of drinking water resources, regarding their applicability, adoptability, and costs across EU.

The main conclusions of the assessments of most promising nitrate measures using MITERRA-EUROPE are:

- Balanced N fertilization in which the N application is adapted to the N demand of the crop is a promising measure to reduce nitrate leaching to groundwater and gaseous nitrogen (N) emission to the atmosphere. A scenario calculation indicate that balanced N fertilization can reduce nitrate leaching to groundwater on EU scale with 22%, N surface runoff with 8%, and N leaching to surface water with 81% (based on data of 2016). Balanced N fertilization also reduces the emissions of N_2O (5%) and NH_3 (3%).
- Cover crops are already grown in many regions in EU, and especially in Denmark, the Netherlands, Flanders and parts of Germany and France. If it is assumed that no cover crop was grown in 2016, the nitrate leaching to groundwater and N leaching to surface water would have been 2-4 percent higher in EU level.
- Increasing the area of cover crops to 40% of the technical potential in EU reduce N leaching to ground and surface water with 2 – 4%. Implementation of cover crops to 80% of the technical potential reduce N leaching (4 – 8%).
- Application of balanced N fertilization in combination with cover crops (at 40% implementation) can strongly reduce N leaching; on EU level up to 36% for nitrate leaching in combination with balanced N fertilization.
- Reduction of more than 20% in N leaching and runoff by implementation of a combination of cover crops and balanced N fertilization can be achieved in many areas in EU, including Flanders/Belgium, the Netherlands, parts of Germany, the northern parts of Spain and Portugal, the northern part of Italy, regions in Poland, Czech republic, Croatia, Bulgaria, and Greece.
- The reduction of the combination of N balanced fertilization and the growth of a cover crop on N leaching is larger than the sum of the single effects of both measures. This is due to the fact that N fertilizer input can be reduced because N from incorporated cover crop is released by mineralization.
- Cover crops increase N_2O emission. However, when the growth of a cover crop is combined with balanced N fertilization, emission of N_2O is reduced. The risk on pollution swapping can be reduced if a combination of measures is taken.

The results of an assessment of measures to decrease pesticide leaching in the Netherlands using the model GEOPEARL shows that the risks of leaching of pesticides strongly depend on the sorption and degradation characteristics, but the values for these parameters mentioned in literature differ largely. This emphasizes the importance of field studies to underpin these characteristics and thus the permission of pesticides. The following recommendations on most promising measures can be derived from the results of GeoPearl calculations:

- Decrease input of pesticides is an efffective measure to protect drinking water resources; decreasing the amount of applied pesticides with 50% reduces the concentration of pesticides in groundwater with more than 50% in the simulations.

- Consider the application time; an autumn application has a higher leaching risk than a spring application.
- Substitution of pesticide with a comperatively high risk of leaching to groundwater by another pesticide with similar efficacy but with a lower leaching risk.

Based on the key messages presented in Chapter 2 and the Appendices and the assessments on EU and National scale, the following main recommendations of the FAIRWAY project are derived.

Multi-actor platforms

- Engagement processes in multi-actor platforms require long-term investments in terms of time, resources, and facilitation. This realization should be acknowledged by project partners and funders, as well as participants, to enable management of expectations and contribution of all parties, and to avoid fatigue in the engagement processes.

Water safety plans

- During all phases of Water Safety Planning, engagement of stakeholders in the development of the methodology and content is essential. Establishing cooperation between large and small suppliers contributes to overcoming barriers for effective risk assessment and management for small suppliers.

Indicators and monitoring

- Water and nitrate transfer through geological material is not instantaneous. There is a lag time between agricultural nitrogen leaching from the fields and its impact on water quality in aquifers. This time lag should be taken into account when developing drinking water projection strategies.
- Nitrogen surplus at the farm or regional level is a useful agri-environmental indicator. However, different calculation methods are used between countries. There is a need for harmonization of the calculation method (e.g. the Eurostat gross balance methodology) and of the use of such a common approach at the European level.
- For monitoring groundwater quality, detecting pollution sources and evaluating mitigation measures it is necessary to rely on a consistent database, which enables scientists to link pollution and mitigation measures to water quality. A lot of data with relevant indicators is available on different spatial and temporal scales, but they are seldom presented in consistent databases with similar set-up. There is a need to harmonize databases in the EU member states and ease the transmission of data to compare Pressure and State indicators. There is also a need to harmonise the methods for analysing all relevant substances and to ease collection of direct or indirect data. There is also a need to solve or at least improve personal data protection related constraints.

Measures

- Implementation of measures to reduce nitrate losses should not only consider the effectiveness, and costs, but also the likelihood of (unwanted) side-effects such as pollution swapping to emissions of ammonia, nitrous oxide and phosphate.
- For measures to reduce nitrate losses, there is a discrepancy between the type of field- or trial-based measures tested and reported in literature and real-world farm-level management options that are used or reported in the case studies. Developing strategies to mitigate nitrate leaching should not be solely based on results in literature, but should also take successful experiences in practice into account.
- Reduction of pesticide pollution of drinking water resources demands a combination of input reduction, farm system redesign and point source mitigation.

- Results of the assessments of most promising nitrate measures using MITERRA-EUROPE show that balanced N fertilization in which the N application is tuned to the N demand of the crop strongly decrease nitrate leaching, and also reduces the emissions of N_2O and NH_3. Farmers can use decision support tools (see WP3 of FAIRWAY), the N surplus indicator (WP3 of FAIRWAY), soil and plant analyses, and precision farming techniques to apply N balance fertilization practices.
- Cover crops reduce nitrate leaching; the effect is largest when the growth of a cover crop is combined with balanced N fertilization, so that the N fertilizer application rate can be adjusted to the N released after incorporation of the crop into the soil.
- Results of calculations with GeoPEARL show that decreasing the input of pesticides, splitting the total application quantity over more application times (more dressings), alteration of pesticides with less harmful products and application of mechanical methods reduce leaching to groundwater and thus protect drinking water resources to a large extent.
- There are potential synergies for evidence-based practices for reducing nitrate and pesticide pollution of drinking water resources, regarding their applicability, adoptability, and costs across EU. Potential win-win solutions for all stakeholders are shown for bio beds/filters and/or constructed wetland for pesticide pollution, and changes in the application method, grassed waterways and/or changes in cropping system and crop rotation for nitrate pollution.

Decision support tools

- Decision support tools are helpful in advising farmers about best practices in the application of fertilizers and pesticides. Successful tools are simple and self-explanatory, flexible in data input and output, and should be freely available online in the local language and with a possibility to get support.
- Many farm management tools promoting smart nutrient and/or pesticide use are available, but only a few explicitly consider the impact of mitigation methods on water quality. There is a need to include measures and indicators in these tools to reduce pollution of water with nitrogen and pesticides.

Governance

- Good drinking water quality delivery requires sufficient capacity at the local level to ensure that implementation of policies and law results in effective local action. This includes feedback mechanisms and intersectoral learning.
- Improving correlations between directives, policies, objectives and requirements, including cross-referencing them, will strengthen the overall policy framework towards protection of drinking water resources from agricultural pressures.
- In the context of water resource protection, local adaptation and result-based schemes directed at the implementation of clear objectives have better environmental impacts and higher cost-effectiveness than uniform payments and greening schemes in CAP.

Scientific policy support

- Project clustering with stakeholder involvement (science, policy, stakeholders, and citizens) is a strategy to make science and research more connected to current policy challenges and stakeholder needs with the aim of establishing sustainable long-term relationships and communication flows.

1. INTRODUCTION

The aim of Task 7.3 is to provide recommendations of the most promising package(s) of measures, policies, governance models and tools at national and EU level using the results of WP2-WP6 and assessments with integrated assessment tools at national and EU level, such as MITERRA-EUROPE and GeoPEARL. These tools use agricultural and pedo-climatic data to calculate emission of nitrogen and pesticides to the environment and can be used to screen the effectivity of measures to decrease nitrogen and pesticide pollution of water at national and EU scale (Velthof et al., 2009). These assessments at the EU scale will deliver input for the recommendations of the most promising approaches to improve drinking water quality.

This recommendation report for task 7.3 (D7.3) consists of two parts. In first part, the most promising activities, policies and tools obtained in WP2-WP6 are investigated. The project's most important key messages are determined, from which the knowledge for most promising activities, policies and tools evolves. A methodology was applied to build project's key messages without losing track of the original authors, linkage to WPs and case studies, and dedication to stakeholder groups. With this methodology a vertical and horizontal distribution of knowledge between science and practise has been clearly documented and can be followed through for any interested public.

In second part, assessments with integrated assessment tools at national and EU level presented. The MITERRA-EUROPE model was applied to assess the potential effects of the promising measure cover crops (WP4, WP6 and WP7) on nitrate leaching on NUTS 2 level in the EU (Chapter 3). The results are compared with scenarios without cover crops, high implementation rate of cover crops, and balanced nitrogen (N) fertilization (see Chapter 3).

In Chapter 4 the effectiveness of measures that can reduce leaching of pesticides (residues of plant protection products) was assessed using the spatially distributed model GeoPEARL. The leaching to groundwater of pesticides in the safequard zones of seven drinking water areas in the south of the Netherlands were for potatoes, maize, grass and leek. The seven areas are part of the Fairway Case "Schoon water Brabant. Measure include mechanically weeding instead of use pesticides, a reduction the pesticide dose with 50%, and less applications in time (1 instead of 2 applications and 2 instead of 3 applications).

2. MOST PROMISING ACTIVITIES, POLICIES AND TOOLS FROM WP2 TO WP6

Janja Rudolf (University of Ljubljana), Jane Brandt (MEDES), and Gerard Velthof (Wageningen Research)

2.1 INTRODUCTION

The purpose of this task was to check the horizontal and vertical aspects of results derived from the project activities and then provide a condense overlook of what has been most important message or new knowledge for interested public. The project's most important key messages are determined from which the knowledge for most promising activities, policies and tools evolves. A methodology for building the project's key messages and not losing track of the original authors, linkage to WP and case studies, dedication to stakeholder group. With this methodology a vertical and horizontal distribution of knowledge between science and practise has been clearly documented and can be followed through for any interested public.

Section 2.2 presents the methodology part and 2.3 the results and discussion. At the methodology part, an insight into building the main key messages of Fairway project by its dedication to most promising activity, policy or tool is given. Firstly, a design of gross list of project's key messages provided by original authors called *original key messages* is given. Secondly, an explanation on how the authors of the R7.3 made a cross check between the different key messages (KM) in the gross list is given. Thirdly, a process of deciding which are the most important Fairway's KM and their linkage to specific author of original KM in the gross list is explained. Lastly, the template format is explained in detail and its purpose of presenting the main project' KM in a common way.

At the result and discussion part, firstly the results of the main Fairway KM are explained in detail and presented in a template format, separated by its dedication to most promising activity, policy or tool. Then, the KM for project's objectives are presented and discussed. At the end a gross list of condensed KM that are separated by its applicability to the certain stakeholder group (EU decision makers, multi-actor platforms or case studies) are given, followed by a table with 20 most important KM with a linkage to the work package that delivered results and links to Appendixes I and II are given and presented.

2.2 METHODOLOGY

2.2.1 **Building the gross list of project's key messages from WP2 to WP6**

Building the gross list of project's KM was a continuous work of all leading partners, lead researchers and CS leaders that are included in the project. The idea was to collect and organize, in a table format, all the most important conclusions of the project's tasks and deliverables, calling them *original key messages*.

The contributions were made not only by WP, but also by CS. We included the view of case studies because it was observed that case studies can have different emphasis when it comes to the question: "What is the most important activity or tool for keeping drinking water resources safe in your area?" The CS view can be more technical and practical than the researchers' view, and it seemed important to collect their views too in order to see a bigger picture with several perspectives concerning what are the most important activities or policies or tools that can protect drinking water resources for next generations.

Figure 1 shows where there were exchanges of data, information and results between the WP research themes and the MAPs and or CSs, as exemplified and reported in the project deliverables. Evidence and results from the CSs are also included in the one-page key message summaries described below.

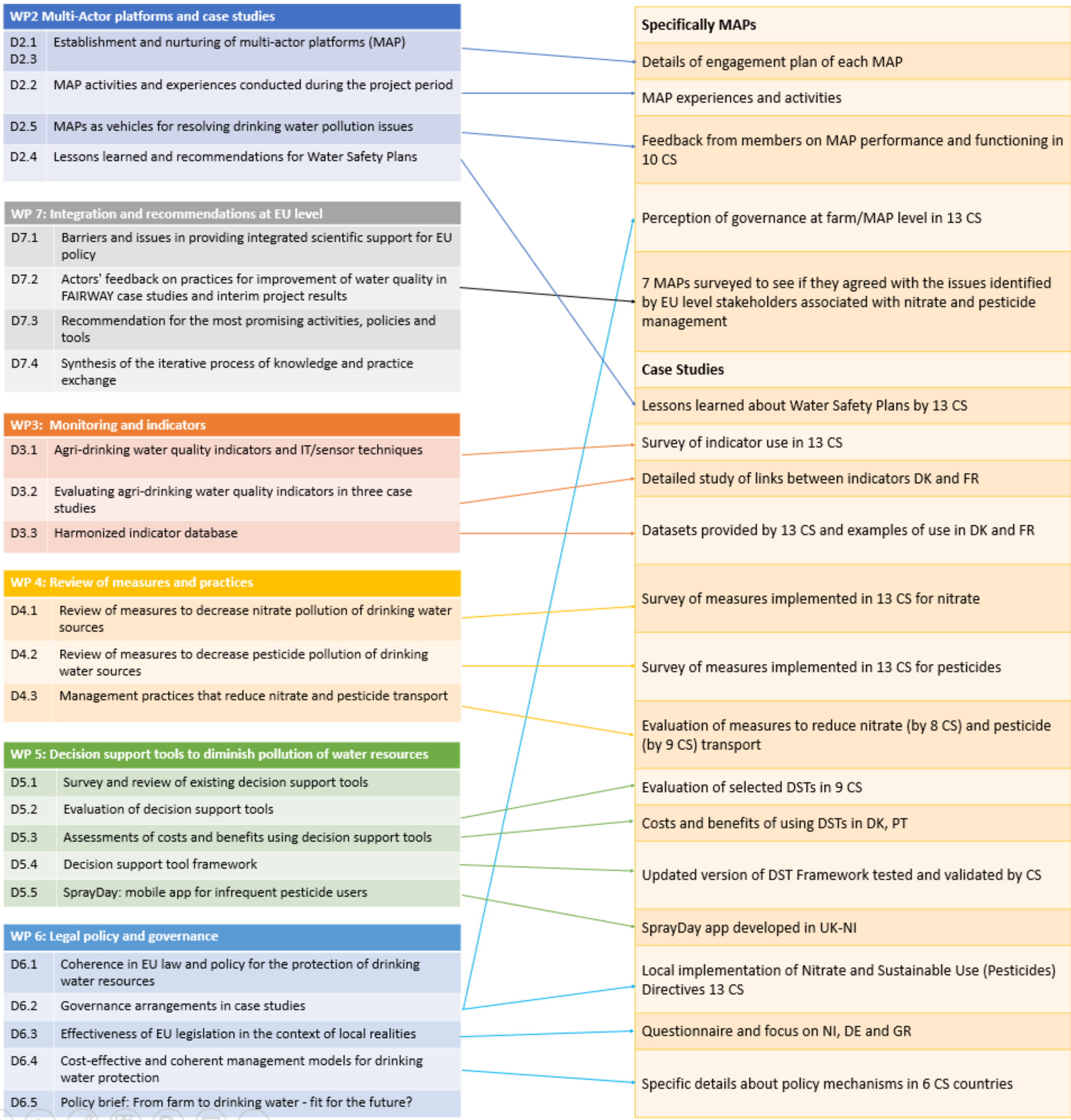

Figure 1: Links between WPs and CSs/MAPs (as exemplified in the deliverables)

To get insight how results of WPs influenced CS and how messages from case studies were used in the work within the WPs , we asked separately WP leaders and CS. WP leaders were asked: “Please define most important key messages that derive from your tasks and link them to deliverables or tasks." The CS were asked: "Please define the key messages that are most important for your case and linked them to the deliverable or task from WP." This is how we provided evidence for project's horizontal contribution. Furthermore, we linked the original KM to stakeholder group that the original KM intitles to, for all KM from WP and CS. The stakeholder groups were EU decision makers, and the Multi Actor Platforms (MAP) of the case studies. The MAPs, include different type of actors, such as water boards, farmers, farmers' organization, NGO's, industry (the actors involved, differ between the case studies). This is how we provided evidence for project's vertical contribution to the new knowledge.

The gross list with original key messages provided from WP and CS and the linkage to deliverables/tasks and stakeholder groups are archived in excel spreadsheet and can be found in the Appendix I and Appendix II.

2.2.2 Cross check between WP and CS, finalizing and presenting the key messages

Several cross checks between original KM provided from WP and CS were carried out to identify where there was repetition of the context in whole or in part of the KM provided. Some KM were condensed because the list of original KM was long (see Appendix I and II). This procedure ended in a list of 32 condensed KM of which 20 were selected to be the most important for WPs and CSs. The original information about the provider of original KM was archived, so every condensed KM had a linkage to which WP or CS provided the information for condensed KM. The authors of original KM had the possibility to cross check again the condensed KM with the original KM to allow each author of original KM to check the correctness of the condensed version with the original.

Finally, a request was made again to the WP2-7 leads who were asked to check the accuracy of the condensed KMs and to provide a full description of them in a standard, one page format.. In this iteration, a few KMs were dropped because they were not chosen by the original authors as FAIRWAY's most important and resulting in a final list of 16. The KM can be divided in three groups: 'most promised activities', 'most promised policies' and 'most promised tools' in order to fulfil the R7.3 objective.

The intention of standardising the presentation of the KMs was to create a dossier of concise and technical output written in easily accessible language.. The KM sheets are included in this report (Section 2.3.2) and are also being used as standalone documents for other FAIRWAY dissemination activities (webpage, FB, twitter, conferences). They are designed to be distributed to wide range of interested stakeholders: EU decision makers, scientists, farmers, agriculture advisers, and non-governmental organizations of promotors of safe drinking water and take into account lessons learned from those stakeholders in WP7.1 and 7.2 about their preferences for receiving information from research projects.

2.3 RESULTS AND DISCUSSION

The original KM are presented in Appendix I and II. Appendix I presents gross list of information provided from WP and CS and their linkage to specific stakeholder group and specific project's deliverables. An output of certain KM in publication of original scientific papers is also stated there. Appendix II presents a gross list of synthesized KM by their dedication or importance to specific stakeholder group. In brackets "()" a linkage to WP and/or CS that provided with specific statement is also stated there.

In Section 2.3.1 the main KM related to the most promising activities, policies and tools are presented in the templates. At the start of the FAIRWAY project, several main questions were indicated. Section 2.3.2 shows the main key messages related to the project's objectives. The gross list of condensed KM are given in Section 2.3.3.

2.3.1 Main key messages related to promising activities, policies and tools

On the following pages the 16 sheets with the main KM are presented. Each sheet contains five main sections:

- Key message statement: a concise one or two sentence summary of the KM.
- Identification of target audience: which groups of stakeholders are most likely to be interested in the KM and why.
- Explanation: the context to which the KM is relevant.
- Evidence: summary of FAIRWAY's results (including evidence from the Case Studies) from which the KM conclusion is drawn, including a photo or figures.
- Further details: links to the full results from which the KM is derived on FAIRWAYiS and any relevant publications.

FAIRWAY

PARTICIPANTS, FACILITATORS, AND FUNDERS OF MULTI-ACTOR ENGAGEMENT PROCESSES.

Enabling meaningful engagement is key for sustainable and long-lasting multi-actor platforms with real impact.

KEY MESSAGE

Multi-actor platforms are valuable in building networks and creating a common understanding about complex issues in the agriculture-water governance interface. While they are important for setting joint strategies, they might not be sufficient to achieve desired impacts.

EXPLANATION

Multi-actor platforms connect actors, improve dialogue, increase awareness, and enable knowledge transfer. They therefore have the potential to contribute to building networks and creating common understanding of complex issues in the agriculture-water governance interface. While improved interaction between actors and sectors can be considered a success factor of engagement processes and can be important for setting joint strategies in cross-sectoral decision-making, it is not necessarily sufficient to achieve desired impacts.

Engagement processes require long-term investments in terms of time, resources, and facilitation. This realization should be acknowledged by project partners and funders, as well as participants, to enable management of expectations and contribution of all parties, and to avoid fatigue in the engagement processes.

EVIDENCE

A review of ten multi-actor platforms in the FAIRWAY project was carried out to harvest lessons from engagement processes in a multi-actor context. A literature review and surveys in the respective multi-actor platforms enabled a mapping of opportunities and bottlenecks for meaningful engagement, as well an exploration of the prospects for long-term sustainability of the multi-actor platforms.

Farm visit. Nordjylland, Denmark (FAIRWAY 2019)

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FURTHER DETAILS

Sundnes, F. et al. (2020) Advancing MAPs as vehicles for resolving issues on drinking water pollution from agriculture. FAIRWAY Project Deliverable 2.5

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FAIRWAY

EU DECISION MAKERS: PROTECTION OF LARGE AND SMALL WATER SUPPLIES

For EU decision makers it is important to understand the distinct phases in Water Safety Planning, and how stakeholders should be engaged in the process.

KEY MESSAGE

During all phases of Water Safety Planning, engagement of stakeholders in the development of the methodology and content is essential. Establishing cooperation between large and small suppliers contributes to overcoming barriers for effective risk assessment and management for small suppliers.

EXPLANATION

Water Safety Planning (WSP) is a step-wise approach to ensuring the safety of drinking water. It is undertaken in distinct phases: identification of the problem; assessment of the problem; scenarios to solve it; and implementing the solution. It is thus a comprehensive risk assessment and risk management approach, that covers all stages in the water supply system.

EVIDENCE

FAIRWAY combined information shared about experiences with Water Safety Planning in the FAIRWAY case studies with an extended literature review for small and large water supply systems. Key lessons learned are that (1) engagement of stakeholders by those developing WSP is essential during all phases and is a two-way process: vernacular knowledge of stakeholders and their understanding of the local socio-economic context also contributes to effective protection of water resources; (2) designating a process owners helps bring together departments and stakeholders, spread information throughout organizations and provides congruence between different risk assessment and risk management systems; (3) an agreed methodology and content enhances the effectiveness of WSP and cooperation and communication between those involved; and (4)sharing context, best practices and lessons learned in operating large water supplies, contributes to the safety of small water supplies.

Roma family and their small (private) drinking water well in Romania (FAIRWAY 2017)

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FURTHER DETAILS

van den Brink, C. et al. (2021) Lessons Learned and Recommendations for Water Safety Plans. FAIRWAY Project Deliverable 2.4, 97 pp

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FAIRWAY

POLICY MAKERS AT EUROPEAN AND AT LOCAL SCALE

To evaluate the impacts of mitigation measures in a given hydrological context, complete and readily available databases are necessary. Since water (and especially groundwater) has long travel times before being extracted as drinking water, long and continuous data sets are necessary to carry out reliable statistical analyses.

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FURTHER DETAILS

Laurencelle, M. et al 2021. (Short note for the) database containing harmonised datasets, 28 pp. FAIRWAY Project Deliverable 3.3

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KEY MESSAGE

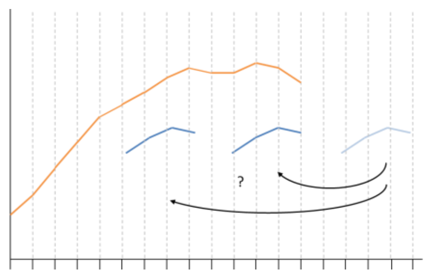
Monitoring groundwater quality, detecting pollution sources and evaluating mitigation measures have to be done to ensure a safe, sustainable drinking water supply for citizens. Hence, it is necessary to have access to consistent databases that enable scientists to link pollution and mitigation measures to water quality.

