Exchanging knowledge to improve organic arable farming: An evaluation of knowledge exchange tools with farmer groups across Europe

Keywords: Knowledge exchange, internet, peer-to-peer, video, technical guide, organic arable farming

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Abstract

Organic farming is knowledge intensive. To support farmers in improve yields and organic agriculture systems, there is a need to improve how knowledge is shared. There is an established culture of sharing ideas, successes and failures in farming. The internet and information technologies open-up new opportunities for knowledge exchange involving farmers, researchers, advisors and other practitioners. The OK-Net Arable brought together practitioners from regional Farmer Innovation Groups across Europe in a multi-actor project to explore how online knowledge exchange could be improved. Feedback from the groups was obtained for 36 'tools', defined as end-user materials, such as technical guides, videos on websites informing about practices in organic agriculture. The groups also selected one practice to test on farms, sharing their experiences with others through workshops, exchange visits and through videos. Farmers valued the same key elements in face-to-face exchanges (workshops and visits) as in online materials. These were the opportunity for visual observation, deeper understanding of the context in which a practice was being tried and details about what worked and what did not work. Videos, decision support tools and social media can provide useful mechanisms for taking knowledge exchange online, if farmers' experiences and practical implication are shared, and more visual information about the context, economics, successes and failures is provided. Online platforms and forums should not be expected to replace but rather to complement face to face knowledge exchange in improving organic farming.

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1 INTRODUCTION

The global literature for temperate and Mediterranean climate zones narrows the yield gap between organic and conventional farms down to 9 to 25 percent (Seufert et al., 2012; De Ponti et al., 2012), with legumes showing a considerably smaller yield gap than cereals or tubers (Roös et al., 2018). There is now a re-vitalized interest in increasing yields in organic agriculture to provide more organic food for a growing population. Yield differences within organic farming are a starting point for potential yield improvements but are less well documented. Yields vary considerably with growing conditions, management practices and crop types. According to Roös et al. (2018) much can be gained from better management on farms that substantially underperform in comparison with top-performing farms under the same conditions.

The Organic Knowledge Network Arable (OK-Net Arable), a three-year thematic network funded under Horizon 2020 aimed to improve knowledge exchange (KE) between farmers, advisors and scientists and thus to improve organic arable production throughout Europe. It was founded in the belief that there is potential for improving agronomic practices through KE on best and innovative practices, which could help to bridge the yield gap between organic and conventional, as well as among organic, farmers. Cullen et al. (2016) reported on yield differences between different organic farmers in innovation groups that took part in the OK-Net Arable project. For example, for winter wheat, the reported variation in yields ranged from 0.3 to 8 t ha^{-1}, with the majority of groups reporting yields ranges from 1 to 6 t ha^{-1} (Cullen et al., 2016). Similarly, long term trends on five organic farms for organic winter wheat yield in the UK show a range of 2.4 to 6.9 t ha^{-1} (Calbeck and Sumption, 2016). All these data suggest a need to improve yield performance and stability in organic farming. Niggli et al. (2016) describe a number of practices for organic arable cropping that could help to improve yields. This involves the implementation of well-known best practices, e.g. the use of favourable crop rotation design to prevent weed infestation and disease and pest outbreaks, but also the sharing of less-known practices and innovation (e.g. bio-effectors, robotics). The OK- Net Arable project contributes directly to key features of Organic 3.0 of continuous improvement towards best practice, of using the internet and social media, of empowering as well as systematically extracting, evaluating, preserving and renewing tacit knowledge of farmers and farm communities (Arbenz et al., 2017).

Innovation is closely related to information flows, learning and social interaction and different types of knowledge can play important roles in social learning (Knickel et al., 2009). A focus on innovation processes rather than singular innovative ideas is typical of transition theory, recently used to look at innovation for sustainability in European agriculture. This recognises the importance of improving the flow of information from scientists to farmers and advisors in supporting farmers to make better decisions (Pretty et al., 2010). With this goes a need to rethink communication in agriculture – moving away from the idea of a linear 'transfer of technology' from research to practice to supporting knowledge exchange between all actors in an innovation system, including researchers, farmers and advisors (Leeuwis and Aarts, 2011). This interactive model of innovation underpins the

European Innovation Platform for Agriculture, EIP-AGRI[1]. One the instruments of EIP-AGRI are the thematic network projects for agriculture in H2020, such as OK-Net Arable.

