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Organic Knowledge Network Arable

OK-Net Arable

Recommendations for a common European research agenda

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Executive summary

Organic farming is knowledge intensive and in supporting farmers in enhancing their production systems, there is a need to improve how knowledge is shared. This is the overall aim of the OK-Net Arable project. Work Package 2 of the project is concerned with facilitating the testing of practical and educational materials with farmer innovation groups to improve knowledge provision in this sector. The work package adopts an interactive multi-actor approach, bringing together practitioners from regional innovation groups with each other, and with advisers and scientists.

The aim of this report is to give a brief overview of the most important topics in organic arable farming for a common European research agenda. It identifies topics and open questions that are related to the main obstacles for increasing and stabilising yields in organic arable farming in Europe that should be considered in a common research agenda.

It builds on the farmers' perspective of knowledge gaps and questions (Cullen et al 2016, D2.1) and the experience from testing knowledge exchange tools with farmers (Bliss et al 2018, D2.2). This is contrasted with the researchers' perspective from the Ok-Net Arable project on which knowledge is already there and which is still needed (Niggli et al 2016, D3.1). Perspectives from the project partners, the partner countries and national research agendas on approaches that bring together the relevant actors to discuss and shape research agendas were also considered.

The ten recommendations for research topics are based on experiences made in the OK-Net Arable project. They include topics related to cropping systems and interactions, weed management, soil fertility and nutrient management and pest and disease control. Not all topics are equally relevant across the whole of Europe and in all areas both fundamental and applied research is needed. The farmers taking part in the OK-Net arable project were interested in a better understanding of the systemic aspects of organic cropping systems as well as in applied solutions to specific problems. There also is a need for further opportunities for knowledge exchange between farmers and farmers and advisors in Europe.

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1 Introduction

As organic farming is knowledge intensive, knowledge communication is a key aspect for bringing together ideas and approaches from practice and research to develop innovation. This report has been produced as part of the Organic Knowledge Network Arable (OK-Net Arable) project which has the overall aim to improve the exchange of innovative and traditional knowledge among farmers, farm advisers and scientists to increase productivity and quality in organic arable cropping throughout Europe, and to improve their environmental performance, to satisfy citizens' and consumers' demands. The project has adopted an interactive multi-actor approach, bringing practitioners from regional innovation groups together with advisers and scientists.

The project has three specific objectives: 1) to create a European network of well-functioning organic arable farmer innovation groups representing the best examples of co-innovation by farmers and researchers; 2) to digest and synthesize scientific and practical knowledge about organic arable farming to identify best practices (the project will develop and test innovative practical and educational material based on this information); 3) to create a European platform for knowledge exchange focusing specifically on organic arable drawing on experiences from diverse contexts.

To better understand how to create farmer facing knowledge exchange tools which better meet the needs of farmers, a range of practical and educational materials were tested with farmer innovation groups (mainly D2.1, D 2.2, D 2.3 and D3.2). However, the work of the project also highlighted areas where there appear to be knowledge gaps that required new research rather than improved knowledge exchange Moreover, a review on the state-of-the art in research for organic arable farming was written (D3.1). The aim of this report is to synthesise the results and findings, supplement them with further experiences from project partners and partner countries thus and identify topics and learnings for co-developing common research agendas to improve organic arable farming.

The aim of this report is to synthesise the findings from the project regarding and identify some learnings for the better targeting of new knowledge exchange tools as well as topics that should feature in developing a European research agenda for organic arable farming. Both can help to enhance research-farmer knowledge exchange and improve organic farming.

The next section presents a section on the identification of knowledge and research gaps, where the researcher and farmer perspective expressed in the project have been contrasted with each and with research needs reporting in national research agendas in some of the participating countries on a topic by topic basis. This is followed by a reflection on suitable approaches for the identification of research agendas and a section on conclusions/recommendations.

2 Identification of knowledge and research gaps

In the project, we made an evaluation of the main obstacles to increasing yields in organic arable farming among farmers across Europe. We found that according to the farmers, weed management was the most limiting factor, followed by soil fertility and nutrient management and by pest and disease control (D2.1, Cullen et al 2016). We therefore had a closer look at the knowledge and research gaps within these fields. In each of the following sections, we have contrasted the views expressed by the research experts that worked in the project considering (Niggli et al., 2016, D 3.1) and the results of focus group of EIP-AGRI on organic arable farming[1] with those of the farmers groups (see Cullen et al., 2016, D2.1) and with views reported by project partners as well as national research agendas.

2.1 Weed management

2.1.1 The view of the OK-Net Arable farmer innovation groups

The farmers' perspective on knowledge and research needs regarding weed management is centred around the real on-farm problems. According to Cullen et al (2016, D 2.1) and Bliss et al (2018, D2.2) the farmers' innovation groups highlight the design of weed suppressing crop rotations as one of their biggest knowledge gaps regarding weed management. In this field, a lot of research has already been done. It seems that farmers' knowledge gaps should be filled with detailed information on crop rotation effects for different soils, sites, conditions and farming systems. Crop rotation planners which are currently available do mention weed suppression but do not put a major focus on it. Moreover, the crop-rotation planners that were tested in the OK-Net Arable project by the farmers innovation groups were not evaluated very positively when it comes to user-friendliness and usefulness of the results (Bliss et al 2018, D 2.2). The task for the researchers will therefore be to enlighten the questions which are still open and compile the knowledge to a crop rotation recommendation that focused on weed suppression and takes into account the farm specific requirements. To make sure that the results are ready to be implemented in practice, co-development and participatory approaches should be used.