EXPLANATION

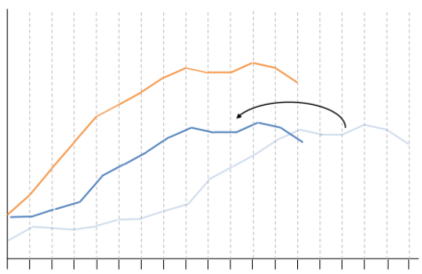
Water and contaminant transfer through most types of geological materials takes place over a long time. In any hydrogeological system, there is a specific delay (lag time) between substance application and its first detection at the waterworks. For a database to be fully usable for statistical analysis (in particular correlation analysis), the pressure indicator datasets (i.e. inputs of nitrate and pesticides from the agricultural system to the hydrogeological system) and state indicator datasets (water quality monitoring parameters) need to be continuous and the series should be longer than the local lag time.

EVIDENCE

In selected FAIRWAY case studies, correlation analyses were performed between pressure indicators of pollution (e.g. N fertilization application amount) and state indicators of water quality (e.g. N concentration in water). However, building a complete database of all the case study sites covering both pressure and state indicators over the sufficient time periods was a challenging task. Each member state has its own needs, regulations and institutions to collect and manage the data.



No relation can be found between the parameters here. The dataset is too short and discontinuous for this kind of analysis and no clear conclusions can be drawn.



Time lag	Correlation
0 year	0.2
1 year	0.4
5 years	0.5
10 years	0.6
15 years	0.7
20 years	0.8
25 years	0.7

With a longer and continuous dataset, correlation tests can be performed and clearer relationships can be found.

FAIRWAY

POLICY MAKERS AT EUROPEAN AND AT LOCAL SCALE

Decisions often have to be made about mitigation measures to improve drinking water quality. It is important for policy makers, farmers, and drinking water companies to take into account the fact that there can be a considerable lag time between implementing a measure and seeing its effect on the water quality.

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FURTHER DETAILS

Hansen, B. et al. (2021). Evaluation of ADWIs: agri-drinking water quality indicators in three case studies (FAIRWAY Project Deliverable 3.2)

Kim, H. et al. (2020). Lag Time as an Indicator of the Link between Agricultural Pressure and Drinking Water Quality State. Water 2020, 12, 2385.

Summary leaflet

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FAIRWAY received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727984

KEY MESSAGE

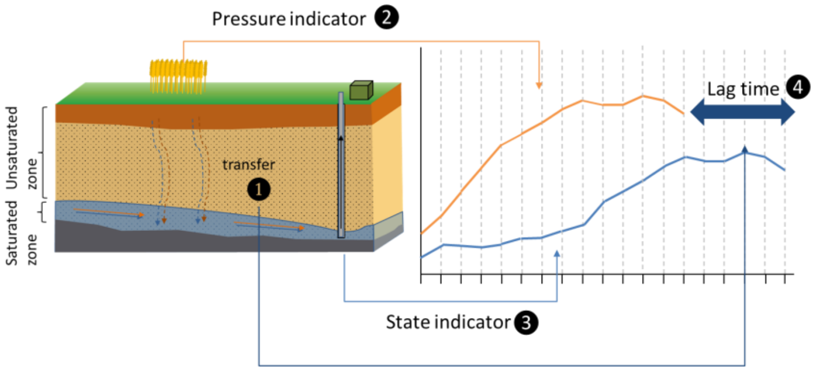
Water and nitrate transfer through geological material is not instantaneous. There is a lag time between agricultural nitrogen leaching from the fields and its impact on water quality in aquifers, and wells. This time lag should be taken into account when developing drinking-water protection strategies.

EXPLANATION

Water and nitrate can take several years to transfer through one meter of subsurface material, depending on the type of hydrogeological layers. In some European geological settings, the distance between surface (where the mitigation measures are applied) and the aquifer (where the concentration level is measured) can vary by many meters.

EVIDENCE

Using data from FAIRWAY case studies with deep aquifers in France (La Voulzie) and Denmark (Island Tunø and Aalborg), correlation analyses were performed between N fertilization, N surplus (pressure indicators) and N concentration in groundwater (state indicator). Using water age measurements, lag times of more than 10 years were estimated between indicators of measures made on the surface and detected groundwater concentrations.



Flow paths ❶ determine how long it takes for the effect of drinking water protection measures to be detected in the groundwater quality.
The long-term effects of mitigation measures can be studied by monitoring State indicators (concentrations) ❷ and Pressure indicators ❸ over several years to decades. Pressure indicators and State indicators can be linked by taking lag time into account ❹.

KEY MESSAGE

Nitrogen surplus at the farm or regional level is a useful agri-environmental indicator. However, because Member States apply different calculation methods, comparisons at the European level are ambiguous. As calculation data, particularly on farm level, may not sufficiently represent local conditions and activities, the indicator may not fulfil legal certainty.

EU DECISION MAKERS: MEASURES TO PROTECT DRINKING WATER

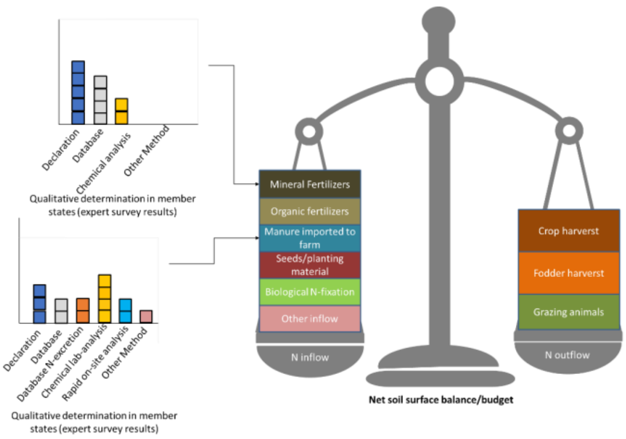
N surplus could be an effective indicator to link N pressure to N concentration in groundwater. However, there is a need for a common method across EU member states to collect data, calculate N surplus and define relevant frame conditions.

EXPLANATION

Many agri-environmental indicators, as developed by OECD and Eurostat, are used for monitoring and evaluating the positive and negative impacts of agricultural activities on the environment and used for comparison between countries on a national scale. One of these, N surplus, is calculated as the difference between nitrogen inputs and outputs. However, the calculation methods and input data vary widely between Member States. Consequently, a cross country comparison of N budgets calculated on regional or national level needs to be interpreted carefully. On farm level, standard data may not cover local conditions, while there are still methodological problems to overcome in on site sampling and chemical analysis.

EVIDENCE

Questionnaires on the use of N indicators at farm level were completed by FAIRWAY partners. In almost all FAIRWAY case studies, N surplus is used as an indicator by water authorities, albeit using different calculation methods. A positive correlation was found between N surplus of arable farms and N concentration in groundwater in cases analysed further. Therefore, N surplus on farm level may be an indicator for the N concentration in corresponding groundwater bodies. However, input data need to be carefully checked for their reliability and certainty. Due to differences in calculation methods, the outcomes are not comparable between Member States.



Net nitrogen soil surface budget with sources of information on chemical composition for selected elements (Klages et al., 2020).

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FURTHER DETAILS

Klages, S. et al. 2018. Review report of Agri-Drinking Water quality Indicators and IT/sensor techniques, on farm level, study site and drinking water source. FAIRWAY Project Deliverable 3.1, 180 pp

Klages, S et al. (2020) Nitrogen Surplus—A Unified Indicator for Water Pollution in Europe? Water, 12, 1197

ACKNOWLEDGEMENT

FAIRWAY received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727984

FAIRWAY

FARMERS, ADVISORS, LOCAL AND REGIONAL MANAGERS, AND EU POLICY MAKERS

Policies that include measures to reduce nitrate leaching to ground and surface waters should take into the risk of pollution swapping to other nutrient and greenhouse gas emissions. An integrated approach is needed, so that the environmental targets in different polices are met.

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FURTHER DETAILS

Ros et al. 2020. Identification of most promising measures and practices: 2. Reduction nitrate transport from agricultural land to groundwater and surface waters by management practices. FAIRWAY Deliverable 4.3, 72 pp

Ros et al. 2021. Exploring the potential of measures to reduce nitrate leaching in the EU (in prep.)

ACKNOWLEDGEMENT

FAIRWAY *received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727984*

KEY MESSAGE

Implementation of measures to reduce nitrate losses should consider not only their effectiveness, and costs, but also the likelihood of (unwanted) side-effects such as pollution swapping to emissions of ammonia, nitrous oxide and phosphate.

EXPLANATION

Implementation of policies such as the Water Framework, Groundwater, Drinking Water and Nitrates Directives promotes the use of measures to reduce nitrate losses to ground and surface waters. However, some of these measures may increase the levels of greenhouse gas emissions, contrary to the objectives of other climate change related policies.

EVIDENCE

FAIRWAY conducted a review of existing meta-analyses and quantitative studies on measures to reduce nitrate losses to ground and surface waters. The results showed that there is a lot of information available on the effectiveness of measures on nitrate leaching and this is often in combination with their effects on other N parameters such as nitrous oxide emissions or increasing ammonia volatilization. Some studies showed that measures to decrease nitrate leaching (e.g. incorporation of a cover crop into the soil) can increase other N losses and may enhance greenhouse gas emissions. This is true for measures at both the field and farm scales.

A winter crop may decrease nitrate leaching but may increase nitrous oxide emission after it is incorporated into the soil.

KEY MESSAGE

For measures to reduce nitrate losses, there is a discrepancy between the type of field- or trial-based measures tested and reported in literature and real-world farm-level management options that are used or reported in the case studies.

EXPLANATION

In scientific literature reviews, measures reported to mitigate nitrate losses to surface and ground waters are often field- and trial-based, so that it is relatively easy to compare treatments with control plots. Examples are the use of cover crops after the growing season and application of (nitrification) inhibitors or biochar. While some of these measures are also used in practice, experiences from the FAIRWAY case studies reveal that more holistic practices targeted at source reduction or education and information of farmers are equally important. Examples are the use of integrated nutrient management tools, balanced nitrogen fertilization, and the organisation of field days. These measures are often less straightforward to test in field experiments.

EVIDENCE

We inventoried and reviewed the scientific literature on the effectivity of various measures to reduce nitrate losses (leaching and runoff) to ground- and surface waters. The effects of various measures were distilled from existing reviews and individual field studies. Additionally, we collected experiences from ten FAIRWAY case studies, in which various measures were applied. Experts were asked about the effectivity, costs, applicability, and adoptability of the different measures.

Example of a grass cover crop sown after maize to reduce nitrate losses.

FAIRWAY

FARMERS, ADVISORS, LOCAL AND REGIONAL MANAGERS, AND EU POLICY MAKERS

For anyone involved in agricultural production, it is important to know which measures are effective at reducing nitrate losses to ground and surface waters. A range of effective measures do exist, but they do not all receive equal attention in the literature.

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FURTHER DETAILS

Oenema, O. et al. 2018. Review of measures to decrease nitrate pollution of drinking water sources. FAIRWAY Project Deliverable 4.1, 125 pp

ACKNOWLEDGEMENT

FAIRWAY received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727984

FAIRWAY

FARMERS, ADVISORS, LOCAL AND REGIONAL MANAGERS, AND EU POLICY MAKERS

For anyone involved in agricultural production, it is important to know which measures are effective at reducing pesticide losses to ground and surface waters. A range of measures exist, and it is important to use them in combination.

KEY MESSAGE

Reduction of pesticide pollution of drinking water resources demands a combination of input reduction, farm system redesign and point source mitigation.

EXPLANATION

Agriculture is a main source of pesticide pollution of the aquatic system, both groundwater and surface water. Applied pesticides can be transported to water bodies via leaching and surface runoff. The amount of loss depends on farming system, management, soil type, geomorphology, and climate.

EVIDENCE

FAIRWAY made an inventory of and compared measures to reduce pesticide pollution to surface and groundwater using: a systematic literature analysis, (including a quantitative meta-analysis for some measures when data quality allowed); and experiences from the eight FAIRWAY case studies across Europe. Measures were evaluated in terms of their effectiveness, costs, adoptability and applicability. The literature review and case study inventory complemented each other.

On-field measures (e.g. vegetative buffers, tillage practices) are effective at reducing off-site pollution, but costly to install and maintain. Such on-field measures contribute to reduced pollution for overland flow but are not sufficient to mitigate pollution. Input reduction and farm redesign (e.g. Integrated Pest Management (IPM), crop rotations) as well as point-source mitigation (e.g. safe storage and bio beds) are needed to achieve reduction of pesticide pollution to surface water. Sustained adoption of measures is a challenge in many case studies. Regional or national legislation helps to adopt measures, such as reduced inputs.

Buffer near wetland *(source: MN Pollution Control Agency; CC BY-NC 2.0)*

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FURTHER DETAILS

Commelin, M. et al. 2018. Review of measures to decrease pesticide pollution of drinking water sources. FAIRWAY Project Deliverable 4.2, 79 pp

ACKNOWLEDGEMENT

FAIRWAY *received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727984*

FAIRWAY

EU DECISION MAKERS: MEASURES TO PROTECT DRINKING WATER

Decision support tools can help users identify which measures are most efficient at addressing drinking water protection issues. While there are many DSTs available, the most successful ones are also those that have the best potential for application or usage in the field.

KEY MESSAGE

Decision support tools are helpful in advising farmers about best practices in the application of fertilizers and pesticides, in order to both optimize crop yield and prevent water pollution problems.

EXPLANATION

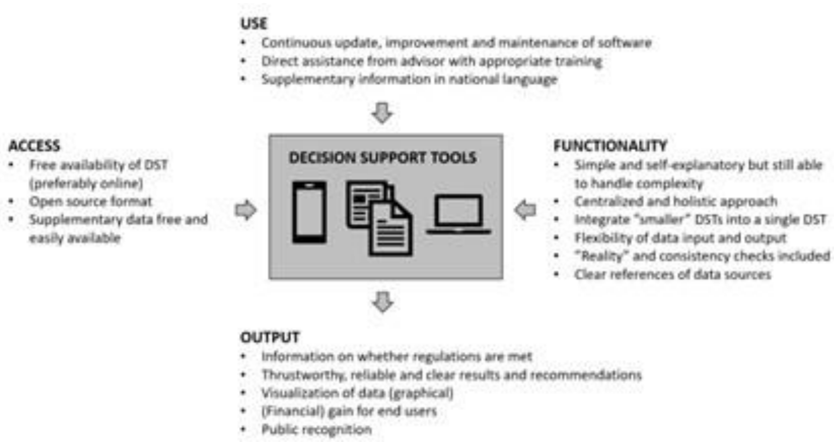
Decision support tools (DSTs) are designed to help end users make more effective decisions about best practice in the most appropriate use of fertilizers and pesticides to minimize the contamination of drinking water. A number are currently in use in European countries, varying according to scale, pollutions addressed and integration of mitigation measures.

EVIDENCE

FAIRWAY conducted a literature survey and review of DSTs currently used by farmers, advisers, water managers and policy makers in the FAIRWAY case studies and countries. 36 of particular interest were identified, varying in scale of use (field, farm, catchment, regional), pollutants addressed (nutrients, pesticides) and if mitigation measures were integrated.

Criteria for successful DSTs were identified that included

- Functionality: simple and self-explanatory (but able to handle complexity), centralised and holistic approach, integration of smaller DSTs into a single one, flexibility of data input and output, reality and consistency checks, reference of data sources.
- Accessibility: freely available online, open source, supplementary data available
- Use: software update, improvement and maintenance, available support, local language.



Criteria that successful DSTs should fulfil

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FURTHER DETAILS

R.K. Laursen et al. (2019) Evaluation of Decision Supports Tools. FAIRWAY Project Deliverable 5.2 216 pp

ACKNOWLEDGEMENT

FAIRWAY *received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727984*

FAIRWAY

FARMERS, AGRICULTURAL ADVISORS, WATER QUALITY MANAGERS, POLITICAL DECISION-MAKERS, MODEL DEVELOPERS, RESEARCHERS

Many decision support tools, with a high numbers of users, give advice on smart use of nutrient and pesticides. However, very few consider water quality directly or include mitigation measures to reduce water contamination.

KEY MESSAGE

Many farm management tools promoting smart nutrient and/or pesticide use are available, but only a few explicitly consider the impact of mitigation methods on water quality.

EXPLANATION

Decision Support Tools (DST) are used to improve decision-making on management practices. Of the many that are used in Europe to make effective decisions about use of fertilizers and pesticides, only few include specific mitigation measures to reduce losses to water. Instead, in most cases the tools take a holistic approach aimed at improving the efficiency of the resources used through sophisticated management.

EVIDENCE

FAIRWAY conducted a literature survey and review of DSTs currently used by farmers, advisers, water managers and policy makers in the FAIRWAY case studies and countries. Of the 36 DSTs that were identified as most relevant to managing nitrate and pesticide usage to prevent water contamination, only three tools were explicitly developed to consider the impact of mitigation methods on water quality:

- FARMSCOPER (UK) - 100 mitigation methods can be tested individually or in combination
- ENVIRONMENTAL YARDSTICK FOR PESTICIDES (NL) - 4 mitigation methods
- CATCHMENT LAKE MODELLING NEWTORK - 5 mitigation methods

Increased use of clover is one of the mitigation measures considered by FARMSCOPER.

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FURTHER DETAILS

Nicholson, F.A. et al. (2018) Survey and Review of Decision Supports Tools. FAIRWAY Project Deliverable 5.1 166 pp

Nicholson, F et al. (2020) How Can Decision Support Tools Help Reduce Nitrate and Pesticide Pollution from Agriculture? A Literature Review and Practical Insights from the EU FAIRWAY Project. Water 2, 768.

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FAIRWAY

FARMERS, FARM ADVISORS, POLICY MAKERS

Decision support tools can help users identify which measures are most efficient at addressing drinking water protection issues. While there are many DSTs available in Europe, transferring their use from one country to another is not easy.

KEY MESSAGE

Although most EU countries already have comparable decision support tools, designed to address similar problems, there are obstacles to exchanging the tools between countries.

EVIDENCE

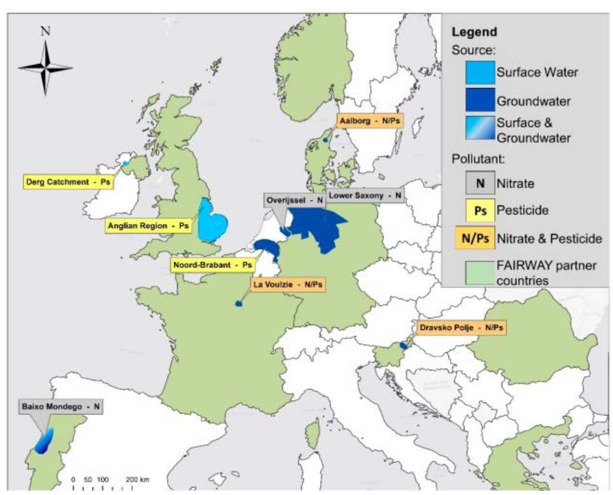
Decision support tools (DSTs) are designed to help end users make more effective decisions about best practice in the appropriate use of fertilizers and pesticides to minimize the contamination of drinking water.

EXPLANATION

FAIRWAY conducted a literature survey and review of DSTs currently used by farmers, advisers, water managers and policy makers in the FAIRWAY case studies and countries.

Bilateral contact was made with the developers of a shortlist of 12 DSTs for support and access to the software. Nine FAIRWAY case studies then trialed the use of the DSTs with local data and meetings with and demonstrations to stakeholders.

Being able to exchange and test this number of DSTs across the EU is unique and provided valuable information and insights including: information about the needs of farmers and stakeholders in term of functionality, use and access and their attitude towards DSTs. Barriers to exchanging DSTs between countries included differences in: legislation, advisory frameworks, country-specific and statistically sound data, geo-climate and language. Users preferred to either enhance their existing tools or to develop new region-specific ones, rather than attempt to modify a DST developed for another country.



The nine FAIRWAY case study sites involved in the DST evaluation (Nicholson et al. (2020)

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Nicholson, F et al. (2020) How Can Decision Support Tools Help Reduce Nitrate and Pesticide Pollution from Agriculture? A Literature Review and Practical Insights from the EU FAIRWAY Project. Water 2, 768.

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FAIRWAY

EU POLICY MAKERS

Effectiveness of agricultural and water governance approaches can be improved through transdisciplinary and cross-sectoral approaches, over scales and sectors.

KEY MESSAGE

Good drinking water quality delivery requires sufficient capacity at the local level to ensure that implementation of policies and law results in effective local action. This includes feedback mechanisms and intersectoral learning.

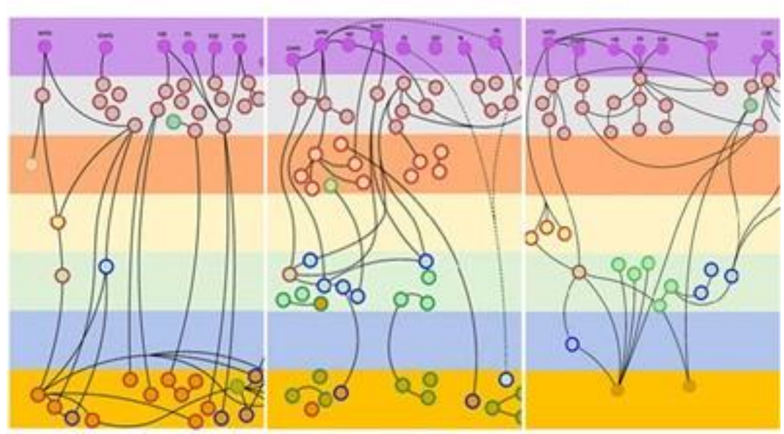
EXPLANATION

Agricultural and water governance is complex with a plethora of policy and legal instruments provided by the EU and national governments to control the quality of drinking water. These policies and instruments are integrated differently at regional and local levels by different Member States, leading to highly diverse implementation across Europe. However, it is difficult to visualise this complexity in a meaningful way.

EVIDENCE

FAIRWAY has developed a new methodology to visualise how water and agricultural governance cascades down from the EU to farm level. The method takes a bottom-up approach and includes active engagement with local actors. By taking account of stakeholder perceptions, a different picture of the reality of governance may be provided.

The impressions may help to determine weaknesses in the effectiveness of governance approaches and policy implementation especially if caused by lack of capacity at local level. They can contribute to impact and actions to either reduce the complexity or facilitate how to deal with it supported by well-designed feedback mechanisms and intersectoral learning. They also highlight the risk for core messages to become lost if they are delivered exclusively top down and sector by sector.



Example impressions from three EU countries that visualise the governance cascade from EU level (on top, purple) to national, multiple regional levels and finally farm scale level (on bottom, orange).

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FURTHER DETAILS

Boekhold, S. et al. (2021) From farm to drinking water - fit for the future? FAIRWAY Project Deliverable 6.5, 9 pp

ACKNOWLEDGEMENT

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FAIRWAY

EU POLICY MAKERS

Improving coherence and consistency of EU policies is needed to better protect drinking water resources.

KEY MESSAGE

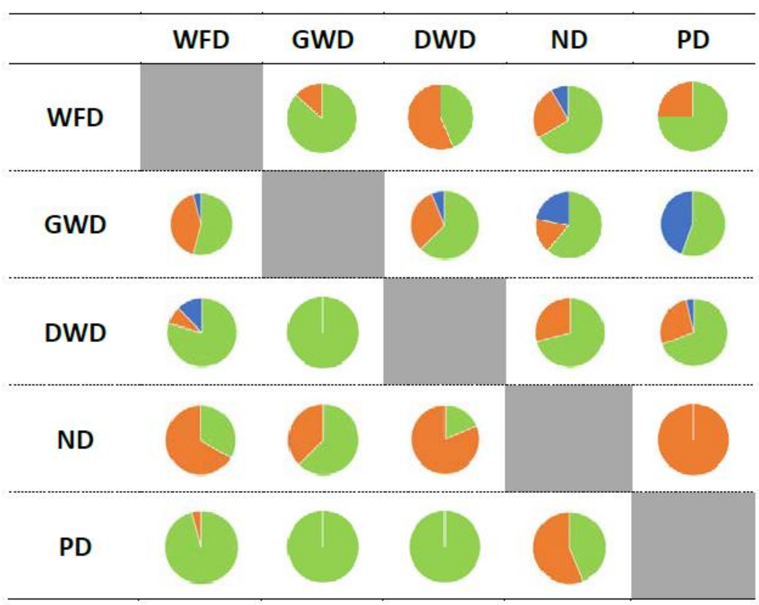
Improving correlations between directives, policies, objectives and requirements, including cross-referencing them, will strengthen the overall policy framework towards protection of drinking water resources from agricultural pressures.