For improving weed management, farmers often ask for systemic approaches. For example, farmers require ideas how cover crops efficiently suppress weeds and how to manage intercropping systems. Furthermore, by-cropping, undersowing or cover crops and mulching to suppress weeds are of great interest to farmers. They feel that not enough knowledge is available to make practical use of it. Regarding mulching, it will be important not only to address the question which mulch to use, but also the questions how to apply it and to have a close look at further consequences for preceding crops in the rotation. Solutions for perennial weeds are also demanded by the farmers in the project. Another farmers' demand is more detailed available knowledge on weed biology. Farmers expect this knowledge to be helpful in using weeds as bioindicators and to be consequently able to reduce the reasons for the weed occurrence instead of focussing only on reducing weeds. In this case, research data and knowledge is already available, but the challenge for researches is to identify remaining gaps and to produce a compilation of information on weed biology in a format that is useable by farmers. Bliss et al (2018, D23.2) also report that farmers ask for more tools which provide information on weed biology.

[1] https://ec.europa.eu/eip/agriculture/en/content/focus-group-organic-farming-optimising-arable-yields-recommendations-and-outputs

It is interesting to note that the farmers participating in the project asked for more knowledge systemic approaches to weed control and were not so much focussed on more/better direct weed control measures.

2.1.2 The OK-Net Arable researchers' focus

The research needs in organic weed management on arable farms identified by Niggli et al (2016) (D3.1) are quite diverse. On the large and holistic scale, further steps in the system-based weed management are required. One interesting and important aspect in this field is approaches which reduce the weed seedbank in the soil by making use of ecological processes and interaction. According to Niggli et al (2016), this field of research is still in its infancy but will become of increased importance especially for organic farming. Therefore, research projects should be set up to provide more detailed information on weed-environment interactions, which can in a subsequent step then be used to build up systems with e.g. increased weed seed decay (e.g. through green manures and mulches) or consumption by animals (e.g. through management of fields and field margins). Moreover, new holistic approaches are also required for reducing perennial weeds. According to Niggli et al (2016), for dealing with perennial weeds, researches should start to think beyond the commonly known and used techniques such as turning the soil, stubble cultivation, over crops and ley phases.

Researchers are also required to give weeding techniques in new organic production systems such as reduced or no tillage systems a closer look. Weed control in organic no tillage is a problem, as, contrary to no tillage in conventional farming, no broad-spectrum herbicides are available to terminate the green manure, and therefore other measures both to prevent re-growth of the green manure and second growth of weeds must be taken. At the same time, it should also be taken into account that as recent research results indicate, it may be possible that even though weed incidence under organic reduced tillage is massively increased, this does at the same not significantly reduce yields. Reduced tillage is an interesting topic for organic farmers, and the interaction between reduced tillage, weed pressure and crop yield under different climatic conditions is a of great relevance.

On the level of direct weed control, Niggli et al (2016) highlight two aspects which should be more addressed by research in the coming years: One is precision farming and robot farming, which is presently strongly focused on conventional farming. Research should therefore produce tools specifically for organic farming, e.g. robots for direct weed control. The second field for development is, in contrast to the first, are low-tech solutions and tools for weed management. The reason why research in this field id much needed is that low-tech solutions are at the time being more likely to be adopted by a big number of organic farmers across Europe and should therefore get more scientific attention.

Besides concrete field and topics, Niggli et al (2016) also point out that the weed challenges are predestined for mutual learning and participatory research to turn new scientific knowledge into innovation on farm.

2.1.3 Topics raised by project partners and in national organic research agenda s

Topics related to weed management in research agendas and research topic consultation in OK-Net arable countries include the following. In the UK, there is not enough knowledge on suitable varieties for organic arable production, especially regarding weed suppression. Whereas for UK, more knowledge on crop varieties for organic in general is needed, in Germany variety testing, which already happens in many regions, should be more focused on weed suppression of the varieties. So far, mainly parameters which are important for conventional farming are collected.

The knowledge on weed biology and weed populations is also an aspect which according to experiences from Denmark should be looked at more closely. There is a multitude of questions that don't have

sufficient answers yet: how do certain weeds develop, what influences their development and how can we make use of the knowledge on weed biology to develop farming and weed management strategies that are economically viable?

The questions on weed biology are closely linked to the broader topic of systemic weed control instead of mechanic control. Background knowledge on target weeds coming from research is crucial for development in this field. It is also important to keep in mind that approaches for systemic weed control will differ from region to region and that therefore different (locally adapted) systems should be developed.

For the UK context, practical implications for weed management in no-till or minimum tillage systems in organic arable farming are still missing. Also, in Denmark, practical implications for no-/minimum tillage under local and organic conditions are missing. In Belgium, research is needed to find reduced tillage systems for small-scale and intensive farming systems, especially to find suitable machinery, practical options for weed control and ideas for green manures (which species for which conditions and for certain succeeding crops, how to terminate the green manure effectively). In this field, experiences and knowledge from successful systems in Southern Europe should be adapted to the more cold and wet climate conditions of the north. And in general, more focus should be placed on strategies to adapt no-till systems to different (local) farming types and vice versa (adapt farms and their farming systems to no/min tillage). . Besides research, development of practical guidelines to successfully farm with no/minimum tillage and adaption of existing machinery for the local conditions are required.

The Danish strategy for an organic research and development plan (Mathiesen & Sørensen 2012) also mentions systemic approaches to weed management such as prevention, use of functional biodiversity, identification of useful varieties and crop types, no till systems, perennial crops, cover- and inter-cropping as field in which knowledge is still required. The Flemish strategy points in the same direction and also mentions that knowledge is still needed for developing systemic approaches against weeds. The research agenda of the German Agricultural Research Alliance (Hamm et al 2017) also mentions the exploitation of the contribution that micro-organisms bring for plant resistance against weeds as a field for further research.

2.1.4 Conclusion

The research need regarding weed management in organic arable farming can be divided in two big themes:

- Systemic approaches, which try to build up the farming system as a whole in a way that helps to prevent and reduce weeds. Examples are crop rotations and intercrops which take into account weed biology, but also approaches such as no tillage.
- Direct measures. In contrast to the first, these are measure that can be taken when weed infestation occurs and which therefore target the weeds directly instead on creating a weed resilient system (or in addition to creating a resilient system) for cases when prevention fails, for example through hoeing and harrow combing. This should also include low-tech solutions and tools.

Systemic approaches to weed management in organic arable farming have a higher priority for all stakeholders than direct measures. The need to further research and develop systemic approaches is mentioned by farmers, researchers and national research agendas alike. One aspect is weed biology, with a focus on results and tools that are useful for practice. Research questions should therefore be carefully set up in cooperation with farmers and advisers to meet the needs of practice. The issue is not the lack of knowledge in general, but the lack of knowledge that is relevant to farmers and addresses their questions.

The design of crop rotations to suppress weeds (including cover-/intercrops etc.) and the adaption of no-till or minimum tillage systems should also be addressed more in depth by (on-farm) research. An interesting approach that should get more attention is the reduction of the weed seedbank in the soil, through developing measures to enhance either seed predation or decay. These aspects are all topics which can and should be addressed with practical research. Addressing weed aspects with participatory research is recommended by researches and demanded by farmers (in the way that they ask for tools which are tailored to their need). Another interesting finding is that researchers seem to be more interested in new technologies for weed management such as precision farming than the farmers are.

2.2 Soil fertility & Nutrient management

2.2.1 The view of the OK-Net Arable farmer innovation groups

When it comes to soil fertility and nutrient management, the farmers' questions range from very general and broad to rather specific aspects (Cullen et al 2016, D 2.1). For the management of organic arable systems with maximum soil fertility, practical knowledge and guidelines seems to be missing. The impression is that regarding soil fertility, knowledge on many separate parameters and questions is available, but the link between the topics to bring them together to get the big picture seems to be missing, from the farmers' point of view. The farmers' demand for tools and guidelines how to measure soil fertility supports this notion.

Apart from these general questions, farmers find that knowledge on systemic aspects of soil fertility and nutrient dynamics is still missing. For example, there is a need for sound information on the choice of cropping systems that make efficient use of nutrients available in the soil while preventing nutrient losses. Also, knowledge on management effects on nitrogen mineralisation is lacking. Crop rotation management to improve soil fertility and nutrient management also is a field in which farmers feel there is not enough sound knowledge available. Systems with undersowing and cover crops are interesting topics for farmers, but the knowledge on management is missing. The farmers positively evaluated a tool box for choosing cover crops, but some groups were doubtful that the information would be suitable for their conditions (Bliss et al., D2.2 2018). Specific questions such as "Which legume species/mixtures are most suitable for intercropping?" still cannot sufficiently be answered based on the knowledge available to farmers.

Regarding inputs, there are also knowledge gaps. For example, farmers are still stuck with the question how to sustainably increase soil organic matter by applying manures and composts and with the question which consequences the increased organic matter has for the farming practice. And finally, farmers see that knowledge on bringing nutrients back to the farm is missing. They ask for systems to recycle and return nutrients to the farm by using sewage sludge, municipal waste composts and biogas digest in a toxin-free way.

2.2.2 The OK-Net Arable researchers' focus

According to Niggli et al (2016), reduced or no tillage systems should not only be looked at more in-depth regarding weed management, but also regarding the synchronisation of nitrogen availability with plant nutrient requirements. Mulching of the green manures preceding the crops brings high amounts of carbon into the soil. Green manures and options for managing green manures and preceding crops to provide nitrogen at the time when the crop requires it are needed. As no-till systems can be linked to different types of farming systems, on-farm research seems suitable to bring answers for these questions.

Legumes play an important role in soil fertility on organic farms, they are known as the motor of crop rotations. Nevertheless, research that incorporates pre-crop effects and takes rotational design into

account is still lacking. Especially the integration of different spatial and temporal approaches within the crop rotation and the interactions with tillage should be taken into account (Niggli et al., 2016).

Intercropping is another interesting option to make optimum use of the available nutrients in the soil. The concept of "ecological precision farming", meaning small scale-intercropping, could be especially interesting and should be addressed by research.

Bio-effectors, comprising micro-organisms and bio-active compounds, are an interesting yet not very well researched option to enhance nutrient acquisition in arable crop plants. Currently, research projects are running, but besides a broader knowledge base on bio effectors for the transformation of nutrients into plant-available forms or to promote root growth, next steps to get the technology ready for on-farm use are also required.

Regarding phosphate, steps need to be taken in two directions: On the one hand, options to improve the plant availability of phosphate rock should be addressed. On the other hand, recycled and pollutant-free P from sewage sludge and other sources is an even more interesting option. Production processes are already at hand, research must minimise the risk of potential contamination and the recycling products need to be tested in organic farming in practice to find the best application modes.

For a deeper understanding of soil fertility and therefore as a basis for developing tools to improve soil fertility on farm, more research on indicators for soil biological activity are required.

2.2.3 Topics raised by project partners and in national organic research agenda

In 2017, the German V.Ö.P (Verbund Ökologische Praxisforschung, network for organic practical research) organised a multi-stakeholder workshop on nutrient management in organic farming. Farmers, advisers and researchers jointly defined research and knowledge gaps in this field. There are research needs on many different topics. Starting with how to analyse the nutrient status on farm, one gap is the implementation and interpretation of results of soil nutrient analyses. Methods and interpretation schemes come from conventional farming, they are therefore in many cases not directly applicable for organic farming. Developing tests and interpretation schemes aimed at organic farming is therefore a task for research. More in depth, knowledge is also needed to assess the nutrient optimum for different legume species and the nutrient status of the fields to be able to supply the "motor of the crop rotation" with the nutrients for optimum growth and plant and soil health. Here, a scheme for optimal values for fertilisation under different conditions for legume varieties and species would be useful. Apart from that, the German group also mentioned research needs regarding systemic questions: more information on site-specific nutrient dynamics are needed and based on that, practical guidelines for optimisation of on-farm nutrient flows to reduce external inputs.