EXPLANATION

The (cost-) effectiveness of the overall policy and legal framework to protect drinking water resources is affected by the mode of implementation of directives and policies by Member States, the use of ambiguously interpreted key terms and the lack of clear cross-referencing across directives and CAP. There is a clear need to improve policy effectiveness and cost-effectiveness through increased cross-referencing across different directives and policies.

EVIDENCE

FAIRWAY has identified strengths and weaknesses in the legal and policy frameworks. The figure below presents interactions between the five most relevant directives. Positive interactions support the realisation of objectives, negative interactions may hinder this process, and more neutral connections may become positive (strengthening) or negative (blocking) factors, depending on the choices made during the implementation phase.



The proportion of interactions between the requirements of each directive that respondents judged to be positive (green), neutral (orange) and negative (blue). WFD: Water Framework Directive; GWD: Ground Water Directive; DWD: Drinking Water Directive; ND: Nitrates Directive; PD: Pesticides Directive

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KEY MESSAGE

Economic pressures in agriculture severely limits farmers' room to maneuver. The effect of local optimisation processes is only a fraction of what can be achieved with more structural policy choices that reduce inputs and pressures at their source.

EU POLICY MAKERS

In the context of water resource protection, local adaptation and result-based schemes directed at the implementation of clear objectives have better environmental impacts and higher cost-effectiveness than uniform payments and greening schemes in CAP.

EXPLANATION

Agricultural activity to date has been the major source of pollution of drinking water resources throughout Europe. In view of current policy initiatives such as the Green Deal and From Farm to Fork, the EU, its Member and partnering States should incorporate water quality impact in assessments and policy choices at all levels.

In the Farm to Fork initiative the EC stipulates that a sustainable food system is essential to achieve the climate and environmental objectives of the Green Deal (and upcoming Climate Directive). The initiative also highlights this as an opportunity to improve the incomes of primary producers and reinforce the EU's competitiveness.

EVIDENCE

Stakeholders in the FAIRWAY case studies emphasized the tensions between taking measures to protect water resources and trying to achieve (small) economic revenues for farmers. The assessment shows that further revisions of the CAP are necessary because uniform payments and greening schemes have shown to be ineffective in delivering environmental benefits. Instead, local adaptation and result-based schemes directed at the implementation of clear objectives indicate better effects and cost-effectiveness.

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FAIRWAY

POLICY MAKERS AT EU AND NATIONAL LEVELS

The national dimension of the science-policy interface is not currently considered adequately but is particularly relevant for implementation purposes. National research agencies could support competent authorities in implementing relevant EU legislation at the local scale.

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FURTHER DETAILS

Železnikar, S. et al. (2021) Evaluation report on barriers and issues in providing integrated scientific support for EU policy. FAIRWAY Project Deliverable 7.1R 56 pp

Rudolf, J. et al. (2021) Actor's feedback on practices for improvement of water quality in FAIRWAY case studies and interim project results. FAIRWAY Project Deliverable 7.2R 74 pp

Glavan, M. et al. (2019) How to Enhance the Role of Science in European Union Policy Making and Implementation: The Case of Agricultural Impacts on Drinking Water Quality. Water 11, 492.

ACKNOWLEDGEMENT

FAIRWAY *received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727984*

KEY MESSAGE

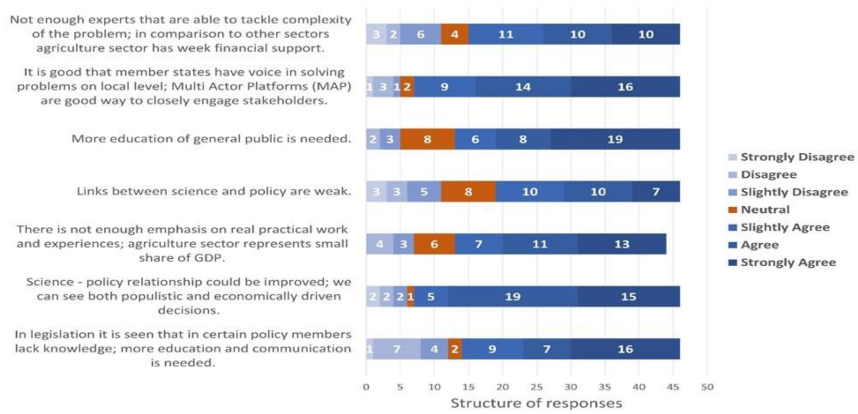
Barriers to protection of water quality in the EU are mostly observed at the national or regional levels and relate to lack of political will, and scarce instruction on the process of legislation implementation. Project clustering is a strategy to make science more connected to policy challenges and stakeholder needs.

EXPLANATION

The role of the science/research sector in policy making and implementation is vague and dispersed across different stages of the process. It also has different roles in the process: as an initiator of policy, a follower of policy or political strategies, or a participant in the public discussion. Project clustering with stakeholder involvement (science, policy, stakeholders, and citizens) is a strategy to make science and research more connected to current policy challenges and stakeholder needs with the aim of establishing sustainable long-term relationships and communication flows.

EVIDENCE

FAIRWAY conducted surveys on the major barriers for solving issues relating to nitrate and pesticide pollution of drinking water. Members of the multi-actor platforms in the [FAIRWAY case studies](), participants of a conference of EU policy makers and stakeholders (Brussels, December 2018), and a wider group of EU land managers were asked for feedback. Most respondents agreed that member states should have a voice in solving problems at the local level and that multi-actor platforms are the right way to engage stakeholders closely. The idea of designing project clusters between research projects and the political agenda for possible long-term relationship/communication flows seemed very useful to the vast majority (86 %) of respondents.



Responses (in a Likert scale) to barriers in solving the issues concerning the protection of drinking water resource at the local level, n=44-46

FAIRWAY

KEY MESSAGE

There are potential synergies for evidence-based practices for reducing nitrate and pesticide pollution of drinking water resources, regarding their applicability, adoptability, and costs across EU.

EU DECISION MAKERS

It is important for EU decision makers to know which nitrate and pesticide pollution mitigation practices are not only of experimentally proven effectiveness but are also acceptable to farmers for adoption.

EXPLANATION

Despite policy measures implemented in the EU from the early 1990s onwards to decrease pollution of drinking water resources by nitrates and pesticides, contamination remains a significant problem in some areas. The current view is that, although many practices have been shown to be effective in field trials, many are not used because they are not appropriate to the local situation, too expensive, or farmers are unwilling to adopt them for some other reason.

EVIDENCE

FAIRWAY made an inventory of all management practices used to reduce nitrate and pesticide losses in the FAIRWAY case studies, combining it with a review of the scientific literature. A group of land managers from across the EU (mostly from COPA-COGECA and EUFRAS associations) were asked to choose from a short-list of those practices for which there was the best evidence, the 5 most promising management practices considering their applicability, cost and adoptability. The results show that there are some potential win-win solutions for all stakeholders involved if the following practices are used:

- for pesticides regulation - bio beds/filters and/or constructed wetland;
- for nitrate regulation - changes in the application method, grassed waterways and/or changes in cropping system and crop rotation.

Grassed buffer strip near a ditch, one of the potential win-win practices for both drinking water suppliers and farmers.

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FURTHER DETAILS

Rudolf, J. et al. (2021) Actor's feedback on practices for improvement of water quality in FAIRWAY case studies and interim project results. FAIRWAY Project Deliverable 7.2R 74 pp

ACKNOWLEDGEMENT

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2.3.2 **Key messages for project's objectives**

The FAIRWAY project had eight main objectives. In this section the main key message related to the main objectives of FAIRWAY are presented.

2.3.2.1 Objective 1

Analyse success and failure factors associated with the implementation of strategies that mitigate nitrate and pesticide pollution of vulnerable drinking water resources in 13 case studies across Europe, using a multi-actor approach (MAP) to facilitate effective cooperation between actors.

Key message:

Multi-actor platforms function well as platforms for exchange of opinions and ideas, and for sharing information and knowledge. Sharing of perspectives and trust between key actors is a necessary condition for common understanding and for setting joint strategies, but does not necessarily lead to desired impacts on water quality. Multi-actor platforms do not have a generic formulation but need to be made specific to each situation.

2.3.2.2 Objective 2

Identify and further develop transparent "Agri-drinking water quality indicators" for the evaluation of drinking water protection strategies, with a special attention to develop indicators that are understandable and appealing to farmers and citizens.

Key message:

Agri-drinking water quality indicators are useful at all spatial levels: at farm level as an aid in farmer's consultation, at local and national level as an evaluation and monitoring tool for administration work and for policy-makers. The agricultural nitrogen surplus pressure indicator is identified as a suitable Agri-drinking water quality indicator as it is the most significant, prevalent, effective, and easy to use indicator regarding nitrate contamination of water. However, a comparison of calculated nitrogen budgets needs to be interpreted carefully, because of differences in methods, and data. For pesticides, there is not a similar indicator, because of the many compounds that are used. The time lag between agricultural pressure and drinking water quality response is an important indicator to be used in a successful drinking water protection strategy.

2.3.2.3 Objective 3

Develop harmonized datasets for water quality monitoring of drinking water resources.

Key message:

A database has been developed and delivered. There is a need to harmonize databases in the EU member states and ease the transmission of data to compare Pressure and State indicators. There is also a need to harmonise the methods for analysing all relevant substances and to ease collection of direct or indirect data. There is also a need to solve or at least improve personal data protection related constraints.

2.3.2.4 Objective 4

Identify and evaluate novel measures and practices aiming at maintaining and/or improving water quality under different conditions, using literature review, results of previous projects, and experts' and stakeholders' opinions.

Key message:

There are potential synergy solutions of evidence-based practices for water quality protection from contamination by pesticides and nitrate residues concerning their applicability, adoptability and cost. Reduction of pesticide pollution of drinking water resources demands a combination of input reduction, farm system redesign, and point source mitigation. Win-wins for pesticide regulation include bio beds/filters and artificial constructed wetlands. Balanced N fertilization and cover crops are most promising measures to reduce nitrate leaching. Win-wins for nitrate regulation include changes in the application method of manure, grassed waterways and changes in cropping system and crop rotation. Implementation of measures to reduce nitrate losses should not only consider the effectiveness, and costs, but also the likelihood of adoption and possible (unwanted) side-effects such as pollution swapping to emissions of ammonia, nitrous oxide and phosphate.

2.3.2.5 Objective 5

Review, adapt, demonstrate and evaluate decision-support tools for advice, training and communication in order to inform cost-effective mitigation practices and establish common awareness for diffuse pollution of vulnerable drinking water resources among farmers and water suppliers.

Key message:

Decision support tools are helpful in advising farmers of best practice and planning in the application of fertilizers, in order to optimize crop yield and prevent water pollution problems with nitrates. Many farm management tools promoting smart nutrient and/or pesticide use are available, but only a few tools explicitly consider the impact of mitigation methods on water quality. Improving nutrient use efficiency generally increases both farm profit and the quality of groundwater. Key obstacles to exchange tools between countries include differences in legislation, advisory frameworks, country-specific and geo-climate data and language issues.

2.3.2.6 Objective 6

Analyse how EU and national policies and governance practices can be better balanced when focusing on the cost-effective protection of drinking water resources and derive recommendations for improvement at national and EU level.

Key message:

The legal framework for the protection drinking water resources from pollution by pesticides and nitrates by agricultural practices is both very comprehensive and fragmented. The overall framework is likely to be fit for purpose, but the extent to which this purpose will be realized depends to a large degree on implementation. Formalizing the interactions between directives institutionally by requiring cross-referencing with regards to monitoring and enforcement could help with this. Complexities and inconsistencies in European legislation become most explicit at the local level where cross-sectoral measures have to be taken and effects monitored. A facilitated, cross-sectoral approach to policy application at local level should be adopted to improve stakeholder networks, and between institutional levels and hydrological scales Across all FAIRWAY case studies, the coherence of governance was considered compromised at catchment and farm level. Although based on a small sample size, there appears to be consensus that citizen participation and involvement of civil society is yet to be fully functional and effective.

2.3.2.7 Objective 7

Identify key strategies and good practices for drinking water protection and assess the implications of these options for policy and practice, based on the findings and results of WP2 to WP6 (WP7).

Key message:

The legal framework for the protection drinking water resources from pollution by pesticides and nitrates by agricultural practices is both very comprehensive and fragmented, but is likely to be fit for purpose. A facilitated, cross-sectoral approach to policy application at local level should be adopted to improve stakeholder networks. Multi-actor platforms can play a role in this, as they function well as platforms for exchange of opinions and ideas. Reduction of pesticide pollution of drinking water resources demands a combination of input reduction, farm system redesign, and point source mitigation, such as bio beds/filters and artificial constructed wetlands. Most perspective strategies to reduce nitrate leaching include balanced fertilizations, precision application of fertilizers and manure, grassed waterways and changes in cropping system and crop rotation, including cover crops. The agricultural nitrogen surplus pressure indicator is identified as a suitable agri-drinking water quality indicator for nitrate contamination of water, but there is not a similar indicator for pesticides because many compounds are used as pesticide. The time lag between agricultural pressure and drinking water quality response is an important indicator to be used in a successful drinking water protection strategy. There is a need to harmonize databases and assessment methods with pressure and state indicators for water quality in the EU member states to compare and assess indicators using a harmonized approach. Many farm management tools promoting smart nutrient and/or pesticide use are available, but only a few tools explicitly consider the impact of mitigation methods on water quality. Tools could be extended with agri-drinking water quality indicators and promising measures to reduce nitrate and pesticide pollution.

2.3.2.8 Objective 8

Disseminate projects results via demonstration in the case study sites, multi-actor workshops, and publications in practical and scientific journals, using a variety of formats and media to engage actors at regional, national and EU-level (WP8).

Key message:

The workshops and webinars[1] organized by the FAIRWAY project were successful, because of high number of people that participated, and the lively discussions of the results and related topics with a wide range of stakeholders. Infographics, fact sheets, newsletters, videos and films, were also produced and were used in these workshops and MAPS.

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[1] Main workshops organized by FAIRWAY

- 6 December 2017 FAIRWAY Workshop on scientific support of EU policies
- 7 December 2018 - FAIRWAY & WATER PROTECT Joint Conference: EU policies in addressing drinking water management challenges
- May 2019 - Joint FAIRWAY – Water Protect national stakeholder group meeting in Denmark
- 4 June 2019 – Workshop at Land Use and Water Quality Congress
- 22, 25, 26, 29, 30, and 31 March 2021: Is it a good day to spray? Webinar about new app
- 22 September 2021 - Webinar on nitrate and pesticide measures & DSS tools
- 25 November 2021 – Workshop with EU policy makers
- Eind of November 2021 – Webinar with stakeholders

2.3.3 **Gross list of condensed KM**

The original gross list of project's KM can be found in the Appendix I and II. The list of condensed KM are presented in this Section (Table 1). This condensed KM were grouped together by their dedication to specific stakeholder group (decision makers on EU level, MAP or CS). In the brackets "()" a WP and/or CS is stated that contributed the original KM. A decision was made by the authors of R7.3 which of this condensed KM could be the most important for Fairway project.

Table 1: Condensed project's key messages of FAIRWAY belonging to different research activities of WP2 to WP7

Twenty most important condensed KM	**Source WP and CS[2])**	**Dedication to stakeholder group**
To improve nutrient management at a supra-regional scale, many different actors have to be involved. Practical and effective on-farm measures need to be communicated to policy makers by scientists, land users and other actors to create ownership of the issue and successful implementation	WP2, CS 3, CS 5	Decision makers on EU level
Multi-actor platforms at the regional to local level comprising farmers, retailers, water companies, research institutes and authorities effectively contribute to the protection of drinking water quality. MAPs connect the different actors, increase network connections, knowledge transfer, improve dialogue and awareness and decision making in cross-sectoral issues and trigger new developments.	WP2 and 7, CS 13, CS 3, CS 9	Multi-Actor Platforms
During all phases of Water Safety Planning, engagement of stakeholders in the development of the methodology and content is essential. Establishing cooperation between large and small suppliers contributes to overcoming barriers for effective risk assessment and management for small suppliers.	WP2, CS 3	Case studies
Because building and fostering good relationships and common understanding amongst key actors requires a long-term commitment, ongoing facilitation of and continued financial support for multi-actor engagement platforms is essential for their success.	WP2, WP 6, CS 10, CS 11	Multi-Actor Platforms
Agricultural nitrogen surplus is the most significant, prevalent, effective and easy to use indicator of nitrate contamination of water. However, a comparison of calculated nitrogen budgets across Europe needs to be interpreted carefully, because methods, data and emission factors vary between countries.	WP3, WP4	Decision makers on EU level
The time lag between agricultural impact and drinking water quality response is an important indicator to be used in a successful drinking water protection strategy. The time at which effects of measures for drinking water protection are shown in groundwater is dependent on the local hydrogeological conditions and flow paths and vary from several years for shallow groundwater to several decades for deeper groundwater.	WP 3	Decision makers on EU level Case studies
There is a discrepancy between the type of field- or trial-based measures tested and reported in literature and real world farm-level management options that are used or reported in the case studies.	WP 4	Decision makers on EU level Multi-actor Platforms

[2] Case studies of FAIRWAY: https://fairway-is.eu/index.php/case-studies

Reduction of on-site pesticide pollution of drinking water resources demands a combination of: input reduction; farm system redesign; and point source mitigation.	WP 4	Decision makers on EU level Multi-actor Platforms Case studies
Implementation of measures to reduce nitrate losses should not only consider the effectiveness, and costs, but also the likelihood of adoption and possible (unwanted) side-effects such as pollution swapping to emissions of ammonia, nitrous oxide and phosphate	WP 4, CS 4	Decision makers on EU level Multi-actor Platforms Case studies
Key obstacles to exchanging decision support tools between countries include differences in legislation, advisory frameworks, country-specific and statistically sound data, geo-climate and language. Users prefer to either enhance existing tools or develop new region-specific ones, rather than to attempt to modify a decision support tools developed for another country.	WP4, WP5, CS 11	decision makers on EU level
Support and advice from knowledgeable advisors skilled in communication is highly valuable in guiding the decisions of farmers. There are best practices for implementation of low pesticide use already available which do not negatively affect the crop production.	WP5, WP2, CS 2	Case studies
Decision support tools are helpful in advising farmers of best practice and planning in the application of fertilizers, in order to optimize crop yield and prevent water pollution problems associated with nitrates and nitrogen.	WP5, CS 3, CS 7, CS 11, CS 13	Case studies
Many farm management tools promoting smart nutrient and/or pesticide use are available, but only a few explicitly consider the impact of mitigation methods on water quality.	WP 5	Multi-actor Platforms Case studies
A novel methodology was to develop to unravel the cascade of governance addressing agricultural pollution of drinking water resources from EU directives to national law and policy to implementation at the local level. The methodology uses a bottom up approach to engage with actors and is helpful in identifying the anomalies between understanding and perceptions of local stakeholders and intentions of the policy makers. The method highlights the potential for core messages to be lost if delivered using a top down approach only. However, although still valuable, the methodology can be subjective and care is needed when making comparison between cascades constructed by different authors.	WP 6	Decision makers on EU level
At local level, land managers and farm decision makers are well aware of many examples of practices that are effective in the context of EU directives including riparian strips and catch crops (Nitrates Directive) and advice, training and testing (Sustainable Use of Pesticides Directive)	WP 6	Case studies
A hybrid approach to water quality management is needed that includes i) (discretionary) decentralisation in order to ensure collaboration and engagement of stakeholders at local level and ii) a (mandatory) centralised governance system to enable national standards to be set and enforced.	WP 6	Decision makers on EU level Multi-actor Platforms
Complexities and inconsistencies in European legislation become most explicit at the local level where cross-sectoral measures have to be taken and effects monitored. A facilitated, cross-sectoral approach to policy application at local level should be adopted to improve stakeholder networks, and between institutional levels and hydrological scales, so that higher effectiveness can be achieved.	WP 6	Decision makers on EU level Multi-actor Platforms

A mix of mandatory requirements with voluntary uptake and use of subsidies seem to be working in many countries. However, but more research is needed into the potential conflicts and complexity caused by these mixes.	WP 6	Decision makers on EU level Multi-actor Platforms Case studies
Barriers to protection of water quality in the EU are mostly observed at the national or regional level. They are perceived to be connected with a lack of political will, scarce instruction on the legislation implementation process, and a lack of funding opportunities for science to be included in policy making and implementation.	WP 7	decision makers on EU level
There are potential win-win solutions for water quality protection from contamination by pesticides and nitrate residues. Win-wins for pesticide regulation include bio beds/filters and artificial constructed wetlands. Win-wins for nitrate regulation include changes in the application method of manure residue, grassed waterways and changes in cropping system and crop rotation.	WP 4, WP 7	Decision makers on EU level Case studies

3. ASSESSMENT OF NITRATE LEACHING AT EU LEVEL USING MITERRA-EUROPE

Gerard Velthof, Mart Ros, and Jan-Peter Lesschen, Wageningen Research

3.1 INTRODUCTION

An assessment of most promising measures to decrease nitrate leaching on a EU scale was made using the MITERRA-EUROPE model. Two measures were selected based on the results of WP3, WP4, and WP6 and questionnaires filled in by case studies leaders.

The first measure is balanced N fertilization, which aims at reducing N fertilizer inputs by adjusting application rates to the N requirement of the crops, thereby decreasing the N surplus. The second measure is growing a cover crop after the main crop, so that the residual mineral N in the soil after harvest of the main crops can be reduced through uptake by the cover crop.

3.2 METHODOLOGY

3.2.1 MITERRA-EUROPE

The model MITERRA-EUROPE was developed in a service contract for DG Environment (Velthof et al., 2007; 2009). MITERRA-EUROPE is a deterministic emission and nutrient flow model, which calculates greenhouse gas (CO_2, CH_4 and N_2O) emissions, nitrogen emissions (N_2O, NH_3, NOx and NO_3), N and P flows, soil organic carbon stock changes, and soil erosion on an annual basis, using emission factors and leaching fractions. The model was developed to assess the effects and interactions of policies and measures in agriculture on N losses on a NUTS-2 (Nomenclature of Territorial Units for Statistics) level in the EU-28 (Velthof et al., 2009; De Vries et al., 2011). The model was originally based on the models CAPRI (Common Agricultural Policy Regionalised Impact) and GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies), and was later supplemented with a N leaching module, a soil carbon module based on RothC (Merante et al., 2014). , and a module for greenhouse gas mitigation measures. In addition, a module for water-induced soil erosion was included based on the Revised Universal Soil Loss Equation (RUSLE) approach (Panagos et al., 2015a; 2015b).

Input data consist of activity data (e.g., livestock numbers, crop areas, and crop yields from CAPRI, Eurostat and FAOSTAT), soil data (LUCAS), climate data (WorldClim), GHG emission factors (IPCC, UNFCCC), and NH_3 emission factors, excretion factors and manure management system data (GAINS, UNFCCC). The N flow calculation module is schematically presented in Figure 2. The N leaching fractions used in MITERRA-EUROPE are presented in the map in Figure 3. The model includes measures to simulate carbon sequestration and mitigation of GHG, NH_3 emissions, and NO_3 leaching.

The MITERRA-Europe model is described in more detail in Velthof et al. (2007; 2009) and Lesschen et al. (2011), and the most recent input data is described in Duan et al. (2021).