In Belgium, research for specific problem is needed: historically, soils have a high content of P, therefore inputs of P per hectare are limited by regulations. This restricts organic farmers in their nutrient use and organic matter supply Therefore concepts for nutrient and organic matter management under these strict limitations are needed.

As already mentioned in the chapter on weed management, both for the UK context and for Denmark, practical implications for no-till or minimum tillage systems in organic arable farming are still missing, also with regard to nutrient management and soil fertility.

In the German Future strategy for organic farming (BMEL 2017), one of the five pillars the study has found for arable farming is nutrient management and soil fertility. Two other pillars also have connections with nutrient management: technical innovations and more competitive plants in complex environments. The

research agenda of the German Agricultural Research Alliance (Hamm et al 2017) also mentions the exploitation of the potential of bio-effectors (the contribution that micro-organisms bring) for plant nutrition as a field for further research.

The Danish strategy for an organic research and development plan (Mathiesen & Sørensen 2012) also mentions the optimal use of nutrients on farm and recirculation of nutrients as field for development. The knowledge of systemic processes as a basis for system optimising is here also seen as key factor. Two more detailed aspects are also mentioned: cropping systems that retain nutrients in the soil during winter should be developed and strategies for phasing out the use of conventional manure are needed.

The Flemish research strategy also mentions knowledge needs on biological processes and systemic approaches to nutrient management.

2.2.4 Conclusion

Regarding nutrient management and soil fertility, all stakeholders agree that deeper knowledge on systemic aspects such as nutrient dynamics and different aspects of crop rotation design and management are required. Focus areas should be the establishment of closed nutrient cycles at regional levels.

Strategies for offering optimal (nutrient) conditions to legumes to improve their efficiency and thus enhance their fertility building effects in the rotation are another issue for which all stakeholders ask for more knowledge.

Phosphorus is another common topic on which more knowledge and research is required. The German farmers seem to focus more on P recycling, whereas for researchers (Niggli et al 2016) are also interested in improving of rock phosphate products for higher plant availability.

Bio-effectors are only mentioned by researches, both in Niggli et al., (2017) and in national research agendas. The fact that farmers groups did not mention it illustrates that the topic is not much known to them (yet) rather that a lack of interest in this option. If research on the topic is continued, the practical implications or use on farms as well as dissemination should be carefully planned as well.

2.3 Pest & disease control

2.3.1 The view of the OK-Net Arable farmer innovation groups

When it comes to knowledge gaps regarding pest and mainly to diseases, there is less overlap between the partner countries than for weed control or soil fertility, likely because of differences in climate, soil, crops grown and crop rotations (Cullen et al., 2016). Moreover, risks are variable from year to year, depending on the weather conditions. Therefore, in this report country specific issues mentioned by the farmers' groups regarding pests and diseases are not considered, each region would have its own specific problems. Problems are more common where more horticultural crops are grown. However, we identified one common disease problem reported in most partner countries: rusts (in particular yellow rust in temperate, cold, wet and humid climates.

The farmers' perspective is that new, copper-free plant protection products are lacking and should therefore be developed. Also, the conflict of interest between no-till and soil hygiene should be more researched. Pest problems do not seem to be a major issue for the farmers involved in the project. In general, farmers expressed interest in deeper knowledge on cover cropping and intercropping to reduce pests and diseases.

2.3.2 The OK-Net Arable researchers' focus

For the control of diseases, Niggli et al (2016) see research needs mainly in two big areas: first, breeding of varieties suitable for organic farming should be intensified, mainly with regard to disease resistance. Especially the late blight resistance of potatoes should be more intensively targeted. Intensified breeding programmes are also needed for legumes, mainly lupins which are resistant against brown spot and anthracnose. Secondly, the resilience of cropping systems to prevent diseases and thus holistic preventive measures are another aspect where not only more research is needed, but also a combination of different approaches. A big amount of research has been done in this field in the last years, but research in physical methods, biocontrol organisms and botanicals should be intensified to have on-farm solutions ready as soon as possible.

Only few options for direct measures against plant diseases are available in organic farming and they are even completely absent for some specific disease problems. Preventive measures are important and farmers should aim at applying as many of these measures as possible. Nevertheless, the entire know-how of preventive measures cannot be applied on every farm. On the one hand, lowering one risk might enhance the risk for another disease. On the other hand, certain weather conditions, development of resistances etc. may lead to an outbreak even if all possible preventive measures had been taken (Niggli et al 2016). Consequently, there is a need for developing more direct measures which can act as a backup in case preventive measure fail or cannot be applied fully due to the above mentioned reasons.

Regarding pests, severe problems mainly occur in two arable crops (note: this does not apply for horticulture), potatoes and oilseed rape. For the later, research for methods against pollen beetle, stem weevils and flea beetles is required. In potatoes, more knowledge on how to reduce wireworm problems is still needed. In organic arable crops in general, better measures against slugs should also be developed.

2.3.3 Topics raised by project partners and in national organic research agenda

In France, measures against predation of sunflower and soybean seeds by birds are still required, and the discussion with partners from other European countries showed that no solution is at hand at the time being.

In Belgium, solutions for late blight and wireworms in potatoes are mentioned, as they are responsible for harvest losses and no effective measures are at hand yet. Another big issue in Belgium are soil- borne diseases, here measures to prevent harvest losses are required. Ideas such as green manures and tillage strategies exist, but more research and knowledge is needed before it can be of help in farming. Options for treatment for soil-borne diseases should also be researched.

The Danish strategy for an organic research and development plan (Mathiesen & Sørensen 2012) names prevention and management strategies against pest and diseases including the use of functional biodiversity as important aspects to be further developed and researched.

Both the research agenda of the German Agricultural Research Alliance (Hamm et al 2017) and the Future strategy organic farming of the German Federal Ministry of Agriculture (BMEL 2017) mention alternative methods against fungal diseases (especially alternatives for copper) as one important field of research for the future. The research agenda of the German Agricultural Research Alliance (Hamm et al 2017) also mentions the exploitation of the contribution that microorganisms (bio-effectors) bring for plant resistance against pests as a field for further research.

2.3.4 Conclusion

Apart from breeding for resilience and resistance, which is seen as highly important by researchers, research needs regarding pest and diseases seems to be either very general (resilience, direct measures, cover- and intercropping, functional biodiversity) or very specific (seed predation by birds). This indicates that in this field, both a better understanding of underlying factors (such as the role of functional biodiversity) and strong practical research and participative agenda setting approaches, which integrate researchers, advisers and farmers, are required. This approach will help to specify the general demands and to break them down into topics which can be worked at in research projects. Most likely, apart from a common research agenda for jointly tackling open questions on pests and diseases, regional strategies for problems which occur on a local level or in local crops will also be needed. Organic farmers that currently use copper-based fungicides as a tool for disease control have concerns about the long-term use of the products are may be looking for alternatives to developed, registered and made available to them.

3 Further knowledge gaps identified by project partners

Apart from the above-mentioned themes, OK-Net Arable partners identified a couple of research/knowledge needs related to improving organic arable yields that do fit in the three big themes discussed above.

Functional agrobiodiversity is for many OK-Net Arable partners a very interesting aspect about which not enough is known. In Belgium, the main question is how farmers with fixed production structures (e.g. greenhouses, tunnels…) can incorporate the concept. In the UK, some farmers are already experimenting with methods to enhance functional agrobiodiversity. But apart from a few fundamental trials, there is so far not much research in this field. More knowledge on plant-soil-insect interaction is required. Based on that, practical recommendations for farmers on how to use trap crops, companion crops, pollinator strips and on economic effects of those measures should be developed.

In Belgium there is a demand for a closer research look at economics and synergies between arable farming and animal husbandry. The first interesting aspect that researchers should provide data for is the profitability of locally grown arable crops (mainly protein crops) for feed (and food). The second aspect is the development of a transparent cost model for organising the co-operation between arable and livestock husbandry farms, in which they exchange fodder crops, manure and land.

Besides technical aspects, new insight in and the full exploitation of already existing socio-economic knowledge regarding participatory approaches will play a key role in setting up research agenda for improving yields in organic arable farming in the future. The following chapter is dedicated to these aspects and explains more in depth why and how they will contribute to this task.

On the European level, the TP Organics Strategic Research and Innovation Agenda (Moeskops & Cuoco 2014) mention the availability of organic seeds as an important field of research. The aim is to get towards 100% organic seeds. Besides seed production and availability, breeding is also seen as an important field to be further developed as for organic arable farming, robust plant varieties are required (see also pest and disease control). Moreover, innovative information and communication technology (ICT) tools for organic cropping systems need to be developed. Another aspect which needs more input from research are improved ecosystem services for organic arable farming.

TP Organics unites companies, farmers, consumers, civil society organisations and researchers active in the organic value chain from production, input & supply, to food processing, marketing and consumption in

Europe. brings together small and medium-sized enterprises, larger companies, farmers, researchers, consumers and civil society organisations involved in the organic value chain from production, input and supply, to food processing, marketing and consumption. Its mission is to strengthen research & innovation for organics and other agroecological approaches that contribute to sustainable food and farming systems. It identifies research and innovation needs and communicates them to policy-makers. The Strategic Research and Innovation Agenda is the result of an intensive participatory process lasting a year and a half. It was a stepwise process, starting with a Stakeholder Forum to discuss trends and research needs. This was followed by a call for experts to contribution to the drafting of the document based on the results of the forum discussion. Ultimately, more than 40 experts contributed over the duration of the process. The first draft was then discussed with different actors in two workshops and an online consultation with about 300 responses was organised. The results were processed in the second phase document, which then was brought into another consultation phase with international actors and other European technology Platforms. In the last processing phase these comments were integrated and the document was finalised. Due to its various iterations loops and due to the involvement of a multitude of relevant actors and groups, the development of the Strategic Research and Innovation Agenda for Organic Food and Farming can be seen as a best-practice example.

4 Methodology for the identification of research gaps - Examples from OK-Net Arable partner countries

The chapters above show the status quo of research needs in organic arable farming according to experiences in the OK-Net Arable project and the project partners' experiences in their own countries. The represents only be a proportion of the collective whole of research and knowledge needs at present. This chapter covers o concepts and approaches that help to produce a future research agenda that meets the needs of the organic sector and includes the ideas of all relevant stakeholders.

The section is based on experience in the project, examples and experiences from the partner countries and the Strategic Research Agendas of TP Organics (Moeskops & Cuoco 2014, Schmid et al 2009).

4.1 Multi-actor workshops

Multi-actor workshops with farmers, advisers and researchers are a widely used option to set up research agendas. In the workshops, facilitated group discussions are used to define topics and aspects to be covered by a research agenda. In Estonia (EOFF) this approach it was used to prepare the Estonian Organic Farming Cluster for field and vegetable crops. In Germany (Bioland/V.Ö.P.) it was used to define research needs regarding nutrient management in organic arable and vegetable farming. Denmark (ICROFS) uses a similar but even broader approach to develop new research and innovation strategies for 3 to 5 year terms: besides farmers, advisers and researchers, also food processing companies and politicians are also included in the workshops. Further stakeholders are invited if necessary. Another example of this format is the farmer workshop that is organised each year by Inagro in Belgium and inspires them to set up and apply for research project.