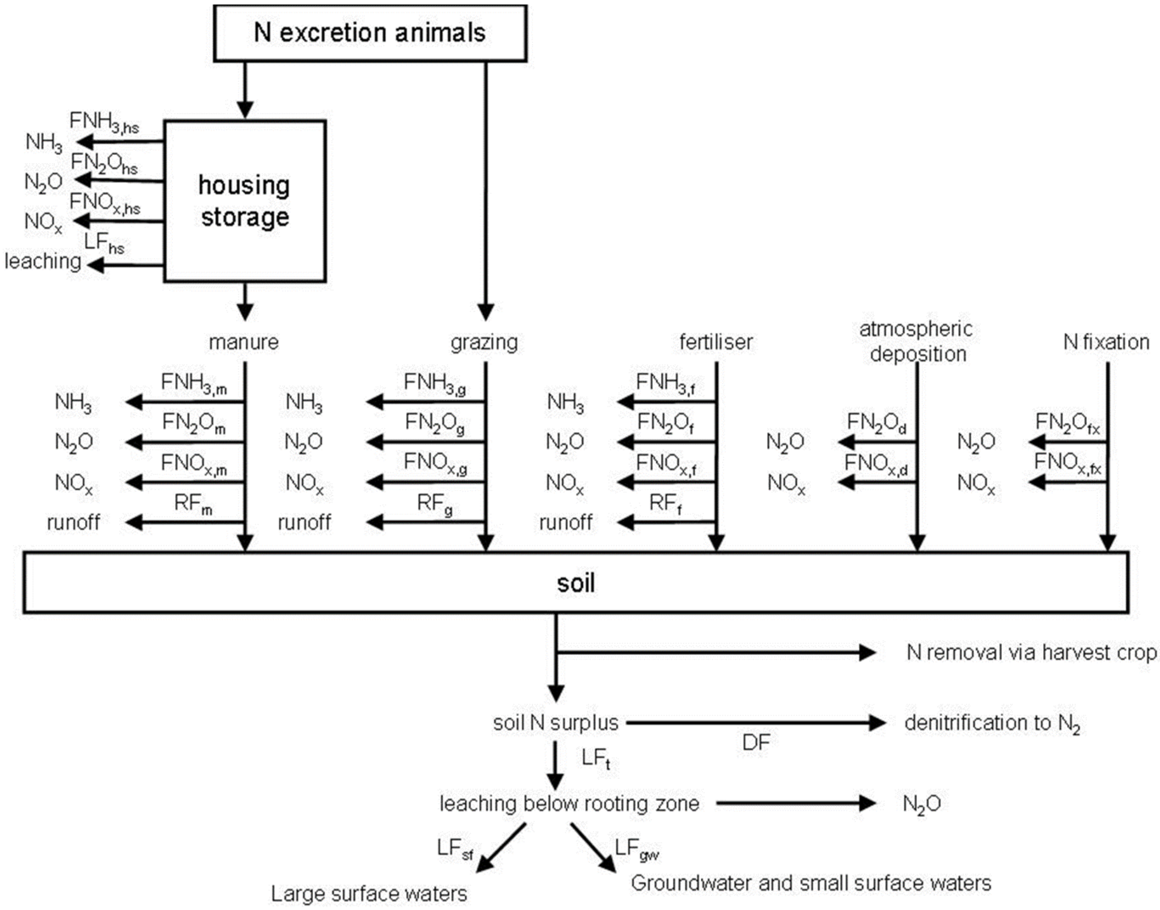

Figure 2. Schematic presentation of the N flows and fractionations, and the calculation procedure in MITERRA-EUROPE.

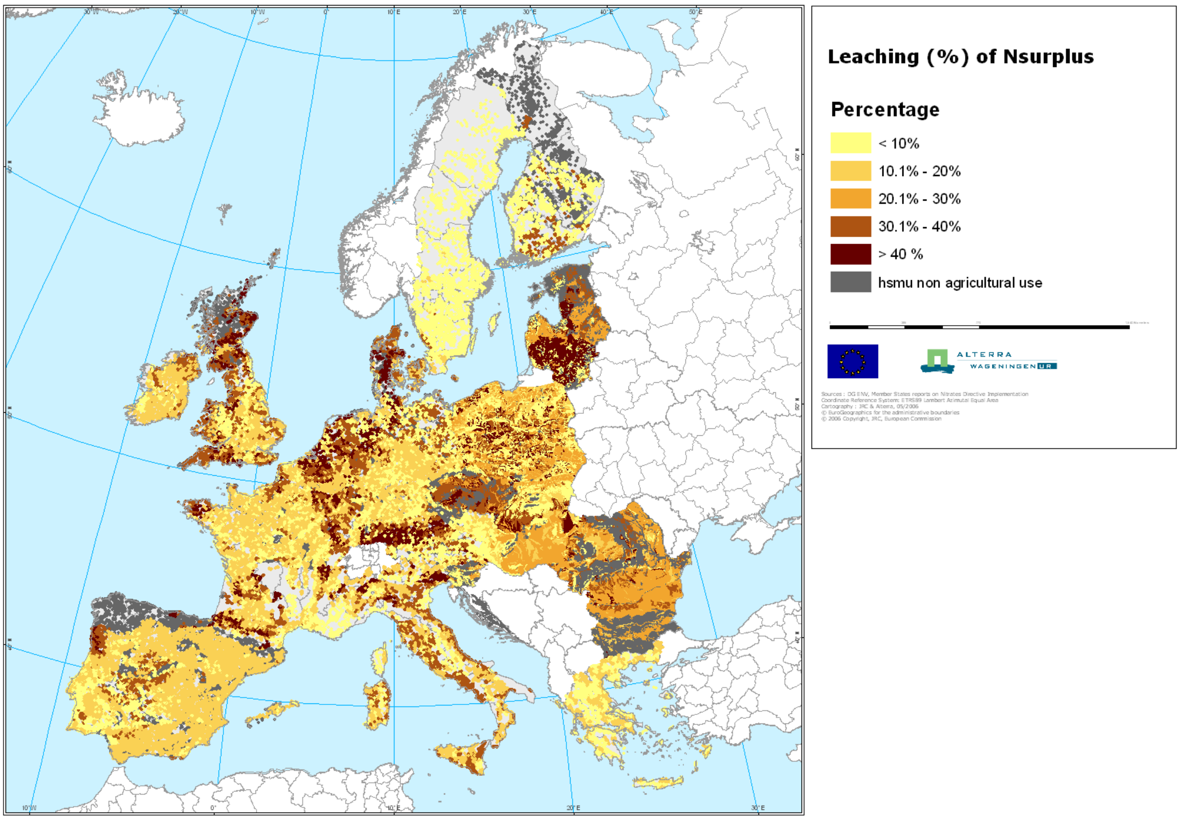

Figure 3. Leaching fractions in % of the N surplus, used as input in MITERRA-EUROPE (Velthof et al., 2009).

3.2.2 **Measures and scenarios**

The effect of balanced N fertilization and the growth of cover crops were assessed with MITERRA-EUROPE.

Balanced N fertilization

A detailed description of the balanced N fertilization measure in MITERRA-EUROPE is given in Velthof et al. (2007; 2009). Briefly, the total supply of plant-available N is equal to the total N demand of the crop. The crop N demand is calculated as the total N content of the crop (harvested part + crop residue) times an efficiency factor. Crops are not able to take up all N in the soils, because of limited density of roots in the soil. It is assumed that on average 25% more available N must be present in the soil than the amount of N in the harvested crop and crop residue. This factor differs among crops (different rooting systems) and regions (different soils and growing conditions), but as a first approach one efficiency factor is used. If the amount of plant-available N is higher than the crop demand, less N must be applied in order to achieve balanced N fertilizer application. Only the mineral N fertilizer input is decreased. However, most farmers always will apply some fertilizer and they will not only apply manure (e.g. because they do not have the equipment, manure is not easily available, they are afraid of seeds of weed in manure, cannot apply manure on wet soils with heavy machinery etc.).

Cover crops

Based on a literature survey and meta-analyses in the FAIRWAY project WP4 (D.4.4), an average reduction of N leaching by 45% was assumed. In addition we assume that N losses through surface runoff are reduced by 25%, following Velthof et al. (2009). When the cover crop is incorporated into the soil, the N taken up by the cover crop becomes available for the following main crop. This means that the amount of N supplied by fertilizer applications during the following growing season can be reduced. Hence, we assumed a reduction in N fertilizer application based on the amount N in the cover crops. Data on CN ratios in cover crops are scarce, and show quite high variation, with low CN ratios for leguminous cover crop species and higher ratios for non-legumes. We assumed an average CN ratio of 35, which results in an average uptake of 42 kg N/ha by the cover crop. This amount is added to the crop residues in the model calculations, and part of this N is mineralized over time and becomes available for the following crop. The model calculates the amount of mineral N fertilizer that can be saved as a result. Scenarios were defined in which cover crops were either used in isolation (resulting in reduction of leaching of 45%), or in combination with balanced N fertilization, taking the N release from incorporated crop residue into account.

The level of implementation of cover crops was derived from Eurostat data at NUTS II level from the agri-environmental indicator ‘Soil Cover’, which is based on information from the Farm System Survey (FSS) of 2016. This indicator provides information on the soil cover and distinguishes the following classes: normal winter crop, cover crop, multi-annual plants, plant residues and bare soil. The current cover crop share has been derived from these data (Figure 4). In total, the area under cover crops in 2016 was about 7.6 million ha in the EU-28 (Figure 4). The technical potential of cover crop implementation was set by the area of land that was classified as ‘bare soil’ or ‘plant residues’ in 2016. For the scenarios, we assumed that cover crops could be applied on 40 to 80% of this technical potential (Figure 5), which would increase the total area under cover crops to 16.8 to 33.7 million ha. For some of the NUTS II regions no complete information was available on soil cover in the Eurostat data, this area for which no data was recorded was disregarded during the calculations.

Scenarios

The reference scenario was the year 2017 with cover crops implementation in NUTS II regions according FSS 2016. The following six scenarios with measures were used to calculate the changes in NO3 leaching, N runoff, and other N emissions with MITERRA, based on the reference year 2016:

1. without cover crop implementation.
2. with a reference cover crop implementation rate FSS 2016 and balanced N fertilization.
3. with a cover crop implementation rate of 40% of the technical potential.
4. with a cover crop implementation rate of 40% of the technical potential and balanced N fertilization.
5. with a cover crop implementation rate of 80% of the technical potential.
6. with a cover crop implementation rate of 80% of the technical potential and balanced N fertilization.

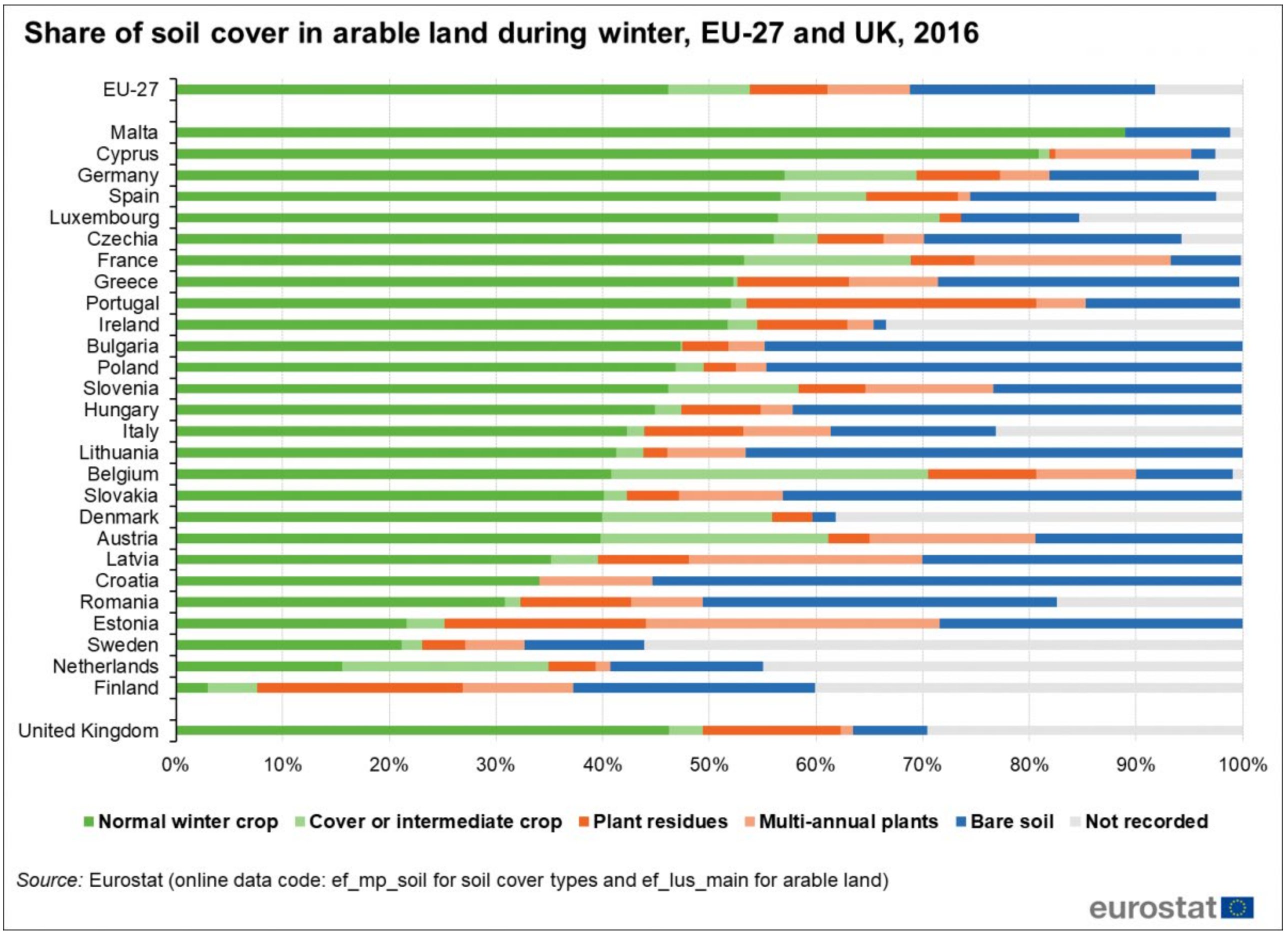

Figure 4. Share of soil cover in arable land during winter EU27 UK 2016 (Source: FSS, 2016; Eurostat).

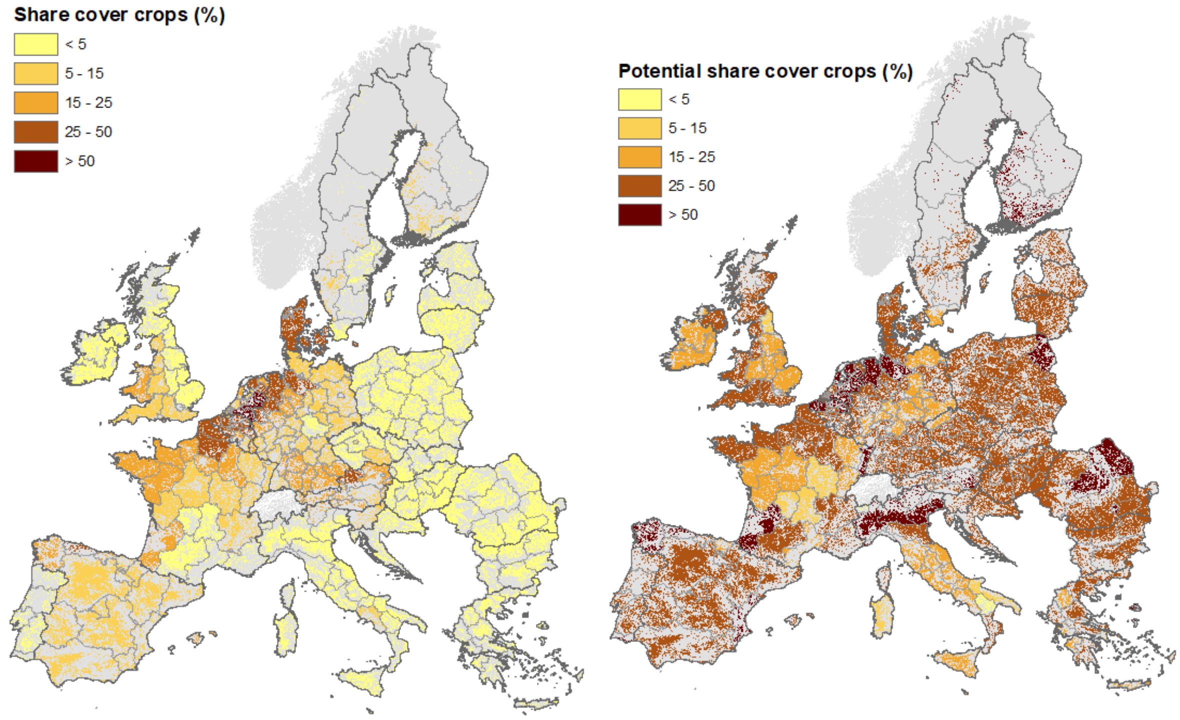

Figure 5. Current cover crop share on arable land (left), based on FSS 2016, and the potential cover crop share (right) as used for the simulation.

3.3 Results and discussions

Figure 6 shows a map of the EU of the calculated nitrate concentration in reference year 2016 and for the scenario with balanced N fertilization. Figure 7 shows the EU map with results of N leaching and runoff in kg N per ha per year in the reference year 2016 and the change in leaching compared to the reference for three of the six scenarios. In Table 2, the results of simulations of the measures are summarised on EU-28 level for the main environmental N indicators, including emissions to nitrous oxide (N_2O) and ammonia (NH_3).

Calculated nitrate concentration exceeds the threshold of 50 mg per l in regions with intensive agricultural systems, including the Netherlands and Flanders (Belgium) and regions in Spain and Greece (Figure 6).

Balanced N fertilization strongly reduced nitrate leaching (Figure 7) and improved water quality (Figure 6). On EU scale, N leaching decreased with 22%, N surface runoff by 8%, and N leaching to surface water by 19%. Inputs of N fertilizer were reduced by 13% across the EU when balanced N fertilization was applied. On average, the soil N surplus decreased by 16%. Balanced N fertilization also reduced the emissions of N_2O (5%) and NH_3 (3%) on EU level. Clearly, balanced N fertilization, in which the N application is adapted to the N demand of the main crop is a promising measure to reduce NO_3 leaching to groundwater as well as gaseous N emissions to the atmosphere. This measure requires specific knowledge of the N demand of the main crop (both in total, depending on the expected yield, and over time during the growing season), the N supply by the soil and by applied organic fertilizers, 4R strategies (N application ar Right time, Right place, Right rate, and Right type) that may enhance the efficiency of added N, and unavoidable N losses through denitrification (gaseous losses of N_2 and N_2O) or nitrate leaching during wet periods in the growing season. Farmers can use decision support tools (see WP3 of FAIRWAY), soil and plant analyses, and precision farming techniques to implement successful N balance fertilization practices.

The growth of cover crops after the main crop is selected as a most promising measure in both WP4 and WP7 of FAIRWAY. The literature review in WP4 showed an average reduction of 45% of NO_3leaching by cover crops. In addition, the release of N from cover crops after incorporation into the soil can reduce the need for N fertilizer during the following growing season, thereby mitigating the risk of N leaching, and N_2O and NH_3 emissions. Cover crops are already commonly grown in many regions in EU, especially Denmark, the Netherlands, Flanders, and parts of Germany and France (Figures 4 and 5). In these regions, the growth of cover crops is part of the Nitrates Directive action plan to reduce nitrate leaching. In the scenario where the use of cover crops was omitted, the average NO_3 leached to groundwater and N leached to surface water was 2-4 percent higher on EU level than in the reference scenario with cover crop 2016 implementation (Table 2).

Increasing the area of cover crops to 40% of the technical potential reduced N leaching to ground and surface water by 2 – 4% on EU level (Table 2). Application of balanced N fertilization in combination with cover crops (at 40% implementation) strongly reduced N leaching; on EU level by 19% for nitrate leaching. Implementation of cover crops to 80% of the technical potential further reduced N leaching, up to 36% for nitrate leaching in combination with balanced N fertilization (Table 2). Model results showed that using a combination of balanced N fertilization and cover crops could lead to large reductions in N leaching and runoff, specifically in Flanders, the Netherlands, and the northern part of Italy (Figure 7). A reduction of more than 20% in N leaching and runoff by implementation of a combination of cover crops and balanced N fertilization could be achieved in many areas in the EU, including Flanders, the Netherlands, parts of Germany, the northern parts of Spain and Portugal, the northern part of Italy, regions in Poland, Czech republic, Croatia, Bulgaria, and Greece (Figure 7).

Additionally, the effect of combining N balanced fertilization and the growth of a cover crop is larger than the sum of the single effects of both measures. E.g., balanced N fertilization reduces total N leaching and runoff with 17%, and the growth of cover crop at 40% implementation reduces total N leaching and runoff with 3%, whereas the combination of both measures results in a reduction of 22%. The synergy of these measures is due to the fact that the combination of both measures accounts for the N supply from incorporated cover crop, by which N fertilizer input can be reduced (in this example 15% with the combination of measures, compared to 13% reduction with only balanced N fertilization).

As a trade-off, implementation of cover crops, may increase N_2O emissions and N losses through denitrification (Table 2). This is due to incorporation of organic C and N, which increases denitrification (the process during which N_2O is produced). This effect has also been reported in review studies (e.g. Basche et al., 2014). However, when the growth of a cover crop is combined with balanced N fertilization, emission of N_2O is reduced (Table 2). This shows that the risk on pollution swapping can be reduced if a combination of measures is taken.

Table 2. Relative emissions of nitrous oxide (N_2O), and ammonia (NH_3), N leaching to groundwater, N surface runoff, N leaching to surface waters, total N leaching + surface runoff, N surplus on the soil N balance, and N fertilizer use in EU 28 at different measures compared to the reference year 2016 (reference 2016 = 100%).

	Balanced fertilization	No cover crops in reference year	Cover crops 40%	Balanced fertilization + cover crops 40%	Cover crops 80%	Balanced fertilization + cover crops 80%
N_2O emission	95%	99%	101%	95%	102%	95%
N leaching to groundwater	78%	104%	96%	71%	92%	66%
N surface runoff	92%	102%	98%	89%	96%	86%
N leaching to surface water	81%	103%	96%	75%	92%	69%
Total N leaching and runoff	83%	103%	97%	78%	93%	73%
NH_3 emission	97%	100%	100%	96%	100%	96%
N soil surplus	84%	100%	100%	80%	100%	77%
N fertilizer use	87%	100%	100%	85%	100%	82%

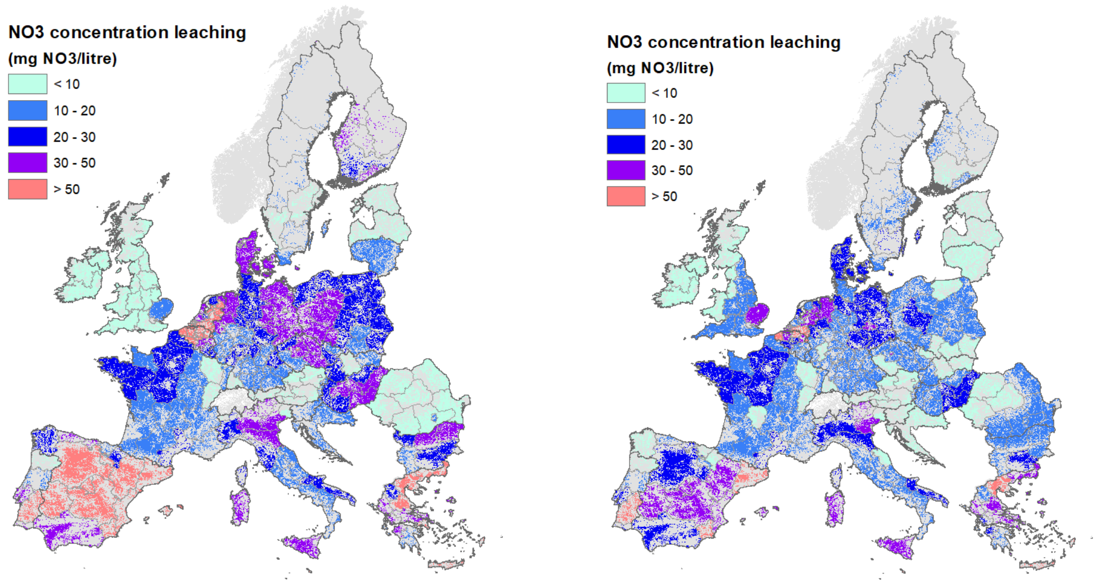

Figure 6. Calculated nitrate concentration (in mg NO_3/L) in water leaching from the rooting zone from agricultural soils in the reference year 2016 (left) and the scenario with balanced N fertilization.