For successful multi-actor workshops, there are some general key factors:

- Invite different people from all target groups
- Choose facilitation format that allows everyone to speak freely and contribute his/her points (e.g. World Café)
- Prepare objectives and questions of the workshops very carefully in advance (be structured and give the participants structure for their discussion)
- Take farmers' opinions seriously. Make it visible that their opinions count and are taken up in research projects
- Reward farmers for their effort (financially)

The limit of this format is that it works effectively only for rather narrowly defined topics, as expert farmers, advisers and researchers are required. Therefore, to produce a research agenda on a broader topic or for organic arable farming in general, several different workshops with different actors will be required. Moreover, using this format on a regular basis is likely to be challenging. Even if a financial reward is offered, the participation is extra work for farmers and it is hard for them to see the benefits is will bring. It is therefore likely that the farmers attending will be the ones that are most loyal to the inviting organisation and not necessarily the ones with the highest expertise or experience.

4.2 Having farmer focussed workshops and approaches

The participation in focus-group meetings of farmers (and other actors) and distilling research needs from their conversations can be seen as an alternative approach. This approach was practised by ICROFS (Denmark) and also recommended by BioForum (Belgium). The advantage of this approach compared to multi-actor workshops is that farmers have no extra-effort for participation; their opinion is collected in meetings they join anyway. In that context, it is also likely that farmers speak more freely about their needs than in a group with researchers. And as a most of these meetings takes place on a regular basis, over time a broader set of research needs will be identified than in just one workshop. The limitation of this format is that one single person or a few persons decides which issues will finally make it into the research agenda and the final selection of topics may not be based on a participatory process. Nevertheless, review of suggestions is necessary to ensure that only aspects that are not researched yet will make it on the agenda. Good documentation of the topics gathered in specific workshop complemented by participatory approaches for developing the priorities can make this approach more participatory and transparent.

4.3 Other approaches

Both Belgium (BioForum) and in the UK networks and network meetings exist, although in details the approaches are quite different.

BioForum has a farmers' network in which they educate farmers to express their research needs and support advisers and researchers to take part in exchanging knowledge in a farmer friendly way. This BioForum-network is again part of a bigger network in Belgium called the Organic Research and Knowledge Network, in which also practical and academic researchers take part. This network meets on a regular basis and discusses ways to exchange knowledge between farmers to researches and vice versa.

In UK, the Innovative Farmers Network (ORC is a partner in the network) consists of farmer field lab groups with participating researchers. Field labs are based on the stable school/farmer field school approach and explore a different topic identified by the farmer group. The farmers visit different colleagues in the course of the field lab and each group has a co-ordinator and researchers. They seek to understand what research already exists and how they can build on that and/or fill research gaps with on-farm trials. This approach works well to engage farmers.

ICROFS in Denmark keeps an "open letterbox" to which farmers can send in suggestions for research questions. This format is quick and easy to use for everyone who knows it and simple to use for the organisation that collects research questions. It is limited by the fact that a wide range of people must know about it to give the incoming topics broadness and relevance and to avoid an emphasis of certain topics that does not reflect reality. Moreover, the quality of the incoming topics will vary broadly, some may go very much in depth and some stay on the surface. Therefore, this format can be seen as a good way to supplement other formats but should not stand alone.

In France, researchers and other stakeholders interested in organic research have launched FROG, the French Research Organic Group, which is one of the seven National Technology Platforms of TP Organics. It is a platform that brings together researchers and other stakeholders of the organic sector in an informal way. The core is a permanent group, but the composition of the platform is variable regarding depending on the topics being discussed. In 2017, the FROG has published a document which brings together research needs for the organic sector. It was collected from existing publications on the topic as well as from researchers and actors and brought together their views and demands.

These examples from partner countries show that there is already a good and strong connection between research, advisory organisations and farmers and that there are plenty of ideas for working together and collecting research needs. This is a good basis for further development, but is the process is still in its infancy in some countries such as Bulgaria and Hungary, where some these of the basic steps still need to be made. However, further development of existing approaches is required as most of the approaches which are presently used involve farmers only in a rather restricted framework, giving them space to define research questions but there is not necessarily co-development in the following steps such as the setup of a research project, the research itself and the development of tools. The examples which involve farmers to a larger extent (Belgium and UK) can help to build a basis for developing a concept to set up a common European research agenda in a participatory and holistic way.

This has not to be developed from scratch, as the Strategic Research and Innovation Agenda for Organic Food and Farming (Moeskops & Cuoco 2014) does offer a good basis to build upon too. This already existing agenda of TP Organics, the European Technology Platform for organic food and farming and for low-input agriculture is also built on participatory approaches.

In general, co-development processes and participatory approaches with real added-value in research for organic arable farming should be integrated from beginning (setup of research questions) to the end (implementation of new findings on farm) to bring the highest benefit for farming practice.

4.4 Suggestions for a stepwise participatory approach to develop a research agenda for organic crop production

Based on experiences reported above, we propose a stepwise approach to further develop a research agenda for organic crop production, which should include farmers meetings, field days and research conferences. A scheme to categorize the topics will need to be developed that should cover e.g. the following points:

- Description of aspect/problem (e.g. late blight in potatoes)
- Part of which broader topic is it (e.g. disease management)
- From which stakeholder group does it come? (e.g. farmers, researchers, advisors?)
- What is the scope of the problem? Under which conditions does it occur (e.g. description of climate, soil etc) Which effects does it have (e.g. yield losses)?
- What is the history? (e.g. since when does the problem exist, what has been tried to solve it, why did it not work)
- Can a concrete research questions be phrased?
- How relevant is it for organic arable farming in the region/in the whole of Europe?
- How urgently is a solution needed?
- Which ideas for useful results/tools etc. are proposed?