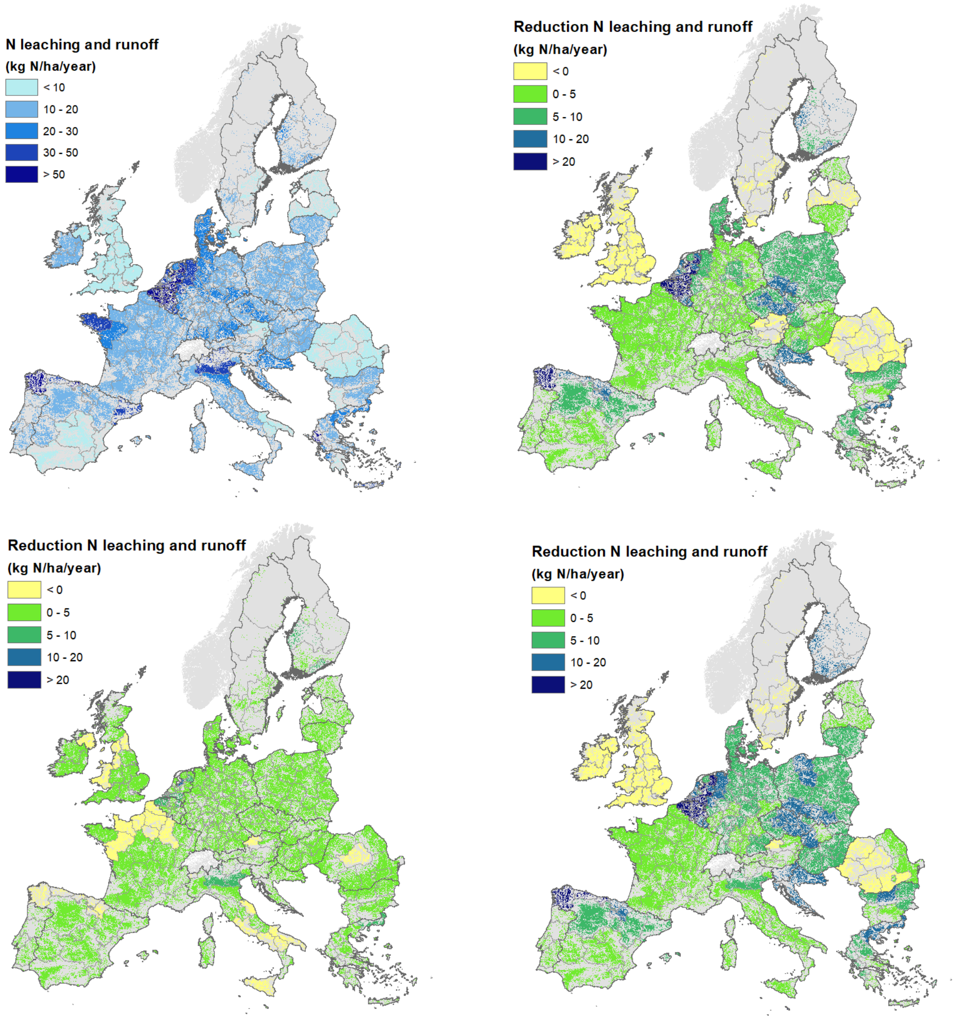

Figure 7. N leaching and runoff (kg N/ha/year) in the reference year 2016 (upper left figure), and reduction in N leaching compared to the reference for balanced N fertilization (upper right figure), cover crops (80% implementation; lower left figure), and the combination of balanced N fertilization and cover crops (80%; lower right figure).

3.4 Conclusions

The main conclusions of the assessments of most promising nitrate measures using MITERRA-EUROPE are:

- Balanced N fertilization, in which the N application is tuned to the N demand of the crop, is a promising measure to reduce nitrate leaching to groundwater and gaseous N emission to the atmosphere. Balanced N fertilization reduced nitrate leaching to groundwater on EU scale in 2016 by 22%, N surface runoff by 8%, and N leaching to surface water by 81%. Balanced N fertilization also reduces the emissions of N_2O (5%) and NH_3 (3%).
- Cover crops are already grown in many regions in EU, and especially in Denmark, the Netherlands, Flanders and parts of Germany and France. Omitting cover crops in 2016 resulted in a 3% increase in the nitrate leaching to groundwater and N leaching to surface water across the EU level.

- Increasing the area of cover crops to 40% of the technical potential reduced N leaching to ground and surface water by 3%. Implementation of cover crops to 80% of the technical potential further reduced N leaching (7%).
- Application of balanced N fertilization in combination with cover crops (at 40% implementation) strongly reduced N leaching; on EU level by 19% for nitrate leaching up to 36% for nitrate leaching in combination with balanced N fertilization.
- Reduction of more than 20% in N leaching and runoff by implementation of a combination of cover crops and balanced N fertilization can be achieved in many areas in EU, including Flanders/Belgium, the Netherlands, parts of Germany, the northern parts of Spain and Portugal, the northern part of Italy, regions in Poland, Czech republic, Croatia, Bulgaria, and Greece.
- The reduction of the combination of N balanced fertilization and the growth of a cover crop on N leaching is larger than the sum of the single effects of both measures.
- Cover crops increase N_2O emission. However, when the growth of a cover crop is combined with balanced N fertilization, emission of N_2O is reduced. The risk on pollution swapping can be reduced if a combination of measures is taken.

4. ASSESSMENT OF PESTICIDE POLLUTION IN THE NETHERLANDS USING GEOPEARL

Peter Schipper, Yanjiao Mi-Gegotek, and Erik van den Berg, Wageningen Research

4.1 INTRODUCTION

The overall objective of the FAIRWAY project is to review current approaches and measures for the protection of drinking water resources against pollution caused by pesticides and nitrate from agriculture. Further, the project goes on to identify and further develop innovative measures and governance approaches for a more effective drinking water protection. This Chapters is a result of the assessment of the effect of most promising activities to prevent and reduce pesticide pollution at national level using the integrated assessment tool GeoPEARL (Tiktak 2002, Tiktak 2004).

4.1.1 **Background**

Safe drinking water is vital for the health and wellbeing of all. In Europe, groundwater is the most important source (50%) for the production of drinking water (EU 2016). Since groundwater moves slowly through the subsurface, the impact of anthropogenic activities may last for a relatively long time, which means that pollution that occurred some decades ago — whether from agriculture, industry or other human activities — may still be threatening groundwater quality today and, in some cases, will continue to do so for several generations to come. For this reason, the WFD requires measures to prevent or limit the input of pollutants into groundwater, and the GWD emphasises that upward pollution trends must be identified and reversed. However, many groundwater bodies including those that are used to produce drinking water in Europe are polluted by pesticides and agriculture is a major driver of failure of good chemical status to EU groundwater and surface waters (EU 2019).

In the Netherlands, 60% of the public drinking water supply is prepared from groundwater. Recent evaluations of the quality of the public drinking water resources in the Netherlands (Driezum 2020; Kools 2019) show that traces of pesticides or degradation products were found at least once in 70 of the 99 phreatic groundwater abstractions for drinking water (71%). Half of these extraction sites included one or more exceedances of the quality standard (0.1 µg/l) for one or two substances. Traces of pesticides or degradation products were also found in the extraction wells of 19% of the non-phreatic groundwater abstractions (abstraction wells under a clay layer), in 9% of which above 0.1 µg/l. A recent interim evaluation of the crop protection in the Netherlands (Tiktak 2019) concluded that progress has been made in many areas (less residues in products and water), thanks to the efforts of the agricultural sector, customers and governments, but the interim policy goals have not been achieved, including the targets for reduction of exceedances in water and drinking water sources.

Monitoring of the Dutch groundwater quality in the shallow aquifers, at approximately 10 and 25 m below ground level, show that residues of pesticides were found in the majority (62%) of the monitoring screens in the periode 2015-2019 (Loon 2020). In 34% of the monitoring wells, concentrations exceed the quality standard of 0.1 µg/l if the human-relevant metabolites are also included (such as ampa). In 7% of the measuring screens the sum of the substances found exceeded the sum standard of 0.5 µg/l.

For the approval of an active substance wiothin the EU, the risk of leaching to ground water need to be assessed according to EC Regulation 1107/2009. The registration of plant protection products for agriculturale use is done at a member state level. In the Netherlands, a tiered approach is followed for the assessment of the risk for leaching to groundwater (Van der Linden et al., 2004). In the first tier, the 80th percentile in time of the annual average leaching concentration at a target depth of 1 m (PEC80) is obtained with FOCUS PEARL for the FOCUS Kremsmünster scenario, according to the European groundwater assessment procedure for approval of active substances (Anonymous, 2014). The potential area of use is not taken into account in the first tier. The second tier involves calculations with GeoPEARL, which calculates the 90th areal percentile of the median leaching concentration at a target depth of 1 m under the potential area of use (PEC90). For the groundwater protection areas, a safety factor of 10 was introduced based on a study by Kruijne et al. (2004). To protect these areas the calculated leaching concentration at the target depth of 1 m, in either a tier 1 calculation using FOCUS PEARL or a tier 2 calculation using GeoPEARL, must be <0.01 μg L-1. In cases where the predicted leaching concentration is > 0.01 μg L-1 but ≤ 0.1 μg L-1 it should be indicated on the label of the product that application in groundwater protection areas is prohibited.

4.1.2 **Objective**

The aim of Task 7.3 is to provide recommendations of the most promising package(s) of measures, policies, governance models and tools at national and EU level using the results of WP2-WP6 and assessments with integrated assessment tools as MITERRA-EUROPE (see Chapter 3) and GeoPEARL. GeoPEARL uses agricultural and pedo-climatic data to calculate emission of pesticides to the environment and can be used to assess the effectivity of measures to decrease pesticide pollution of groundwater at national scale (Verschoor 2019). These assessments will deliver input for the recommendations of the most promising approaches to prevent and limit diffuse pesticide pollution of groundwater resources that are used for drinking water production.

4.2 METHODOLOGY

4.2.1 **Selection of areas, crops, substances and scenario's**

The effectiveness of measures that can reduce leaching of pesticides (residues of plant protection products) was assesed with the spatially distributed model GeoPEARL (Tiktak 2002). The calculations are made for five crops (potatoes, asparagus, maize, grass and leek) and groundwater protection zones of seven drinking water locations in the south of the Netherlands[3]. These seven areas (see figure 8) are part of the Fairway Case "Schoon water Brabant", and according to the actual Drinking Water Protection files of the province Brabant and evaluation of actual situation of the Dutch drinking water sources (Kools 2019), these are most vulnerable for diffuse pesticide pollution by agriculture.

[3] Delineated Groundwater Protection Areas based on travel times of groundwater in the aquifer towards the well field (usually 25 years). To date, the total surface area of these protection areas is 5% of the total land surface in the Netherlands.

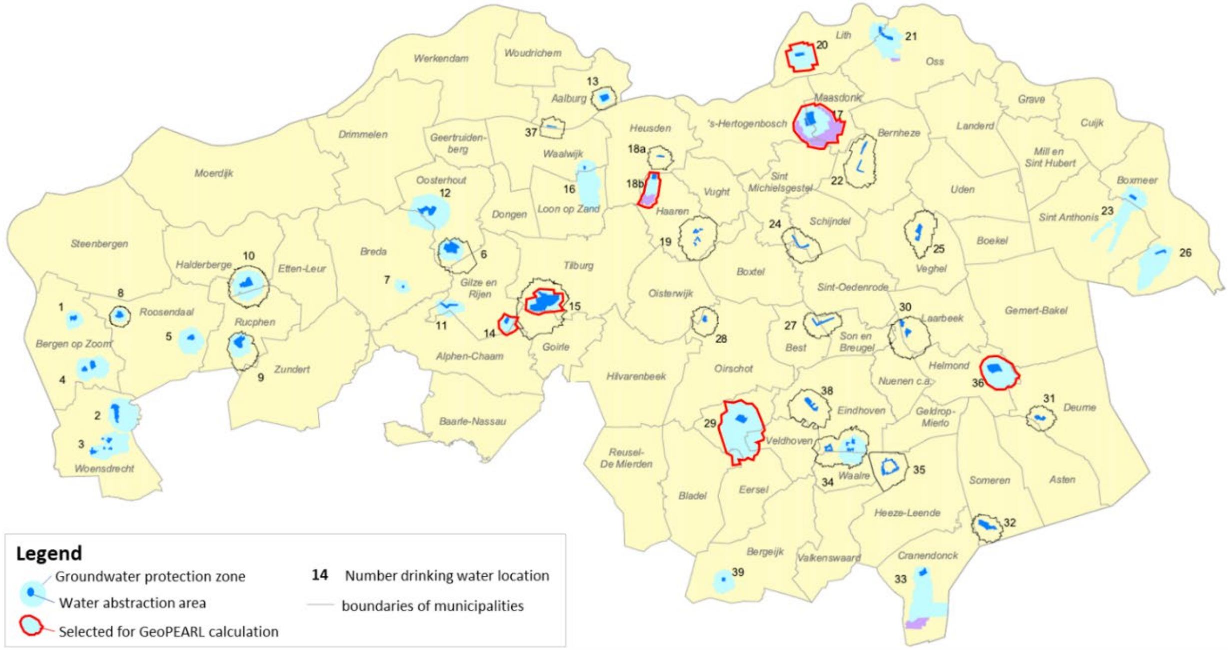

Figure 8. Selected groundwater protection areas drinking water locations N-Brabant: Gilze (14), Gilzerbaan 15), Nuland (17), Helvoirt (18b), Lith (20), Vessem (29) and Helmond (36).

For a baseline (reference) scenario, leaching from agricultural sites is calculated for the most (top 5) commonly used agents per crop in the Netherlands, according to a national survey in 2016 (statistic Netherlands, www.statline.nl) and sales figures of permitted crop protection products. The selected crops are potatoes, asparagus, grass, maize and leek. The(23 selected pesticide substances are listed in table 4 (next section).

Based on these calculations, the common application practices and experiences gained in the project "Schoon Water Brabant" (Hoogendoorn 2020), we have further narrowed down the list of the selected agents for every crop: glyphosate for potatoes, metribuzin and glyphosate for asparagus, mecoprop-P, 2,4-D and glyphosate for grass, bentazone and glyphosate for maize, and oxamyl for leek. The following scenarios with measures are calculated, including reducing application doses, reducing application frequencies, and replacing certain agents with cleaner options:

- Potatoes: Glyphosate, dose of 50%
- Asparagus: Glyphosate, dose of 50%
- Asparagus: Glyphosate, one in stead of two applications
- Asparagus: Metribuzin, two in stead of three applications
- Grassland: Glyphosate, dose 50%
- Grassland: Mechanical treatment, no pesticide application
- Maize: Glyphosate, dose of 50%
- Leek: Oxamyl, dose of 50%
- Leek: Azoxystrobin, dose of 50%
- Leek: Azoxystrobin, one in stead of two applications

These calculations also give an indication of the effectiveness of promosing measures like buffer stripes, biological and mechanical crop protection methods that are assiciated with less chemical applications.

4.2.2 The GeoPEARL leaching model

The GeoPEARL leaching model is based on the spatial schematization of the integrated modeling system STONE (Wolf, Beusen et al. 2003) for calculating nutrient emissions from agriculture in the Netherlands and the parameterization of its hydrological model SWAP (Kroes 2009). This schematization contains 6405 unique different plots with respect to land use, hydrogeology (soil type, soil profile, groundwater level, seepage) and meteorological region. Based on these conditions, 382 unique STONE-plots have been selected. These plots also cover areas outside the seven groundwater protection zones. For GeoPEARL applications, the plots are combined with maps of 24 crops in Dutch agriculture.

Each GeoPEARL plot is represented by a 1-D soil column. The model PEARL (Van den Berg 2016) is run to calculate for each plot the median leaching concentration at a depth of 1.0 m for a period of 20 years. After the completion of all PEARL runs, the spatial 90th percentile is calculated for the area of use. Details on the calculation of the area of the GeoPEARL crops are included in table 2.1. GeoPEARL version 3.3.3 was used for this study.

Table 3. Groundwater protection and water abstraction areas of the selected drinking water locations, and the areas of the representative STONE-units used for the GeoPEARL calculations.

Name of Drinking water locations	groundwater protection zone	water abstraction area	representative STONE-units in the Netherlands (ha) selected for GeoPEARL			
	(ha)	(ha)	arable	grass	maize	total
Gilze	131	17	36	8	51	96
Gilzerbaan	551	320	914	2813	2184	5911
Helmond	696	91	1224	3305	2164	6693
Helvoirt	651	19	30	22	19	72
Lith	505	2	7	71	188	266
Nuland	652	108	376	5436	2228	8040
Vessem	1822	58	1664	3891	2940	8494
total	5009	615	4251	15547	9773	29571
total number selected STONE-plots (calculation units)			121	132	129	382

4.3 Results

4.3.1 Baseline scenario

The major input parameters of the selected substances and their application timing and doses, and the leaching concentrations calculated by GeoPEARL are listed out in table 4.

The (maximum) dose and timing of application is derived from the authorised uses and regulation as indicated on the lables of the permitted products. Properties of the active ingredients (molar mass, saturated vapour pressure, solubility in water) are taken from the compound properties in the Dutch National Pesticide Risk Indicator NMI version 4. The values for half-life degradation values of the substance in the topsoil system (DT50), and the coefficient for sorption on organic matter (Kom) are taken from the end-point values in the European Food Safety Authority (EFSA) peer reviewed journals.

The results are listed in table 4. The results of this baseline scenario show that for most substances (21 of the 23) the 90th percentile leaching concentrations are below 0,01 µg/l. Only for 2,4-D and Terbythylazin, the calculated concentrations were higher than 0.01 µg/l, i.e. 0.29 µg/l and 0.033 µg/l respectively. It should be noted that specific restrictions are prescribed for the use of 2,4D in the protected areas for drinking water abstractions.

These results depend largely on the input parameters, especially with respect to the half-life degradation values of the substance in the soil system (DT50), and the coefficient for sorption on organic matter (Kom). Both are the most sensitive parameters in pesticide leaching models (GeoPEARL and PEARL). The values for these parameters that are mentioned in the EFSA peer review journals differ largely. For instance, in our final calculation for Glyphosate in GeoPEARL, we have chosen the value of 3106 and 40.9 for Kom and DT50, respectively. For potatoes, when a Kom value of 9031 is used in stead of 3106, a 90 procentile of 0.001 is calulated instead of 0.005; if the DT50 value of 40.9 is replaced by 500.3, a 90 procentile of 0.009 is then generated.

To estimate the effect of measures, further calculations for the baseline scenario are made for the applications of glyphosate, metribuzin, Mecoprop-P, 2,4-D, Bentazone, Oxamyl and Azoxystrobin. The model input and results are listed in table 5. Compared to the calculations for the baseline scenario, less favorable values have been used for sorption and degradation. For this scenario, the lowest Kom and highest DT50 values for sandy soils have been selected from the EFSA peer reviews.

Table 4. Baseline scenario GeoPEARL; input of sorption and decay values, application data and doses of the most commonly used pesticide substances per crop in the Netherlands and the resulting calculated 90th percentile leaching concentrations baseline scenario.

Crops	Substance	Kom (L/kg)	DT_{50} (days)	Application Date	Dose (kg/ha)	P90 (µg/l)
Potato	Mancozeb	573.79	0.43	01-May, 15-May, 01-Jun, 15-Jun, 01-Jul, 15-Jul, 01-Aug and 15-Aug	1.4	0.00
	Propamocarb	360.96	26.48	01-May, 15-May, 01-Jun, 15-Jun 01-Jul and 15-Jul	1.0	0.00
	Prosulfocarb	1693	15.27	01-Mar	4.0	0.00
	Maleic hydrazide	26.6	1.83	01-Jul	3.0	0.00
	Glyphosate	13050	16.99	01-Mar	2.16	0.00
	Difenoconazole	92	3760	01-Jul, 15-Jul 01-Aug and 15-Aug	0.125	0.00
	Clomazone	128.3	27.3	01-Apr	0.09	0.00
	Rimsulfuron	47	10.8	01-May and 01-Jun	0.01	0.00
Asparagus	Mancozeb	573.79	0.43	01-Jul, 15-Jul 01-Aug and 15-Aug	2.0	0.00
	Glyphosate	13050	16.99	01-Mar	2.16	0.00
	Pyridate	360.96	26.48	01-Jun and 01-Jul	0.45	0.00
	Metribuzin	1693	15.27	01-Apr, 15-Apr and 01-May	0.21	0.00013
	Isoxaben	26.6	1.83	01-May	0.25	0.000038
Grass	Glyphosate	13050	16.99	01-Mar	2.16	0.00
	MCPA	74	25	01-Mar	1.8	0.000039
	2,4-D	24	29	01-Mar	1.0	0.29
	Fluroxypyr-meptyl	19550	0.32	01-Mar	0.216	0.00
	Mecoprop-P	59.8	21	01-Mar	1.2	0.000014
Leek	Oxamyl	11.67	11.85	01-Mar	0.2	0.0063
	Pendimethalin	6658	146.71	01-Dec	0.8	0.000025
	Pyridate	7.1	1.59	01-Mar	0.9	0.00
	Prothioconazole	2556	0.82	01-Jun, 01-Jul and 01-Aug	0.192	0.00
	Ametoctradin	2335	1.8	01-Jan and 01-Feb	0.21	0.00
Leek	Azoxystrobin	423	180.7	01-Mar	0.25	0.0048
Corn	Dimethenamid-P	133.4	25.63	01-Apr	1.02	0.000004
	Terbuthylazin	130.22	104.8	01-May and 01-Jun	0.165	0.033
	S-metolachlor	132.7	19.89	01-May	0.864	0.000001
	Glyfosate	13050	16.99	01-May	2.16	0.00
	Fluroxypyr-meptyl	19550	0.32	01-Apr	0.288	0.00

Table 5. GeoPEARL results for Glyphosate, Metribguzin, Mecoprop-P, 2,4D, Bentazone, Oxamyl and Azoxystrobin using the lowest input values for Kom and highest DT50 values mentioned in the EFSA peer review journals.

Crops	Substance	Kom (L/kg)		DT_{50} (days)		Application	Dose	P90	Number of calculation units
		Model input	Range EFSA[1]	Model input	Range EFSA[1]	Date	(kg/ha)	(µg/l)	
Potatoes	Glyphosate	3106	503.8-34200	40.9	40.9	01-Mar	2.16	0.005	115
Asparagus	Glyphosate	3106	503.8-34200	40.9	40.9	01-Mar 01-Apr	2.16	0.002	94
	Metribuzin	21.6	Not available	16.8	10.2-17.3	01-Apr 15-Apr 01-May	0.21	0.019	94
Grass	Glyphosate	3106	503.8-34200	40.9	40.9	01-Mar	2.16	0.0000010	143
	Mecoprop-P	6.84	Not available	8.05	Not available	01-Mar	1.2	0.012	143
	2,4-D	38	32.8-73.5	26	Not available	01-Mar	1.0	0.012	143
Maize	Glyphosate	3106	503.8-34200	40.9	40.9	01-May	2.16	0.00073	136
	Bentazone	7.71	1.7-45	8.9	8.9	01-Apr	0.96	0.031	136
Leek	Oxamyl	5	4.6-22.6	9.3	9.3	01-Mar	0.2	0.021	99
	Azoxystrobin	248	173.3-412.7	180.7	Not available	01-Mar 11-Apr	0.25	0.049	99

4.3.2 **Measures**

For mitigation scenarios, the input parameters application (date and dose), and resulting leaching concentrations calculated by GeoPEARL are listed out in table 6. For comparising, the leaching concentrations calculated for the baseline scenario (derived from table 4) are also uptaken in the last column of table 6. Figure 9 shows the spatial distribution of the calculated 50 percentile leaching concentrations.

The mitigation scenarios show that leaching to groundwater can be reduced by a large extend: 50 % less dose can reduces leaching concentrations with more then 50 % (up to more then 80%) for the use of glyphosate and azoxystrobin. Also no late application can reduce leaching significantly.

4.1 DISCUSSION

Decreasing the amount and the frequency of pesticide application, largely decreased the pesticide concentration in leached water. Also alteration of pesticides with less harmful products or mechanical methods can reduce leaching to groundwater and thus protect drinking water resources to a large extent.

Model simulations for the baseline scenario show larges differences if different model input values are used for sorption and degradation. From field experiments and information gathered from the EFSA peer review journals (Europan Food Safety Authority) and the Pesticide Properties DataBase (PPBD, University of Hertfordshire, UK), it can be concluded that the uncertainty margins of these values are very large. For instance, from a field experiment to determine the movement of bentazone in the south of Brabant (Boesten and Van der Pas 2000), a half live (DT50) of 206 days at 5 °C was derived and sortpion coefficent (KL value) of 0.105 $dm^3\ kg^{-1}$, while from the ESFA a DT50 of 8.9 and a Kom range of 1.7 to 45 is mentioned. This illustrates the large uncertainties of these values wich strongly determine the risks for leaching to groundwater.

To calculate valid 90 percentile values, a minimum of 250 calculation plots in the GeoPEARL is required. This precondition is not met, which means that larger margins of uncertainty must be taken into account for the interpretation of the 90 percentile values.

Table 6. GeoPEARL inputs of different pesticides, and their leaching concentrations (mitigation scenarios)

Crops	Substance	Measure	Application Date	Dose (kg/ha)	P90 measure (µg/l)	P90 baseline (µg/l)	Effect measure (decrease)
Potatoes	Glyphosate	Dose 50%	01-March	1.08	0.00094	0.005	81%
Asparagus	Glyphosate	Dose 50%	01-March 01-April	1.08	0.00031	0.002	85%
Asparagus	Glyphosate	1 in stead of 2 applications	01-March	2.16	0.00058	0.002	71%
Asparagus	Metribuzin	2 in stead of 3 applications	01-Apr 01-May	0.21	0.012	0.019	37%
Grass	Glyphosate	Dose 50%	01-March	1.08	<0.00005	0.000001	>90%
Grass	Mechanical	No application	/	/	0		(100%)
Maize	Glyphosate	Dose 50%	01-May	1.08	0.00012	0.00073	84%
Leek	Oxamyl	Dose 50%	01-March	0.1	0.0092	0.021	56%
Leek	Azoxystrobin	Dose 50%	01-March 11-April	0.125	0.0086	0.049	82%
Leek	Azoxystrobin	1 in stead of 2 applications	01-March	0.25	0.0080	0.049	84%

The GeoPEARL model is not designed to calculate concentrations of pesticides in groundwater at specific locations. Validation with measurements from national and regional groundwater quality monitoring wells is not possible, taken into account the uncertainties of the (legal) applications in practice, the local variable conditons that determine the behaviour and movement in the soil and groundwater and the decay between the time of infiltration and sampling in the monitoring well. In addition, the neccecary input data for sorption and degradation (DT50) derived from field study results vary a lot and observed concentrations in groundwater can origin from other (not agriculture) sources, such as infiltrating surface waters or applications in urban areas.

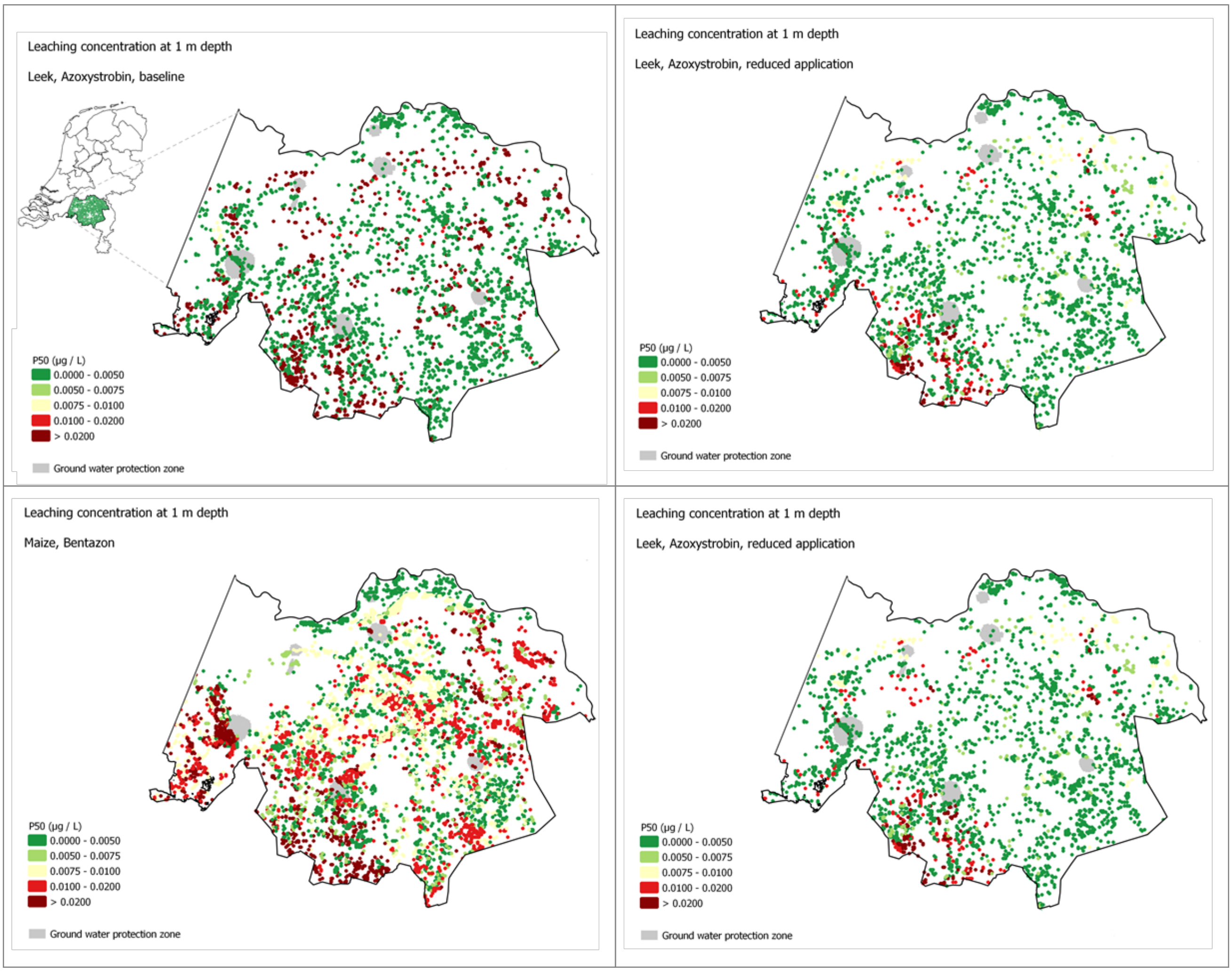

Figure 9. 50-percentile leaching concentrations calculated with GeoPEARL for the use of Azoxystrobin on leek (standard use and 1 in stead of 2 applications), Bentazon and glyphosate on maize (standard application).

4.2 Conclusions

The pesticide leaching to groundwater in Dutch soils where the leaching conditions are representative for the groundwater protection zones the North-Brabant Province were calculated with the spatially distributed model GeoPEARL. Further conceptual mitigation scenarios were used to explore the leaching reduction potential of different management strategies.

For most of the substance – crop – application combinations assessed in this study, the leaching concentrations at a depth of 1.0 me were well below the leaching criterion of 0.1 ug L-1. For some substance – crop – application combinations the 90th percentile leaching concentration this value or the value for groundwater protection areas. For most of the substance – crop – application combinations assessed in this study, the leaching concentrations at a depth of 1.0 me were well below the leaching criterion of 0.1 ug L-1. For some substance – crop – application combinations the 90th percentile leaching concentration this value or the value for groundwater protection area

The mitigation scenarios show that leaching to groundwater can be reduced. A low dosage results in less leaching and replacing a chemical treatment for herbicde control by a mechanical one avoids leaching to groundwater altogether. The timing of the application is also important to consider, as autumn applications result in higher leaching concentrations compared to spring applications. The leaching of the active substance and its metabolites depends strongly on the sorption on organic matter and the degradation half-life in soil. Therefore, it is important to check the values used for these parameters and take the uncertainty in these values into account. So for the assessment of the risk of leaching to groundwater it is important to collect data on these substance properties that have been measured in soil types similar to those in the area of interest.

The model results also show that reliable and representative parameter values for substances are very important. Therefore, more field and laboratory experiments are necessary for the improvement of the model performance. Additionally, the development of good methods to interpret data from monitoring studies could also benifit the understanding of pesticide behavior.

4.3 RECOMMENDATIONS

Rational use of pesticide is important for drinking water quality control. Pesticide application dose should be sufficient but no greater than the level required for best results, and the timing of application is another important factor to consider. The adoption of the appropriate application methods by the growers should also be taken good care of.

The risks of leaching of the pesticides strongly depend on the sorption and degradation characteristics, but the values for these parameters mentioned in literature may differ largely. This demonstrates the importance of data obtained from studies using samples from soils in the area of interest.

Alternative control practices, such as the use of a pesticide with a lower leaching risk or the use of mechanical weed control should be taken into consideration.

To sum up, the following recommendations on most promising measures can be derived from the results of GeoPEARL calculations:

- Decrease input of pesticides: Consider a dosage to be applied that is lower than the maximum dosage allowed.
- Consider the application time; an autumn application has a higher leaching risk than a spring application.
- Substitution of pesticide with a comperatively high risk of leaching to groundwater by another pesticide with similar efficacy but with a lower leaching risk.

4.4 ACKNOWLEDGMENTS

We are grateful to our partner CLM in the FAIRWAY project who have contributed to provide key information about pesticide use in the Netherlands and experiences in the Dutch case study to stimulate farm measures to reduce pesticide leaching to the groundwater bodies that are used for the abstraction of public drinking water in the south of the Netherlands.

5. RECOMMENDATIONS

The aim of Task 7.3 is to provide recommendations of the most promising package(s) of measures, policies, governance models and tools at national and EU level using the results of WP2-WP6 and assessments with integrated assessment tools at national and EU level, such as MITERRA-EUROPE and GeoPEARL. Based on the key messages presented in Chapter 2 and the Appendices and the assessments on EU and National scale, the following main recommendations of the FAIRWAY project are derived.

Multi-actor platforms

- Engagement processes in multi-actor platforms require long-term investments in terms of time, resources, and facilitation. This realization should be acknowledged by project partners and funders, as well as participants, to enable management of expectations and contribution of all parties, and to avoid fatigue in the engagement processes.

Water safety plans

- During all phases of Water Safety Planning, engagement of stakeholders in the development of the methodology and content is essential. Establishing cooperation between large and small suppliers contributes to overcoming barriers for effective risk assessment and management for small suppliers.

Indicators and monitoring

- Water and nitrate transfer through geological material is not instantaneous. There is a lag time between agricultural nitrogen leaching from the fields and its impact on water quality in aquifers. This time lag should be taken into account when developing drinking water projection strategies.
- Nitrogen surplus at the farm or regional level is a useful agri-environmental indicator. However, different calculation methods are used between countries. There is a need for harmonization of the calculation method (e.g. the Eurostat gross balance methodology) and of the use of such a common approach at the European level.
- For monitoring groundwater quality, detecting pollution sources and evaluating mitigation measures it is necessary to rely on a consistent database, which enables scientists to link pollution and mitigation measures to water quality. A lot of data with relevant indicators is available on different spatial and temporal scales, but they are seldom presented in consistent databases with similar set-up. There is a need to harmonize databases in the EU member states and ease the transmission of data to compare Pressure and State indicators. There is also a need to harmonise the methods for analysing all relevant substances and to ease collection of direct or indirect data. There is also a need to solve or at least improve personal data protection related constraints.

Measures

- Implementation of measures to reduce nitrate losses should not only consider the effectiveness, and costs, but also the likelihood of (unwanted) side-effects such as pollution swapping to emissions of ammonia, nitrous oxide and phosphate.
- For measures to reduce nitrate losses, there is a discrepancy between the type of field- or trial-based measures tested and reported in literature and real-world farm-level management options that are used or reported in the case studies. Developing strategies to mitigate nitrate leaching should not be solely based on results in literature, but should also take successful experiences in practice into account.
- Reduction of pesticide pollution of drinking water resources demands a combination of input reduction, farm system redesign and point source mitigation.

- Results of the assessments of most promising nitrate measures using MITERRA-EUROPE show that balanced N fertilization in which the N application is tuned to the N demand of the crop strongly decrease nitrate leaching, and also reduces the emissions of N_2O and NH_3. Farmers can use decision support tools (see WP3 of FAIRWAY), the N surplus indicator (WP3 of FAIRWAY), soil and plant analyses, and precision farming techniques to apply N balance fertilization practices.
- Cover crops reduce nitrate leaching; the effect is largest when the growth of a cover crop is combined with balanced N fertilization, so that the N fertilizer application rate can be adjusted to the N released after incorporation of the crop into the soil.
- Results of calculations with GeoPEARL show that decreasing the input of pesticides, splitting the total application quantity over more application times (more dressings), alteration of pesticides with less harmful products and application of mechanical methods reduce leaching to groundwater and thus protect drinking water resources to a large extent.
- There are potential synergies for evidence-based practices for reducing nitrate and pesticide pollution of drinking water resources, regarding their applicability, adoptability, and costs across EU. Potential win-win solutions for all stakeholders are shown for bio beds/filters and/or constructed wetland for pesticide pollution, and changes in the application method, grassed waterways and/or changes in cropping system and crop rotation for nitrate pollution.

Decision support tools

- Decision support tools are helpful in advising farmers about best practices in the application of fertilizers and pesticides. Successful tools are simple and self-explanatory, flexible in data input and output, and should be freely available online in the local language and with a possibility to get support.
- Many farm management tools promoting smart nutrient and/or pesticide use are available, but only a few explicitly consider the impact of mitigation methods on water quality. There is a need to include measures and indicators in these tools to reduce pollution of water with nitrogen and pesticides.

Governance

- Good drinking water quality delivery requires sufficient capacity at the local level to ensure that implementation of policies and law results in effective local action. This includes feedback mechanisms and intersectoral learning.
- Improving correlations between directives, policies, objectives and requirements, including cross-referencing them, will strengthen the overall policy framework towards protection of drinking water resources from agricultural pressures.
- In the context of water resource protection, local adaptation and result-based schemes directed at the implementation of clear objectives have better environmental impacts and higher cost-effectiveness than uniform payments and greening schemes in CAP.

Scientific policy support

- Project clustering with stakeholder involvement (science, policy, stakeholders, and citizens) is a strategy to make science and research more connected to current policy challenges and stakeholder needs with the aim of establishing sustainable long-term relationships and communication flows.

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APPENDIX I ORGINAL KEY MESSAGES FROM EXCEL SPREADSHEET

Case study / WP	Key message		Source	Target audience	Outputs that include key messages	LINK with the key audience
			i.e. which FAIRWAY Task or Deliverable provides the evidence for the message	e.g. European Commission, national/regional authorities, farmers and farmers organisations, water sector, pesticide and fertilizer industry, scientific community, other parts of the project.		To which key audiences the key messages are linked? The key audiences are: EU decision makers (DM), MAPs and/or Case studies (CS). A term "local" means that the key message is releveant solely to the one CS.
CS01 Island Tunø, DK	1	Lessons can be learned which are of general importance about combining agriculture with groundwater protection.	D3.2, D2.5, D6.2	European Commission, local MAPs, farmers and farmers organisations, water sector, public authorities, scientific community, other parts of the project	Infographic (14.5.2020), Scientific paper (Kim et al., 2020), Video (in progress 2021),	CS
	2	Proved and acknowledged better management practices and technology development can improve water quality and create groundwater protection.	D3.2, D2.5, D6.2	European Commission, local MAPs, farmers and farmers organisations, public authorities, scientific community, other parts of the project	Scientific paper (Kim et al., 2020), Scientific paper (Graversgaard et al., 2021 – in progress)	CS
CS02 Aalborg, DK	1	Better dialogue can combine groundwater protection and agricultural production.	D2.2, D2.3, D2.5, D3.2, D5.2	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, scientific community, other parts of the project	Workshop with WaterProtect (2.6.2019) Infographic about working hypotheses (27.6.2019) Infographic about groundwater protection (11.5.2020) Scientific paper (Kim et al., 2020) Workshop with stakeholders (28.06.2021)	CS
	2	Proved and acknowledged better management practices and technology development can improve water quality and create groundwater protection.	WP5		Infographic about Danish farmers recommendations (30.9.2020) Scientific paper (Kim et al., 2020) Scientific paper (Graversgaard et al., 2021 – in progress)	CS
	3	Participative monitoring has given farmers better commitment to groundwater protection.	WP5			local
	4	Barriers for groundwater protection have been identified.	D3.2, D2,2, D2.3, D2.5	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, scientific community, other parts of the project	Workshop with stakeholders (28.06.2021) Video (in progress) Paper based on interview with farmers and other stakeholders (Paper planned by Graversgaard et al.)	local
	5	Cost-effective solutions for the benefit of both farmers and waterworks have been achieved.	WP5		Berit: Limfjord cost-effectiveness modelling we have done, not specific for waterworks however	CS
CS03 Anglian Region, UK	1	Farm advisers are aware and knowledgeable about the impact of products on drinking water quality to provide sustainable and responsible advice to farmers.		European Commission, National/regional authorities, Farmers organisations, Water sector, Scientific community, Other parts of the project		CS
	2	Users of products (nitrate and pesticides) need to be involved, knowledgeable, accountable and responsible for sustainable use in order to maintain use of products and minimize or reduce regulation.	D2.2	European Commission, National/regional authorities, Farmers organisations, Water sector, Pesticide and fertiliser industry,Scientific community, Other parts of the project		EU DM
	3	The importance of the water industries and agricultural industries to work collaboratively.	D2.2	European Commission, National/regional authorities, Farmers organisations, Water sector, Scientific community, Other parts of the project		CS
	4	The importance and the opportunity to communicate practical and effective on farm measures and practices to policymakers - to create ownership and successful implementation.	D2.2	European Commission, National/regional authorities, Farmers organisations, Water sector, Scientific community, Other parts of the project		EU DM
	5	MAPs can work but needed to be tailored to specific circumstances,	D2.2	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, pesticide and fertilizer industry, scientific community, other parts of the project		MAP
	6	Multi actor platforms are not generic and need to be made specific to each CASE, In some cases (like England) there was already a very mature and complex set of relationships and the MAP processes must be allowed to evolve.	See report D2.5. Further detail pending for final report from the England CS We held an initial steering committee to establish a traditional MAP but there clearly too many overlaps with existing relationships.	European Commission, National/regional authorities, Farmer organisations, Water sector, Researchers		MAP, CS

	7	MAPs can increase networks, knowledge exchange and transfer, and awareness sufficient to trigger new developments	Drinking water company local catchment adviser now working on new initiatives eg herbicide stewardship programme and cover crop trials			MAP
	8	It takes many years to develop an effective MAP.	Pending WP2 report from UoL, there is evidence even within the life of Fairway of increased activity and impact of the MAP. Eg development of trust, information, building confidence over time, related associated activities, knowledge awareness of the water company. Very much a two way flow of knowledge and experience that is proving beneficial to all parties.	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, pesticide and fertilizer industry, scientific community, other parts of the project		MAP
	9	MAPs can feed into policy	Feed into policy from our MAP is indirect via MAP members who belong to bodies such as levy boards, farmers organisations and water companies	European Commission, National/regional authorities, Farmers organisations, Water sector, Scientific community, Other parts of the project		MAP
	10	MAPs need funding and the right facilitator for long term success	D2.2	European Commission, National/regional authorities, Farmers organisations, Water sector, Scientific community, Other parts of the project		MAP
	11	England Case Study Survey results	Coming later			local
	12	How we contributed and fed back from other WPs	Coming later			local
CS04 La Voulzie, FR	1	Better dialogue with farmers about their practices	WP2	Case studies, Farmers		local
	2	Better practices can improve groundwater quality even if it will be long (because of aquifer response time)	DL3.2 ; Hyojin Article; DL3.2 Leaflet	Water companies, Policies Makers (National, E.U.), Scientific community, Case study Leader, Farmers	Dissemination product: Hyojin Article -> Water company (Eau de Paris get the paper before it was published): April 2020 – correction/discussion about the article Dissemination product: Hyojin Article -> Scientific community open access article august 2020 Dissemination product: Webinar -> Policies Makers (National, E.U.), EUROPE-INBO 2020 CAP Workshop – 9th 2020	CS
	3	Importance of diversification of agricultural systems with low input crops (crops rotation improvement, pesticide decrease)	DL4.3	Case studies, Farmers	Dissemination product: DL4.3 report -> Water company Dissemination occasion/date: Discussion about the report (and the need to more dissemination) in march 2021	EU DM, MAP, CS
CS05 Lower Saxony, DE	1	Closing nutrient cycles leads to more sustainability.	WP2-tasks on Case Studies and MAPs	farmers and farmers organisations, farm advisors, local MAPs, national/regional authorities, water sector, scientific community	Dissemination product: info letters for farmers which deal with the application of (processed) organic manure; limited to max. 6 pages; online available Dissemination occasion/date: Continious information for farmers: 30.08.2016: https://www.lwk-niedersachsen.de/index.cfm/portal/6/nav/2092/article/30142.html 17.11.2016: https://www.lwk-niedersachsen.de/index.cfm/portal/6/nav/2092/article/30141.html 27.04.2017: https://www.lwk-niedersachsen.de/index.cfm/portal/6/nav/2092/article/30799.html 18.12.2017: https://www.lwk-niedersachsen.de/index.cfm/portal/6/nav/2092/article/31776.html 27.04.2018: https://www.lwk-niedersachsen.de/index.cfm/portal/6/nav/2092/article/32247.html 03.12.2018: https://www.lwk-niedersachsen.de/index.cfm/portal/6/nav/2092/article/33605.html 17.11.2020: https://www.lwk-niedersachsen.de/index.cfm/portal/56/nav/1195/article/36141.html 05.02.2021: https://www.lwk-	EU DM, CS

	2	Transport and processing of farm manure can contribute to close nutrient cycles.	WP2-tasks on Case Studies and MAPs	farmers and farmers organisations, farm advisors, local MAPs, national/regional authorities, water sector, scientific community, fertilizer industry, machine cooperatives	Dissemination product: info letters to farmers (last two from 1.) Dissemination occasion/date: 17.11.2020 and 05.02.2020	CS
	3	Many different actors have to be involved to improve nutrient management on supra-regional scale.	WP2-tasks on Case Studies and MAPs, WP 6.4	farmers and farmers organisations, farm advisors, local MAPs, national/regional authorities, water sector, scientific community, fertilizer industry, machine cooperatives	Dissemination product: Meetings of multi-actor plattforms Dissemination occasion/date: see MAP activity log from WP2 (attached)	EU DM
	4	EU countries can draw inspiration from each other concerning the reduction of nitrate pollution from agricultural sources	WP5.2 – WP 5.4	farmers and farmers organisations , national/regional authorities, scientific community, European Commission	Dissemination product: extensive report on the comparison between Danish and German fertilization law and the results from decision support tool comparisons Dissemination occasion/date: 11.05.21: https://www.lwk-niedersachsen.de/index.cfm/portal/6/nav/203/article/32333.html	MAP, CS
CS06 North Greece, GR	1	Farmers are not alone. There is help here by specialized people not only from academia. There are available best practices for implementation of low pesticide use which does not negatively affect their quantity of produce.	MAP regular meetings D2.1_Compilation of Multi-Actor Engagement Plans for local cases D2.3_Workshop on how to establish and nurture MAPs for constructive engagement in water– agriculture conflict related issues	Farmers, local MAPs	Aims of FAIRWAY- Vafiohori subcase MAP meeting, oral, presentation, 3May2018 Aims of FAIRWAY- Agios Pavlos subcase MAP meeting, oral, presentation, 23Feb2018 Informing stakeholders of FAIRWAY goals, Inspiring farmers and increasing engagement with stakeholders and farmers, Presenting the plan and focus for next year. Oral presentation at MAP meeting. February 2019 Presentation of main goals of directives (nitrogen and pesticide), bringing together advisors, water authority and companies selling fertilizers/pesticides, technical support on reducing nitrogen use, registering needs of farmers (financial incentives, water scarcity, dissemination of EU programs on nitrogen use). MAP meeting, oral, presentation. June 2019 Best practices for implementation of low pesticide use. telephone contact 15-17/7/20 Aims and progress of FAIRWAY, Leaflet of FAIRWAY, presentation 21-23/7/20 Aims of FAIRWAY and progress. Meetings with separate people. 2-6/9/2019 Implementation of regulation in Greece. Separate meetings. 14-25/9/2020 Communicate results from FAIRWAY and practices from WP4, Present other examples of MAPs and communities of Practice. MAP meeting, oral, presentation. May 2021	CS