The collected aspects should be complemented by literature studies and e.g. by using ‘mental models’. The aspects that are developed in this way should then be transformed into discussions points. In a well facilitated process, the collected aspects should be discussed in a multi-actor workshop (or several ones in different countries affected by the topic to avoid language barriers) with the clear aim to elaborate precise and detailed research topics. This should include specifications on

- The challenge/problem
- The aspects to be researched
- The expected outcomes: what will make them useful for farming practice?
- The planned impact on practice: which tools and strategies will help to make use of the results in farming practice

The setting up of a research agenda should only be the first step of the co-development process. Useful results with a high likelihood to be integrated into practical demand for participatory approaches also during research and in knowledge communication of new results. In other words, an important step to be made is to loosen the focus on knowledge transfer and shift to two-way knowledge exchange for research in organic arable farming. This means including the farmers in the definition of the research question, the research itself (farmer-led on-farm research), the development of tools, the implementation of new practices on the farm and wider knowledge exchange (peer-to-peer learning).

The multi-actor approach of Horizon 2020 programme (EIP-AGRI 2017) shows the structure which is needed for successful research agendas: End-users, in this case farmers, must be involved in defining the problem and thus the research question. This will not only lead to projects which produce knowledge that is needed in practice. It also generates a co-ownership with the involved actors. It is therefore important to include different actors with complementary types of knowledge. Special attention should be paid to the role of the advisers. Advisors have a key role in intermediating and facilitation between research and practice and by taking up and transferring needs and new knowledge. They are both experts in technical questions and in communication, with a strong connection to practitioners and therefore close to their needs. But in many cases advisers seem not to be able to manage that role, mainly due to time restrictions and high workloads, but partly also as it seems to exceed their skills and competencies. To enable advisers to manage this important role and support the development of research agendas, it is important to give them more time and space for these tasks, which e.g. could mean that funding for these tasks will also be granted to advisory organisations instead of only funding for advisory work on farm. Moreover, more training in facilitation as well as support for networking with researchers is required. Upcoming research projects should not only foresee farmers as co-researchers, but also advisers. The role of the adviser as co-researcher should be designed in such a way that it can be managed part-time, to enable the adviser to continue advising, spread the new knowledge and remain close to practice.

One last aspect, which will also help to set up new and relevant research agendas in the future comes from the German future strategy organic farming (BMEL 2017): it demands more efficient frameworks and structures for research for organic farming, a better adapted and higher funding and a strong focus on transdisciplinarity, the development of research-practice-network and of model regions. These improvements could also be a motor for European research in organic arable farming and the setting up of common research agendas, as new demands can easily spin-off from networks and model regions.

5 Conclusions and recommendations for a common research agenda

In this report, we collected the research gaps in organic arable farming identified by researchers and farmer innovation groups in the OK-Net Arable project, which we combined with input from the partner countries about their ow experiences. The report thus contributes to setting a future research agenda for organic arable farming. The key areas of concern to the farmers were weed management, soil fertility and nutrient management as well as pest and disease control and in all areas. Reasons for acceptance successful implementation of new practices appear related to the relevance of the practice to the challenges of the specific system and to presenting the knowledge about them and generating opportunities that allowing farmer to judge for themselves whether the practice is suitable.

Our farmer groups asked for deeper knowledge on systemic aspects of soil fertility, nutrient flows and dynamics, and weed problems and researchers also seem to acknowledge more and more that in-depth and systemic effects need to be investigated. So far only few studies and projects in this field have been identified, probably due to the complexity and the need for longer-term trials that go beyond project cycles.

And apart from this need for basic research, there is also a clear need for applied research under varying climatic conditions of Europe. This was clearly illustrated by the practical testing of innovative approaches that was carried out in the projects, such using reduced tillage and weeding equipment under different conditions. There also is need to generate more opportunities for knowledge exchange between farmers and between farmers, researchers and advisors within countries and across borders. Such visits were hugely valued by the farmer groups taking part in this project and stimulated farmers to try new practices and techniques, so far not used in their own country

The following ten important research topics to improve organic arable yields were identified in the OK-Net Arable Project.

Cropping systems and interactions

1. Research should provide knowledge for a more profound understanding of the interactions between different aspects of the cropping systems, such as the impact of balanced multi-annual crop rotations with fertility-building crops, intercropping and green manures on weed occurrence, pest and disease risks, nutrient flows and crop yield. Based on this, practical tools and recommendations for on-farm implementation under the various conditions across Europe are required.
2. Further steps in **plant breeding** for more resistant and resilient plants which are adapted to organic farming and external low-input conditions and challenges must be taken.

Weed management

3. Systematic approach that help to present and reduce weeds, such as crop rotations taking into account weed biology and understanding reasons for weed occurrence. Some background knowledge exists, and farmers want to be able to make more practical use for taking appropriate action.
4. Direct approaches to weed management that contribute to the reduction of the weed seedbank in the soil instead of controlling the weeds themselves are needed and the interaction between weed control and reduced tillage should be further researched.

5. New technology for weed control, such as robots seem interesting from the researchers' perspective and should be developed in close collaboration with farmers so that meet their practical needs, as well as low-tech solutions and tools.

Soil fertility and nutrient management

6. Developing a better understanding for and recommendations for practical use of **no-till** or minimum tillage systems for different farm types and especially for more humid and cold climates. Both weed control aspects and nutrient flows should be researched more detailed, leading to practical guidelines for on-farm application under different climatic conditions.
7. Research needs to deliver practical options to create optimum growing conditions for **legumes** (both forage legumes and pulses) as the engine of the crop rotation, but also for the choice of legume and other species in crop mixtures and as green manures under varying conditions.
8. **Bio-effectors** could play an important role for legumes, but also for all other crops and should be more closely looked at by research and products/recommendations for practical implementation should be produced.