	2	There is a connection between farmers' practice and water quality.	MAP regular meetings D4.1_Review report on effective nitrate leaching mitigation measures and practices D4.2_Review report on effective pesticides leaching mitigation measures and practices D3.3_Database containing harmonized dataset D8.3_FAIRWAYiS website final version D8.4_Video/film presentations explaining the scientific issues underlying drinking water quality	farmers and farmers organisations, local MAPs, water sector, municipal water utility companies	Aims of FAIRWAY- Vafiohori subcase MAP meeting, oral, presentation, 3May2018 Aims of FAIRWAY- Agios Pavlos subcase MAP meeting, oral, presentation, 23Feb2018 Informing stakeholders of FAIRWAY goals, Inspiring farmers and increasing engagement with stakeholders and farmers, Presenting the plan and focus for next year. Oral presentation at MAP meeting. February 2019 Presentation of main goals of directives (nitrogen and pesticide), bringing together advisors, water authority and companies selling fertilizers/pesticides, technical support on reducing nitrogen use, registering needs of farmers (financial incentives, water scarcity, dissemination of EU programs on nitrogen use). MAP meeting, oral, presentation. June 2019 Presentation of main directives (nitrogen and pesticide) *registered new farmers, water authority members, members of the farmer's union *circulated dissemination material of FAIRWAY *learned about past programs on nitrate minimization. MAP meeting, oral, presentation. Feb 2020 Aims and progress of FAIRWAY, Leaflet of FAIRWAY, presentation 21-23/7/20 Aims of FAIRWAY and progress. Meetings with separate people. 2-6/9/2019 Implementation of regulation in Greece. Separate meetings. 14-25/9/2020	CS
	3	Farmers are not threatened by new practices, instead they are finding tools to make production better, stick to regulations and change the situation from within.	Regular MAP meetings D2.1_Compilation of Multi-Actor Engagement Plans for local cases D2.5_Report (or special edition of appropriate journal) on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector" D3.1_Review report of Agri-Drinking Water quality Indicators and IT/sensor techniques, on farm level, study site and drinking water source D4.1_Review report on effective nitrate leaching mitigation measures and practices D4.2_Review report on effective pesticides leaching mitigation measures and practices D6.2_Report on governance arrangements in cases D6.3_Paper on lacks and spillover, narrative on actor perspectives D7.1_Evaluation report on barriers and issues in providing integrated scientific support for EU policy D7.2_Report on actors' feedback on the evidence based practices for water quality improvement of the different FAIRWAY case studies and FAIRWAY project interim results All of WP8 orientated to give feedback to farmers about the findings of FAIRWAY and practices in other case studies	farmers and farmers organisations, local MAPs, water sector, municipal water utility companies	Groundwater regulations, telephone contact, 08-07-20 Informing stakeholders of FAIRWAY goals, Inspiring farmers and increasing engagement with stakeholders and farmers, Presenting the plan and focus for next year. Oral presentation at MAP meeting. February 2019 Presentation of main goals of directives (nitrogen and pesticide), bringing together advisors, water authority and companies selling fertilizers/pesticides, technical support on reducing nitrogen use, registering needs of farmers (financial incentives, water scarcity, dissemination of EU programs on nitrogen use). MAP meeting, oral, presentation. June 2019 Presentation of main directives (nitrogen and pesticide) *registered new farmers, water authority members, members of the farmer's union *circulated dissemination material of FAIRWAY *learned about past programs on nitrate minimization. MAP meeting, oral, presentation. Feb 2020 Best practices for implementation of low pesticide use. telephone contact 15-17/7/20 Aims and progress of FAIRWAY, Leaflet of FAIRWAY, presentation 21-23/7/20 Recent advances in modern tools to produce without using increased fertilizers / pesticides. Web meeting. 23-25/7/20 Aims of FAIRWAY and progress. Meetings with separate people. 2-6/9/2019 Implementation of regulation in Greece. Separate meetings. 14-25/9/2020 Communicate results from FAIRWAY and practices from WP4,	CS

	4	Producers of fertilizers/pesticides feel there are regulations and systems that not just hinder their business but they actually create a new market of environmentally aware farmers. They therefore find products more friendly based on other examples.	Regular MAP meetings D4.1_Review report on effective nitrate leaching mitigation measures and practices D4.2_Review report on effective pesticides leaching mitigation measures and practices D6.2_Report on governance arrangements in cases	farmers and farmers organisations, water sector, pesticide and fertilizer industry, scientific community	Informing stakeholders of FAIRWAY goals, Inspiring farmers and increasing engagement with stakeholders and farmers, Presenting the plan and focus for next year. Oral presentation at MAP meeting. February 2019 Presentation of main goals of directives (nitrogen and pesticide), bringing together advisors, water authority and companies selling fertilizers/pesticides, technical support on reducing nitrogen use, registering needs of farmers (financial incentives, water scarcity, dissemination of EU programs on nitrogen use). MAP meeting, oral, presentation. June 2019 Best practices for implementation of low pesticide use. telephone contact 15-17/7/20 Recent advances in modern tools to produce without using increased fertilizers / pesticides. Web meeting. 23-25/7/20 Implementation of regulation in Greece. Separate meetings. 14-25/9/2020 Communicate results from FAIRWAY and practices from WP4, Present other examples of MAPs and communities of Practice. MAP meeting, oral, presentation. May 2021	EU DM
	5	Water users/community/consumers of drinking water feel there is a system to observe the cycle of nutrients/pesticides. There are tools to help the authorities. Authorities are involved and not staying passive.	Regular MAP meetings D2.1_Compilation of Multi-Actor Engagement Plans for local cases D4.1_Review report on effective nitrate leaching mitigation measures and practices D4.2_Review report on effective pesticides leaching mitigation measures and practices	local MAPs, national/regional authorities, farmers and farmers organisations, water sector, pesticide and fertilizer industry, scientific community	Best practices for implementation of low pesticide use. telephone contact 15-17/7/20 Recent advances in modern tools to produce without using increased fertilizers / pesticides. Web meeting. 23-25/7/20 Implementation of regulation in Greece. Separate meetings. 14-25/9/2020 Communicate results from FAIRWAY and practices from WP4, Present other examples of MAPs and communities of Practice. MAP meeting, oral, presentation. May 2021	EU DM
CS07 Derg catchment, UK	1	Connecting MCPA use for rush and broadleaf weed control in extensive and improved grasslands to impact (contaminated and expensive water).	The data from the paper of Morton et al (2021), which arose out of the Derg catchment, provided the high frequency sampling data that was used in analysis of passive sampler performance(Task 3.2 (Farrow et al (In prep)). The evaluation of the passive samplers in Task 3.2 has also resulted in one Fact sheet suited for distribution to Water Utility companies.	National agricultural policy makers, water utility companies, scientific community.	• Farrow, L.G., Morton, P.A., Cassidy, R., Jordan, P., and Doody, D.G. (In Prep), Validation of Chemcatchers® as a low-cost alternative for high frequency sampling techniques in agricultural grassland catchments. Target journal: Science of The Total Environment, • Morton, P.A., Cassidy, R., Floyd, S., Doody, D.G., McRoberts, W.C. and Jordan, P., 2021. Approaches to herbicide (MCPA) pollution mitigation in drinking water source catchments using enhanced space and time monitoring. Science of The Total Environment, 755, p.142827. • Fact sheet/leaflet: Surdyk, N., Farrow, L.G., Cassidy, R. and Doody, D.G. Use of passive samplers in drinking water catchments.	local
	2	Improvements (using DST) to farm practices in pesticide use.	A prototype phone app was developed as part of Task 5.5. App development has now ended and a report is being finalised. The App was presented to 65 stakeholder from across the UK, Ireland and EU and their feedback has been recorded.	Target audience: The target audience for this App are farmers and persons/agencies with a role in the sustainable management of pesticides such as water companies, advisory services etc.	• Prototype phone app • Final report, detailing the process of development and next steps post Fairway	CS

	3	Increased awareness across all stakeholders	Extensive dissemination and knowledge transfer has been under taken as part of Task 3.2 and 5.5	• Task 3.2 - National agricultural policy makers, water utility companies, scientific community • Task 5.5 - The target audience for this App are farmers and persons/agency with a role in the sustainable management of pesticides such as water companies, advisory services etc.	Task 3.2 • Presentation - Farrow, L.G., Morton, P.A., Cassidy, R. and Doody, D. Grab or passive sampling. Monitoring the concentrations of MCPA in Irish rivers. Agri-Food and Bioscience Lunchtime Seminar series. 25th January 2021. • Scientific paper - Farrow, L.G., Morton, P.A., Cassidy, R., Jordan, P., and Doody, D.G. (In Prep), Validation of Chemcatchers® as a low-cost alternative for high frequency sampling techniques in agricultural grassland catchments. Target journal: Science of The Total Environment, • Fact sheet/leaflet - Surdyk, N., Farrow, L.G., Cassidy, R. and Doody, D.G. Use of passive samplers in drinking water catchments. Task 5.5 • Stage 1 - Determination of features the app should contain o The interview of 83 farmers/infrequent professional pesticide product users. o Conversations with colleagues at the Agri-Food and Bioscience Institute (AFB) and the College of Agriculture, Food and Rural Enterprise (CAFRE) about the information that they perceived farmers as wishing to know and the information that professional pesticide product users were required to know. • Stage 2 – After conceptualisation of the app we had review meetings with representatives of various government bodies (UK and Ireland), water utilities, User groups (agricultural and amenity sectors) as well as members of the Source to Tap project. • Stage 3 - Post app development stakeholder engagement – webinar presentation of the app to 65 stakeholder from across the UK, Ireland	local
	4	Identifying policy conflicts within and across jurisdictions	Three papers arose out of the Task 6.2, 6.3 and 6.4	The main target audience for these papers are EU Commission, the local MAPS and the Water companies.	• Task 6.2 Rowbottown et al In prep • Task 6.3 - Wuijts, S., Claessens, J., Farrow, L., Doody, D.G., Klages, S., Christophoridis, C., Cvejić, R., Glavan, M., Nesheim, I., Platjouw, F. and Wright, I., 2021. Protection of drinking water resources from agricultural pressures: Effectiveness of EU regulations in the context of local realities. Journal of Environmental Management, 287, p.112270. • Task 6.4 – Hasler et al., Drinking water protection by catch and cover crops in Europe – potentials for efficient implementation. In prep.	EU DM, local
CS08 Overijssel, NL	1	1. A common process – such as Farming for drinking water - with farmers, the drinking water company and regional authority is succesfull when a transition Farming for drinking water helps towards realising WFD objectives on voluntary basis is required	Source: - D2.5 Report on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector"	local MAPs, national/regional authorities, farmers and farmers organisations, water sector, European Commission.	Cors 17 Jun21- The info I have forwarded November 2020 is the most actual info regarding press releases, video's etc.	EU DM, CS
	2	Improving nutrient use improves both the financial profit of farmers and the quality of groundwater - but the ultimate requirements to meet water standards may not be profitable	D2.1 Compilation of Multi-Actor Engagement Plans for local cases D2.3 Workshop on how to establish and nurture MAPs for constructive engagement D2.5 Report on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector"	local MAPs, national/regional authorities, farmers and farmers organisations, water sector, European Commission.		CS
	3	Engagement of farmers increases by being taken seriously, supported monitoring data of groundwater quality and political support.	D2.1 Compilation of Multi-Actor Engagement Plans for local cases D2.3 Workshop on how to establish and nurture MAPs for constructive engagement D2.5 Report on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector"	local MAPs, national/regional authorities, farmers and farmers organisations, water sector, European Commission.		CS

	4	Multi-actor platforms function well as platforms for exchange of opinions and ideas, and for sharing information and knowledge - provided a well defined domaine in which optimized management is relevant as a soluation	-D2.1 Compilation of Multi-Actor Engagement Plans for local cases -D2.3 Workshop on how to establish and nurture MAPs for constructive engagement -D2.5 Report on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector"	local MAPs, national/regional authorities, farmers and farmers organisations, water sector, European Commission.		EU DM, MAP
	5	Sharing of perspectives and trust between key actors is a necessary condition for common understanding and for setting joint strategies, but does not necessarily lead to desired impacts.	D2.1 Compilation of Multi-Actor Engagement Plans for local cases -D2.3 Workshop on how to establish and nurture MAPs for constructive engagement -D2.5 Report on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector"	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, scientific community.		EU DM, MAP, CS
CS09 Noord-Brabant, NL	1	Strong cooperation between regional stakeholders contributes to effective reduction of pesticide leaching.	Task is FAIRWAY WP2.5. Deliverable is paper on lessons learned (Cors van den Brink, Koos Verloop, Alma de Vries, Marije Hoogendoorn, Peter Leendertse and Frode Sundnes, 2020. Farmers' responsiveness to policies and measures: Lessons learned from groundwater protection in the Dutch provinces Overijssel and Noord-Brabant.)	European Commission, local MAPs, regional authorities, farmers organisations and water sector	Infographic:https://www.fairway-is.eu/index.php/key-messages/infographics/206-the-noord-brabant-case-study Movie: Fairway asparagus movie (https://vimeo.com/316124162 password Fair_2019_02)	CS
	2	Involvement of retailers as stakeholders is crucial to implement reduction measures.	Task is FAIRWAY WP2.5. Deliverable is paper on lessons learned (Cors van den Brink, Koos Verloop, Alma de Vries, Marije Hoogendoorn, Peter Leendertse and Frode Sundnes, 2020. Farmers' responsiveness to policies and measures: Lessons learned from groundwater protection in the Dutch provinces Overijssel and Noord-Brabant.)	European Commission, local MAPs, regional authorities, farmers organisations and water sector	Infographic: https://www.fairway-is.eu/index.php/key-messages/infographics/293-cleaning-out-the-pesticide-store	MAP
	3	Each farmer or contractor can take measures to reduce pesticide leaching and should take those measures that are apt for his farm or contractor business	Task is FAIRWAY WP2.5. Deliverable is paper on lessons learned (Cors van den Brink, Koos Verloop, Alma de Vries, Marije Hoogendoorn, Peter Leendertse and Frode Sundnes, 2020. Farmers' responsiveness to policies and measures: Lessons learned from groundwater protection in the Dutch provinces Overijssel and Noord-Brabant.)	European Commission, local MAPs, regional authorities, farmers organisations and water sector	Infographic Environmental Yardstick: https://www.fairway-is.eu/index.php/key-messages/infographics/282-environmental-yardstick-decision-support-tool Animation: https://youtu.be/RCYYWumSQh4 (yardstick)	CS
CS10 Vansjø, NO	1	The sustainability of engagement platforms depends on external frames within the larger governance system.	Task 2.1 and 6.2	EU and Norway national and regional authorities	Policy brief October/November 2021	EU DM
	2	Continued financial support of engagement platforms for planning and for coordination activities are essential.	Task 2.1 and 6.2	EU and Norway national and regional authorities	Policy brief October/November 2021	MAP
	3	A multi-actor engagement platform will itself not allow for interaction with a sufficient number of farmers - considering different types of farmers (small scale, large scale, etc.) additional workshops or focus group discussions with farmers are needed.	Task 2.1, 2.3, 6.2	EU and Norway national, regional and local authorities	Policy brief October/November 2021	MAP
CS11 Baixo Mondego, PT	1	Improving dialogue and collaboration between different actors (farmers, water companies, research institutes, authorities) helps create a connection between groundwater protection and agricultural production.	Task 2.1 (D2.1), Task 7.2 (D7.2)	Local MAPs; regional authorities; farmers; farmers organizations; water sector; scientific comunity.	Dissemination product: MAP meetings involving several entities, focused on the exchange of ideas and different points of view, with the same purpose: improving the quality of drinking water, adapting agricultural practices Dissemination occasion/date: 24.4.2018 | 24.7.2018 | 13.8.2018 | 6.12.2018 | 19.7.2019 | 17.6.2020 | 29.1.2021 | continuing...	MAP
	2	DSTs are an important tool to help and advise farmers to use the best practices and planning in the application of fertilizers, in order to optimize crop yield and prevent water pollution problems associated with nitrates and nitrogen.	Task 5.2 (D5.2), Task 5.4 (D5.4)	National/regional authorities; Farmers organizations; Farmers.	Dissemination product: Presentation of the results of a DST test in the study area (Baixo Mondego), in a portuguese conference (National Congress of Higher Agrarian Schools). Dissemination occasion/date: 14.11.2019	CS

	3	Monitoring and relating to agricultural practices is fundamental to develop strategies to contol and reduce fertilizer use.	Task 3.1 (D31), Task 3.2 (D3.2) Task 4.3 (D4.3)	European Commission; National/regional authorities; Farmers organizations; Farmers.	Dissemination product: Meetings with farmers, in order to know their practices and encourage changes through the dissemination of FairWay results (in our case study and others) Dissemination occasion/date: 16.4.2019 | continuing at the moment with more regular meetings with individual farmers, with a view to obtaining results from their agricultural practices/management to later publish, drawing attention to the need for change | The paper should be ready by the end of the year 2021.	EU DM
CS12 Arges-Vedea, RO	1	Optimum nitrogen and pesticides rates applied according to the plant need and specific local conditions avoid water bodies pollution by surface runoff and leaching	D4.3 Report on most promising measures and practices	farmers, advisers, local public authorities, scientific community.	To inform on Fairway project progress, to collect data on local problems, to collect suggestions of the stakeholders, to plan the activities for a good nutrient management at local level. Presentation; leaflet. MAP meeting. 23.07.2018 Workshop with other scientific national project (INTERASPA) about water loaded with different compounds and sediments and water flux from groundwater to surface water. presentation; leaflet. workshop 19.10.2018 Workshop în the study site area on dissemination of the revised Code of Good Agricultural Practices for water protection against pollution with nitrates from agricultural sources and of the revised Action Program. presentation; leaflet. workshop. 10.10.2019 Dissemination of some results related to applying an optimum fertilization plan at farm level presentation; leaflet; infographic. symposium 07-08.11.2019 Establishing best management practices in the study site area according to the specific local conditions. presentation; leaflet; infographic. Workshop 01.09.2020	CS
	2	Proper nutrients management at farm level increases the security and safety of food production	D5.2 Report on the evaluation of the decision support and information tools and measures	farmers, advisers, local public authorities, scientific community.		EU DM, CS
CS13 Dravsko Polje, SI	1	How to farm on the water protection areas for better slurry management with new application technologies.	WP2, TASK 2.1, WP 5 TASK 5.3, 5.4	FARMERS, AGRICULTURAL ADVISERS, MINISTRIES OR VARIOUS GOVERMENTAL ORGANISATIONS, RESEARCH ORGANISATIONS, AGRICULTURAL COMPANIES	Dissemination product:DEMO EVENT - Improving the water quality of vulnerable aquifers - challenges and solutions Dissemination occasion/date:28.1.2020, Open event, workshop Dissemination product: ANCA – decision suport tools Dissemination occasion/date: Open event, workshop/ 4.3.2019	CS
	2	How to reduce inputs of fertilisers and pesticides with improvements of existing DST.	WP 5, TASK 5.3, 5.4	FARMERS, AGRICULTURAL ADVISERS, MINISTRIES OR VARIOUS GOVERMENTAL ORGANISATIONS, RESEARCH ORGANISATIONS, AGRICULTURAL COMPANIES	Dissemination product: ANCA – decision suport tools Dissemination occasion/date: Open event, workshop/ 4.3.2019	CS
	3	How to adjust the legislation that farmers have to fulfill to allow long term steady development of agriculture in the area.	WP 7 TASK 7.3, WP 2 TASK 2.1	FARMERS, AGRICULTURAL ADVISERS, MINISTRIES OR VARIOUS GOVERMENTAL ORGANISATIONS, RESEARCH ORGANISATIONS, Drinking water suppliers AGRICULTURAL COMPANIES	Dissemination product: DEMO EVENT - Improving the water quality of vulnerable aquifers - challenges and solutions Dissemination occasion/date: 28.1.2020, Open event, workshop	EU DM, MAP
	4	How to effectively connect different actors (farmers, water companies, ministries) in water the protection area for drinking water quality improvements.	WP2 TASK 2.1	FARMERS, AGRICULTURAL ADVISERS, MINISTRIES OR VARIOUS GOVERMENTAL ORGANISATIONS, RESEARCH ORGANISATIONS, Drinking water suppliers AGRICULTURAL COMPANIES	Dissemination product: expert paper -Paper on MAP activities at Mišič Water day /Mišičev vodarski dan Dissemination occasion/date:27.11.2020 Dissemination product: expert paper- Paper on FAIRWAY mid-project results at Vodni dnevi / Water Days Dissemination occasion/date: 18.9.2020	MAP

WP2 Multi-actor platforms and case studies	1	Multi-actor platforms function well as platforms for exchange of opinions and ideas, and for sharing information and knowledge.	- D2.1 Compilation of Multi-Actor Engagement Plans for local cases - D2.3 Workshop on how to establish and nurture MAPs for constructive engagement - D2.5 Report on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector"	local MAPs, national/regional authorities, farmers and farmers organisations, water sector, European Commission.	Infographic 1, October 2021 Presentation at LUWQ conference in Aarhus, 2019: The role of MAPs in addressing challenges to protect drinking water supplies. Journal special issue of 5 papers relating to KM1-3. Submission deadline Sept 2021. Publication date early 2022.	MAP
	2	Sharing of perspectives and trust between key actors is a necessary condition for common understanding and for setting joint strategies, but does not necessarily lead to desired impacts.	- D2.1 Compilation of Multi-Actor Engagement Plans for local cases - D2.3 Workshop on how to establish and nurture MAPs for constructive engagement - D2.5 Report on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector"	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, scientific community.	Infographic 1, October 2021 Presentation at LUWQ conference in Aarhus, 2019: The role of MAPs in addressing challenges to protect drinking water supplies. Journal special issue of 5 papers relating to KM1-3. Submission deadline Sept 2021. Publication date early 2022.	EU DM, MAP, CS
	3	A dilemma for engagement processes is that they need to be conceptualised and planned for in a long-term perspective, while the lack of immediate impact might lead to fatigue that jeopardise the processes.	- D2.1 Compilation of Multi-Actor Engagement Plans for local cases - D2.3 Workshop on how to establish and nurture MAPs for constructive engagement - D2.5 Report on "Advancing MAPs as vehicles for reduced conflict on drinking water pollution from agricultural sector"	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, scientific community.	Infographic 1, October 2021 Presentation at LUWQ conference in Aarhus, 2019: The role of MAPs in addressing challenges to protect drinking water supplies. Journal special issue of 5 papers relating to KM1-3. Submission deadline Sept 2021. Publication date early 2022.	EU DM, CS
	4	Establishing cooperation between large and small supplies contributes to overcoming barriers for effective risk assessment and management for small suppliers.	- D2.4 Lessons Learned and Recommendations for Water Safety Plans - M2.5 Learning module safety plan carried out with stakeholders	European Commission, local MAPs, national/regional authorities, farmers, and farmers organisations, water sector, scientific community, other parts of the project.	Infographic 2, July 2021	CS
	5	Effective Water Safety Planning requires a process owner to bring together institutions and stakeholders, spread information throughout organizations and provide congruence between different risk assessment and management systems.	- D2.4 Lessons Learned and Recommendations for Water Safety Plans - M2.5 Learning module safety plan carried out with stakeholders	European Commission, local MAPs, national/regional authorities, farmers, and farmers organisations, water sector, scientific community, other parts of the project.	Infographic 2, July 2021	CS
WP3 Monitoring and indicators	1	Linking Pressure indicators to state indicators can help to understand contaminant origins (such as fertilisation) and variations.	DL3.1, DL3.2 including the scientific paper of Kim et al., (2020) and the leaflet	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, scientific community, other parts of the project		EU DM, MAP, CS
	2	In some context (hydrogeology), a long time lag between N input and NO3 concentration in groundwater exists.	DL3.2 including the scientific paper of Kim et al., (2020) and the leaflet	Priority 1) Water companies, Policies Makers (National, E.U.), Scientific community, Case study Leader Priority 2) Farmers (There is a priority here since long lag time is not the Farmers main concerns but keep them inform of that will keep them motivated and they will understand why their action do not have a results).		EU DM, CS
	3	Long time series are needed to link pressure and state indicators at the catchment scale (for GW and depending on hydrogeology: long lag times).	DL3.2 including the scientific paper of Kim et al., (2020) and the leaflet	Target audience: European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, scientific community (Just for keeping in mind that data collection is a long-term process. Not losing data collection already is a job in itself).		EU DM, CS
	4	Complex indicators can be difficult to set up at European level because Member States have different systems and rules for data collection and processing	DL3.1; D3.2, including the scientific paper of Klages et al, (2020)	Policies Makers (E.U.)		EU DM
	5	Difficult to find promising participative monitoring techniques for groundwater	DL3.1	European Commission, local MAPs, national/regional authorities, farmers and farmers organisations, water sector, scientific community, other parts of the project		EU DM, CS
WP4 Review of measures and practices	1	Selecting most promising measures for pesticides pollution is hampered by a lack of statistical sound data.	D4.2 and D4.3	Scientific community – to show that sound statistical data, and maybe more experiments can improve understanding. Not so much for policy makers – would rather communicate point 3 to them.		MAP

	2	Based on responses from the case studies, effective results are more often reached through policies and social interventions or on higher farm level management, than through the more physical/agronomical measures.	D4.3	mostly policy makers, but potentially also scientific community and MAPs		EU DM
	3	For nitrate, literature shows that (non-legume) cover crops and the nitrification inhibitor DCD may provide options to reduce losses to the environment. Results on other measures, such as application of biochar or changes in tillage practices, vary.	D4.1 and D4.3	anyone who wants to implement, research, or build policy around these measures, including fertilizer industry (for DCD), EC, water sector.		CS
	4	Here too there is a discrepancy between the field- or trial-based measures reported in literature and the farm-level management options that are used/reported in the case studies.	D4.1 and D4.3	could be relevant to all suggested parties, but I think it is mostly relevant to policy makers (and also scientific community); the effects of comprehensive farm-level management are more difficult to quantify, but may be just as (or even more) important as field measures. Maybe relevant to MAPs as well, as many integral measures are occurring there.		EU DM, MAP
	5	Measures to reduce nitrate losses should consider potential effects of other nitrogen compounds or greenhouse gas losses (NH3, N2O, CO2).	D4.3	policy makers: EC as well as national/regional authorities		EU DM
WP5 Decision support tools	1	Which DSTs are most widely used and why.	This was undertaken in Task 5.1 which combined a structured scientific literature review covering European DSTs for water, nutrient and pesticide management combined (>150 identified) with a survey and collation of DSTs utilised across the FAIRWAY partner regions by farmers, water managers and policy makers (36 identified). DSTs were classified and summarised within information sheets and subsequently a number, selected based on their relevance to the case study target audiences, were selected for evaluation in nine local case study areas. This provided a comprehensive understanding of i) the potential benefits/opportunities presented by use of the DST ii) any barriers to implementation and iii) stakeholder perceptions of the DST.	Farmers, Agronomists and other farm advisors, Water quality managers, Policy makers, Fertiliser or pesticide manufacturers or suppliers, Researchers, App/DST Developers	Nicholson et al. (2020) How can decision support tools help reduce nitrate and pesticide pollution from agriculture? A literature review and practical insights from the EU FAIRWAY project, Water, 12(3) 768, https://doi.org/10.3390/w12030768 R.K. Laursen et al. (2019) Evaluation of Decision Supports Tools. FAIRWAY Project Deliverable 5.2 216 pp	EU DM, MAP
	2	Insights in matching suites of DSTs to specific sites and users.	This emerged from Tasks 5.1 and 5.2; specifically through the more in-depth evaluation of the 36 shortlisted DSTs from Task 5.1 and the detailed testing and evaluation in 9 of the case study sites at farm, catchment and regional scales. In the evaluation of DSTs classification schemes were developed that allowed the nutrient and pesticide management DSTs to be separated into those developed to support water quality/agri-environment policy makers operating at a regional or national level, and those intended to support sustainable N management at the farm level. The DSTs were further divided into groups depending on whether they provided support for (1) evaluation of current practices, (2) strategic advice for farm management and implementation of nitrate/pesticide mitigation measures (3) on-farm operational management. This enabled potential users in different regions to identify DSTs with the characteristics best-suited to their needs.	Farmers, Agronomists and other farm advisors, Water quality managers, Policy makers, Fertiliser or pesticide manufacturers or suppliers, Researchers, App/DST Developers	R.K. Laursen et al. (2019) Evaluation of Decision Supports Tools. FAIRWAY Project Deliverable 5.2 216 pp	MAP, CS

	3	Costs and benefits of DSTs to a range of end users.	This was evaluated in Task 5.3 through an assessment of the costs and benefits of using DSTs for a sub-set of 6 farm level DSTs, 2 catchment level DSTs and a number of DSTs which can be applied to assess the benefits of water quality protection. The evaluated farm level DST's all have in common that total costs of using the tools are kept at a low level and that this is essential for a tool to be effective. This type of tools can save money for the farmers if inputs are reduced, but also important to fulfil the cross compliance requirements, that are compulsory in all countries in EU. The evaluation of the catchment level tools indicate that significant resources can be saved by using such tools to reveal cost-effective solutions and management practices. The catchment level models are also capable for assessment of the effects of assumptions on the cost-effective solutions, and can therefore be used to assess the risk of wrong or limited information.	Farmers, Agronomists and other farm advisors, Water quality managers, Policy makers, Fertiliser or pesticide manufacturers or suppliers, Researchers, App/DST Developers	Hasler, B. et al. (2019) Assessment of costs and benefits for farmers, water companies and society from using Decision Support Tools. FAIRWAY Project Deliverable 5.3 49 pp	EU DM, MAP, CS
	4	Innovative phone app to support pesticide applications in drinking water catchments.	WP5.1 and WP5.2 found that, whilst there are many Decision Support Tools available for pesticide users, the vast majority were customised for the country where they were first released, had a reasonably high level of assumed knowledge and that their use required software purchase or a subscription. Also, none of the identified Decision Support Tools targeted infrequent users of pesticides. Further market research undertaken as part of WP5.5 with farmers in Northern Ireland (the country targeted for initial trials of the app) supported these findings and highlighted that non-agricultural infrequent users of pesticides are particularly poorly served.	The target audience for this App are farmers, amenity sector workers and persons/agencies with a role in the sustainable management of pesticides such as water companies, advisory services etc. Whilst initially targeting the UK/Irish markets, the app is designed in such a way that it could be easily adapted to operate in other countries. Future works could include expansion of the target market to include more frequent users of professional pesticide products and supporting agencies, but this would require the app to become more feature-rich, which could deter the original target audience from engaging.		CS
WP6 Legal policy and governance	1	Nitrate and pesticides from agriculture are among the highest water quality risks for drinking water resourcess	D6.1-6.3			EU DM
	2	EU legislation on the protection of drinking water resources from agriculture is complex.	D6.1-6.3			EU DM, MAP
	3	Implementation would benefit from more advanced cross-referencing at the EU level.	D6.1-6.3			EU DM, MAP
	4	Implementation needs capacity at the regional-local level towards cross-sectoral decision making.	D6.1-6.3			MAP
WP6.2 Governance arrangements in the case studies	1	A new methodology was created that could be used by others for collecting information on the cascade of water governance (specifically addressing agricultural pollution of drinking water resources). The process engaged with actors using a bottom up approach and would be helpful for others seeking to understand the anomalies between understanding and perceptions from local stakeholders and the perceptions from top down. The method has highlighted the potential for core messages to be lost if delivered from a top down approach only. Limitation: can be subjective (still valuable) and so care is needed when making comparison between cascades constructed by different authors.	WP6.2 report defines the basic method. This is further described in the forthcoming paper (in final stages of preparation). (Usefulness proven by the fact that the method has already been selected for a further Fairway academic paper and is being considered for adaptation and adoption in a different H2020 project, Optain)	European Commission, National/regional authorities, Water sector, Scientific community, Other parts of the project (WP6.3 onwards)		CS

	2	New methodology to create an innovative impactful visual Impression from a complex excel cascade. This allows for interpretation by a wider audience. Limitation: only as good as the data in the cascade. The Impression should be interpreted in the context of the associated cascade.	WP6.2 report defines the basic method. This is further described in the forthcoming academic paper (in final stages of preparation). Usefulness proven by the fact that the method has already been selected for a further Fairway academic paper and is being considered for adaptation and adoption in a different H2020 project, Optain	European Commission, National/regional authorities, Water sector, Scientific community, Farmers and farmer organisations, Other parts of the project (WP6.3 onwards)		EU DM
	3	The cascades created using input and perceptions at local level in a bottom up data collection process can be different to the actuality of governance. This may help shed light on weaknesses in the effectiveness of governance.	6.2 report	European Commission, National/regional authorities, Water sector, Scientific community, Other parts of the project (WP6.3 onwards)		EU DM, MAP
	4	There is evidence of barriers in horizontal integration of governance. Such barriers may create inconsistences between policies and cross sectoral differences. This reinforces a similar finding in WP6.1	6.2 report, phase 1 and phase 2	European Commission, National/regional authorities, Water sector, Scientific community, Other parts of the project (WP6.3 onwards)		EU DM
	5	There is diversity in the effectiveness of water governance (using OECD Principles of Effectiveness for water governance 1-4) as perceived by local stakeholders. Further detailed analysis is beyond the remit of 6.2 it was apparent the Case Study responses were variable, yet there was general agreement that i) transboundary water management, data and information sharing was still in a process of development, and ii) vertical coherence experienced fewer obstacles across the different levels of governance. For the latter, some CSs reported fragmentation of water governance, insufficient technical knowledge and an infrastructure undermining the implementation capacities of local actors. Across all CSs, the coherency of governance was considered compromised at catchment and farm level. Based on a small sample size there appeared to be consensus that citizen participation and involvement of civil society was yet to be fully functional and effective.	6.2 report, phase 2			MAP
	6	At local level, land managers and farm decision makers noted many examples of effectiveness in relation to Nitrates Directive and Sustainable Use Directive, including riparian strips and catch crops (ND) and advice, training and testing (SUD).	Report 6.2, phase 3	European Commission, National/regional authorities, Water sector, Scientific community, Farmers and farmer organisations, Other parts of the project (WP6.3 onwards)		CS
WP7 Integration and recommendations at EU level	1	Cross section of issues and barriers in protection of water quality between EU and local level	task 7.1 and 7.2	EU policy makers in water policy sector, local MAPs		EU DM, MAP
	2	Cross section of potential solutions for elimination of the weak points in protection of water quality between EU and local level	task 7.1 and 7.2	EU policy makers in water policy sector, local MAPs		EU DM, MAP
	3	Finding weak and strong communication channels and style to distribute project's findings to relevant decision-making actors	task 7.1, 7.2 and 7.4	European Commission, scientific community, local, regional and national authorities, small and medium sized enterprises, non-governmental organizations, farmers, water sector, pesticide and fertilizer industry		EU DM
	4	Showing greatest weaknesses in communication style between science and policy in water policy issues	task 7.1 and 7.2	European Commission, scientific community, local, regional and national authorities, small and medium sized enterprises, non-governmental organizations, farmers, water sector, pesticide and fertilizer industry		EU DM
	5	Finding measures and practices for water quality improvement that have best potential in their applicability, cost and adoptability on field by different actors that are involved in water quality disturbance	task 7.2 and 7.3	case studies, farmers and farmers organisations, EU policy makers in water policy sector, scientific community		EU DM, CS

APPENDIX II KEY MESSAGES DEDICATED TO STAKEHOLDER GROUPS AND LINKS TO WP AND/OR CS

Key messages that are linked only to one of the groups

An overview was made with links between key messages derived from results of WP2 to WP7 on FAIRWAY project and stakeholder groups. Three types of stakeholder groups are considered: decision makers on EU level (EU DM) for the protection of drinking water resources, the Multi-Actor Platforms or MAPs (the innovative project's platforms) and case studies (CS) that also gave input in some of the project's tasks. The beyond mentioned key messages are linked to only one of the group's type.

Decision makers on EU level

List of key messages that are important mainly to EU DM:

1. Users of products (nitrate and pesticides) need to be involved, knowledgeable, accountable and responsible for sustainable use in order to maintain use of products and minimize or reduce regulation. (WP2, CS 3)
2. The importance and the opportunity to communicate practical and effective on farm measures and practices to policymakers - to create ownership and successful implementation. (WP2, CS 3)
3. Many different actors have to be involved to improve nutrient management on supra-regional scale. (WP2, CS 5)
4. Water users/community/consumers of drinking water feel there is a system to observe the cycle of nutrients/pesticides. There are tools to help the authorities. Authorities are involved and not staying passive. (WP2 and 4, CS 6)
5. The sustainability of engagement platforms depends on external frames within the larger governance system. (WP2 and 6, CS 10)
6. Complex indicators can be difficult to set up at European level because Member States have different systems and rules for data collection and processing. (WP3)
7. Monitoring and relating to agricultural practices is fundamental to develop strategies to control and reduce fertilizer use. (WP3 and 4, CS 11)
8. Based on responses from the case studies, effective results are more often reached through policies and social interventions or on higher farm level management, than through the more physical/agronomical measures.
9. Measures to reduce nitrate losses should consider potential effects of other nitrogen compounds or greenhouse gas losses (NH_3, N_2O, CO_2). (WP4)
10. Producers of fertilizers/pesticides feel there are regulations and systems that not just hinder their business, but they actually create a new market of environmentally aware farmers. They therefore find products more friendly based on other examples. (WP4 and 6, CS 6)
11. Nitrate and pesticides from agriculture are among the highest water quality risks for drinking water resources. (WP6)
12. New methodology to create an innovative impactful visual Impression from a complex excel cascade. This allows for interpretation by a wider audience. Limitation: only as good as the data in the cascade. The Impression should be interpreted in the context of the associated cascade. (WP6)
13. To increase the use of results of projects in policy making, it is recommended to cluster projects to make science and research more connected to current policy challenges and stakeholder needs with the aim of establishing sustainable long-term relationships and communication flows (WP 7).

14. Finding weak and strong communication channels and style to distribute project's findings to relevant decision-making actors. (WP7)
15. Showing greatest weaknesses in communication style between science and policy in water policy issues. (WP7)

Multi-Actor Platforms

List of key messages that are important to all MAPs:

1. Multi-actor platforms function well as platforms for exchange of opinions and ideas, and for sharing information and knowledge. (WP2)
2. How to effectively connect different actors (farmers, water companies, ministries) in water the protection area for drinking water quality improvements. (WP2, CS 13)
3. Involvement of retailers as stakeholders is crucial to implement reduction measures. (WP 2, CS 9)
4. MAPs need funding and the right facilitator for long term success. (WP 2, CS 3)
5. MAPs can feed into policy. (WP2, CS 3)
6. It takes many years to develop an effective MAP. (WP2, CS 3)
7. MAPs can increase networks, knowledge exchange and transfer, and awareness sufficient to trigger new developments. (WP2, CS 3)
8. MAPs can work but needed to be tailored to specific circumstances. (WP2, CS 3)
9. A multi-actor engagement platform will itself not allow for interaction with a sufficient number of farmers - considering different types of farmers (small scale, large scale, etc.) additional workshops or focus group discussions with farmers are needed. (WP2 and 6, CS 10)
10. Continued financial support of engagement platforms for planning and for coordination activities are essential. (WP2 and 6, CS 10)
11. Improving dialogue and collaboration between different actors (farmers, water companies, research institutes, authorities) helps create a connection between groundwater protection and agricultural production. (WP2 and 7, CS 11)
12. Selecting most promising measures for pesticides pollution is hampered by a lack of statistical sound data. (WP4)
13. Support and advice from well-educated and communicative skillful advisors are highly valuable for the end user to make the right decisions. (WP5)
14. Implementation needs capacity at the regional-local level towards cross-sectoral decision making. (WP6)

Case studies

List of key messages that are important to all CS:

1. Establishing cooperation between large and small supplies contributes to overcoming barriers for effective risk assessment and management for small suppliers. (WP2)
2. Effective Water Safety Planning requires a process owner to bring together institutions and stakeholders, spread information throughout organizations and provide congruence between different risk assessment and management systems. (WP2)
3. The importance of the water industries and agricultural industries to work collaboratively. (WP2, CS 3)
4. Transport and processing of farm manure can contribute to close nutrient cycles. (WP2, CS 5)
5. Farmers are not alone. There is help here by specialized people not only from academia. There are available best practices for implementation of low pesticide use which does not negatively affect their quantity of produce. (WP2, CS 6)
6. Improving nutrient use improves both the financial profit of farmers and the quality of groundwater - but the ultimate requirements to meet water standards may not be profitable. (WP2, CS 8)

7. Engagement of farmers increases by being taken seriously, supported monitoring data of groundwater quality and political support. (WP2, CS 8)
8. Strong cooperation between regional stakeholders contributes to effective reduction of pesticide leaching. (WP2, CS 9)
9. Each farmer or contractor can take measures to reduce pesticide leaching and should take those measures that are apt for his farm or contractor business. (WP2, CS 9)
10. Better dialogue can combine groundwater protection and agricultural production. (WP2, 3 and 5, CS 2)
11. Lessons can be learned which are of general importance about combining agriculture with groundwater protection. (WP2, 3 and 6, CS 1)
12. Proved and acknowledged better management practices and technology development can improve water quality and create groundwater protection. (WP2, 3 and 6, CS 1, CS 2)
13. Farmers are not threatened by new practices, instead they are finding tools to make production better, stick to regulations and change the situation from within. (WP2, 4, 6 and 7, CS 6)
14. How to farm on the water protection areas for better slurry management with new application technologies. (WP2 and 5, CS 13)
15. Better practices can improve groundwater quality even if it will be long (because of aquifer response time). (WP3, CS 4)
16. There is a connection between farmers' practice and water quality. (WP3 and 4, CS 6)
17. For nitrate, literature shows that (non-legume) cover crops and the nitrification inhibitor DCD may provide options to reduce losses to the environment. Results on other measures, such as application of biochar or changes in tillage practices, vary. (WP4)
18. Optimum nitrogen and pesticides rates applied according to the plant need and specific local conditions avoid water bodies pollution by surface runoff and leaching. (WP4, CS 12)
19. Innovative phone app to support pesticide applications in drinking water catchments. (WP5)
20. Proved and acknowledged better management practices and technology development can improve water quality and create groundwater protection. (WP5)
21. Cost-effective solutions for the benefit of both farmers and waterworks have been achieved. (WP5, CS 2)
22. Farm advisers are aware and knowledgeable about the impact of products on drinking water quality to provide sustainable and responsible advice to farmers. (WP5, CS 3)
23. Improvements (using DST) to farm practices in pesticide use. (WP5, CS 7)
24. DSTs are an important tool to help and advice farmers to use the best practices and planning in the application of fertilizers, in order to optimize crop yield and prevent water pollution problems associated with nitrates and nitrogen. (WP5, CS 11)
25. How to reduce inputs of fertilisers and pesticides with improvements of existing DST. (WP5, CS 13)
26. A new methodology was created that could be used by others for collecting information on the cascade of water governance (specifically addressing agricultural pollution of drinking water resources). The process engaged with actors using a bottom up approach and would be helpful for others seeking to understand the anomalies between understanding and perceptions from local stakeholders and the perceptions from top down. The method has highlighted the potential for core messages to be lost if delivered from a top down approach only. Limitation: can be subjective (still valuable) and so care is needed when making comparison between cascades constructed by different authors. (WP6)
27. At local level, land managers and farm decision makers noted many examples of effectiveness in relation to Nitrates Directive and Sustainable Use Directive, including riparian strips and catch crops (ND) and advice, training and testing (SUD). (WP6)

Key messages that are linked to two of the groups

Here we present the key messages that are relevant to two of the recognized groups. We have three combinations: EU DM – MAP, EU DM – CS and MAP – CS.

EU DM and MAP

The list of key messages that are relevant to decision makers and MAPs are:

1. Multi-actor platforms function well as platforms for exchange of opinions and ideas, and for sharing information and knowledge - provided a well-defined domain in which optimized management is relevant as a solution. (WP2, CS 8)
2. How to adjust the legislation that farmers have to fulfil to allow long term steady development of agriculture in the area. (WP2 and 7, CS 13)
3. Here too there is a discrepancy between the field- or trial-based measures reported in literature and the farm-level management options that are used/reported in the case studies. (WP4)
4. Which DSTs are most widely used and why. (WP5)
5. EU legislation on the protection of drinking water resources from agriculture is complex. (WP6)
6. Implementation would benefit from more advanced cross-referencing at the EU level. (WP6)
7. The cascades created using input and perceptions at local level in a bottom up data collection process can be different to the actuality of governance. This may help shed light on weaknesses in the effectiveness of governance. (WP6)
8. There is diversity in the effectiveness of water governance (using OECD Principles of Effectiveness for water governance 1-4) as perceived by local stakeholders. Further detailed analysis is beyond the remit of 6.2 it was apparent the Case Study responses were variable, yet there was general agreement that i) transboundary water management, data and information sharing was still in a process of development, and ii) vertical coherence experienced fewer obstacles across the different levels of governance. For the latter, some CSs reported fragmentation of water governance, insufficient technical knowledge and an infrastructure undermining the implementation capacities of local actors. Across all CSs, the coherency of governance was considered compromised at catchment and farm level. Based on a small sample size there appeared to be consensus that citizen participation and involvement of civil society was yet to be fully functional and effective. (WP6)
9. Cross section of issues and barriers in protection of water quality between EU and local level. (WP7)
10. Cross section of potential solutions for elimination of the weak points in protection of water quality between EU and local level. (WP7)

EU DM – CS

The list of key messages that are relevant to decision makers and case studies are:

1. A dilemma for engagement processes is that they need to be conceptualised and planned for in a long-term perspective, while the lack of immediate impact might lead to fatigue that jeopardise the processes. (WP2)
2. Closing nutrient cycles leads to more sustainability. (WP2, CS 4)
3. Farming for drinking water helps realising WFD objectives. (WP2, CS 8)
4. In some context (hydrogeology), a long time lag between N input and NO3 concentration in groundwater exists. (WP3)
5. Long time series are needed to link pressure and state indicators at the catchment scale (for GW and depending on hydrogeology: long lag times). (WP3)
6. Difficult to find promising participative monitoring techniques for groundwater. (WP3)
7. Proper nutrients management at farm level increases the security and safety of food production. (WP5, CS 12)

8. Finding measures and practices for water quality improvement that have best potential in their applicability, cost and adoptability on field by different actors that are involved in water quality disturbance. (WP7)

MAP – CS

The list of key messages that are relevant to MAPs and case studies are:

1. Multi actor platforms are not generic and need to be made specific to each CASE, in some cases (like England) there was already a very mature and complex set of relationships and the MAP processes must be allowed to evolve. (WP2, CS 3)
2. Many farm management tools promoting smart nutrient and/or pesticide use are available, but only a few tools explicitly consider the impact of mitigation methods on water quality. (WP5) Gerard’s
3. Insights in matching suites of DSTs to specific sites and users. (WP5)
4. EU countries can draw inspiration from each other concerning the reduction of nitrate pollution from agricultural sources. (WP5, CS 5)

Key messages that are linked to all three groups

Here we present the list of key messages that could be important to all three of the groups.

1. Sharing of perspectives and trust between key actors is a necessary condition for common understanding and for setting joint strategies, but does not necessarily lead to desired impacts. (WP2, CS 8)
2. Linking Pressure indicators to state indicators can help to understand contaminant origins (such as fertilisation) and variations. (WP3)
3. Importance of diversification of agricultural systems with low input crops (crops rotation improvement, pesticide decrease). (WP4, CS 4)
4. Costs and benefits of DSTs to a range of end users. (WP5)