Pest and disease control

9. Making use of **functional biodiversity** in organic arable farming is an aspect that is still neglected too much. This huge field could bring multiple benefits for pest and disease control, but also for weed control, soil fertility and pollination etc. A detailed agenda based on the farmers' needs and questions should developed and actions be taken accordingly.
10. New products are also needed for disease management, such as copper replacement, but also more products. In general, there is a huge lack of direct control measures for pests and diseases for those cases where preventive strategies have not been successful.

Not all topics are equally relevant across the whole of Europe. There are problems and needs which exist only in certain regions. Therefore, besides a common European strategy, regional approaches are also needed: projects and solutions for regionally relevant topics should be developed in the respective regions only rather than aiming for general solution across Europe. One example is no-till / minimum tillage, are already working quite well in southern regions and under dry conditions, but solutions are required for no-till in organic farming in the northern, more humid and cold climates. It is therefore important to consider the context, under which research questions were raised. The experience in the OK-Net Arable Project illustrates that lack of contextual information is one important factor that limits the uptake of research recommendations by farmers and practitioners.

Two Research and Innovation Agendas (Moeskops & Cuoco 2014; Hamm et al 2017) mention another important aspect that will also improve research on the European level: the collection of long-term farm data as an important basis for research that will deliver an improved knowledge basis for interpretation of new research results. Such data are also needed for developing tools that meet the needs of farmers, and that support farmers in making management and investment decisions. Both Hamm et al (2017) and Padel et al (2010) also ask for a stronger emphasis and involvement of on on-farm research to ensure that the outcomes will be relevant and usable for practice.

Important is also to reflect on the approach to define topics for future research agendas. A useful methodology for developing a common research agenda must also be systemic, bringing together the needs of European partner countries and the expertise of all relevant actors (including organic advisors) in one agenda in a participatory co-development process. This should be stepwise approach that includes

farmers' meetings, field days in the different pedo-climatic zones regions of Europe and research conferences (see Section 4.3).

Consultations should seek to actively engage farmers, who are the target group of the research whose needs should be met. Experience from in Germany (V.Ö.P.) also suggest that it is crucial to strengthen the role of the advisers in the research topic consultations. Advisors have a key role in facilitation between research and practice. They are both experts in technical questions and in communication, with a strong connection to practitioners, and therefore close to their needs. However, time restrictions and workload may prevent them for taking part. The question how organic farmers and advisors can support the development of research agendas needs further attention, and instruments such as funding their time to provide input should be explored.

6 References

Bundesministerium für Ernährung und Landwirtschaft (BMEL) (2017): Zukunftsstrategie ökologischer Landbau. http://www.bmel.de/SharedDocs/Downloads/Broschueren/Zukunftsstrategie-%C3%B6kologischer-Landbau.pdf;jsessionid=0F974F80A4E0CB4E532F560AFA4AA305.1_cid376?__blob=publicationFile

Bliss, K., et al. (2018). Evaluation of the usefulness of tools and end-user materials to farmers. D 2.2 of OK-Net Arable. Newbury, Organic Research Centre.

Cullen, B.; Amos, D. Padel, S. (2016): Organic Knowledge Network Arable - D2.1 Description of farmer innovation groups. http://orgprints.org/30748/

EIP-AGRI Horizon 2020 multi actor projects (2017) https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_brochure_multi-actor_projects_2017_en_web.pdf

EIP-AGRI Focus Group on Organic Farming - Optimising Arable Yields: Final Report (2013). https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/fg1_organic_farming_final_report_2013_en.pdf

Estonian organic farming development plan (2014). Online at https://www.agri.ee/sites/default/files/content/arengukavad/arengukava-mahepollumajandus-2014-2020-eng.pdf

Hamm, U., Häring, A. M., Hülsbergen, K.-J., Isermeyer, F., Lange, S., Niggli, U., Rahmannn, U., Horn, S. (2017): Research strategy of the German Agricultural Research Alliance (DAFA) for the development of the organic farming and food sector in Germany. *Organic Agriculture* 7(3):225-242.

Mathiesen, C. & Sørensen, L.S (2012): Research and development strategy 2012 in Organic farming and food "Growth, credibility and resilient systems". International Centre for Research in Organic Food Systems (ICROFS), Tjele, Denmark. http://orgprints.org/22537/

Moeskops, B. & Cuoco, E. (Eds.) (2014): Strategic Research and Innovation Agenda for Organic Food and Farming. TP Organics, Brussels, Belgium.

Niggli, U., Schmidt, J., Watson, C., Kriipsalu, M., Shanskiy, M., Bàrberi, P., Kowalska, J., Schmitt, A., Daniel, C., Wenthe, U., Conder, M., Wohlfahrt, J., Schild, M., Dierauer, H., Krauss, M., Moeskops, B., Padel, S., Micheloni, S., Constanzo, a., Thonar, C., Wilbois, K.-P. (2016): OK-Net Arable: State of the art research results and best practices – D 3.1. Forschungsinstitut Biologische Landwirtschaft, Frick. http://orgprints.org/30506/

NOBL (2014): Research strategy for Organic Food and Farming. http://www.nobl.be/sites/default/files/Onderzoeksnota2014_NOBL_ENG_website_0.pdf#overlay-context=en/node/16

Padel, S., Niggli, U., Pearce, B., Schlüter, M., Schmid, O., Cuoco, E., Willer, H., Huber, M., Halberg, N., Micheloni, C. (2010): Implementation Action Plan for organic food and farming research. Technology Platform TP organics, Brussels.

Le Pichon V., Tchamitchian M., coord., 2017, Programme cadre français pour la recherche et l'innovation en Agriculture Biologique, FROG, ITAB. http://www.itab.asso.fr/downloads/frog_web.pdf

Schmid, O., Padel, S., Halberg, N., Huber, M., Darnhofer, I., Micheloni, C., Koopmans, C., Bügel, S.,; Stopes, C., Willer, H.,; Schlüter, M., Cuoco, E. (2009): Strategic Research Agenda for organic food and farming. TP Organics, Brussels.