Despite the clear benefits of face-to-face KE and n field events, these are costly in time and travel. It is therefore interesting to consider how KE can be taken online. The internet offers a huge opportunity to enhance KE on sustainable farming. Information can be made rapidly available, updated regularly and shared with a wide audience. Offering the opportunity for more interaction between users. However, there is also a danger of information deluge and it is therefore essential to consider how providing access to relevant and reliable information can be ensured (Bruce, 2016). Information sources aimed at the farming community are often fragmented and disconnected (Klerkx and Proctor, 2013), as such there is a need to pull them together in one place for busy farmers to find information and online hubs can play a key role (Bruce, 2016).

In the Organic Knowledge Network Arable (OK-Net Arable) we adopted an interactive multi-actor, co-innovation approach, based on collaboration of organic research institutes, organic farming associations and a network of regional Farmer Innovation Groups across ten countries (Austria, Belgium, Bulgaria, Denmark, Estonia, France, Germany, Hungary, Italy and the UK). These groups included organic farmers who grow arable crops, advisors and researchers and they meet regularly – at least once per year. The thematic network thus aimed to realise co-innovation processes that bring together a range of actors, including researchers and advisors, to create space for change (Leeuwis and Aarts, 2011).

The project looked at the research communication process from a farmer's perspective. A Knowledge Exchange (KE) tool was defined as formatted information used as a means for the circulation of knowledge among farmers and advisors, potentially involving (as source of information, a reference or other, but not as primary target) researchers (Ortolani and Micheloni, 2016). The project partners identified KE tools on organic arable crops topics in the form of technical guides, decision support tools, websites and videos and presented them on a newly developed knowledge platform (*www.farmknowledge.org* .)

We worked with the Farmer Innovation Groups to improve their access to practical knowledge, but also to learn about their challenges and likes and dislikes of different types of KE tools that are available online. Common challenges identified by the groups related to weed management, soil fertility and pest and disease control, but they also made reference to a general lack of knowledge and research about organic agriculture; nutrient management, especially nitrogen; and challenges with grass clover leys and rotations (see Cullen et al., 2016). Each group was then asked to provide feedback on relevant KE tools through workshops and by using some of the practices, equipment or recommendations described in the tools.

This paper sets out key feedback on KE tools and the process of co-evaluation. . It then seeks to draw on these learnings for improving online KE on organic farming.

2 METHODOLOGY

The approach used in the OK-Net Arable project to evaluate Knowledge Exchange (KE) tools with Farmer Innovation Groups was based on an initial offer of tools for groups to choose from and then

[1]https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_brochure_multi-actor_projects_2017_en_web.pdf

discussing them in moderated structured workshops, supported by some scoring exercises and use of some of the tool recommendations. The tool evaluation considered the thematic fit, i.e. whether a tool provided a useful answer to the challenge that the groups were facing and the preferences of the Farmer Innovation Groups for different types or formats of the tools.

An initial offer of 30 tools describing practices in organic agriculture, divided into five themes, was selected by the project steering group (see Table 1) based on a list of criteria that included type of tool, provision of practical information, availability in English and other languages, potential for translation and wider geographical relevance. Each group was encouraged to select up to ten tools from this initial offer but could also make suggestions for different tools (for example in their own language), which were then added to the offer. The tool evaluation presented in this paper is based on 43 different tools, which included different types of leaflets/technical guides, decision support tools, websites and videos (see Table 2). Of those, 36 tools were evaluated by one or several of the Farmer Innovation Groups in workshops. Most tools have been uploaded to the knowledge platform of OK-Net Arable (*www.farmknowledge.org*), but some have been reclassified under different topics or tool type after they have been evaluated by the farmers group.

The network was made up 12 Farmer Innovation Groups in ten countries, with approx. 343 organic farmers and advisors engaged in total, group sizes varying from 8 -49. All members of Farmer Innovation Groups grow organic arable crops and cereals but represent a range of farm types, including cereal producers, mixed farms with livestock, farms with field vegetables (e.g. potatoes, cabbage, leeks etc.) and horticultural farms, as well as stockless arable cropping systems. Farm sizes ranged from 0.5 ha in Hungary to 1 110 ha in Estonia and varied markedly within the groups, for example 17 ha to 300 ha in Denmark Sjaelland (Cullen, et al., 2016). Each Farmer Innovation Group held two workshops to conduct qualitative evaluations of the KE tools, with a total of 22 workshops in 2015/16. In the first workshop each group discussed 5-7 tools and provided feedback. The groups also scored these tools on a five-point scale (1 = low, 5 = high) for relevance (how appropriate the topic of the tool was to their priorities, challenges and conditions on farm), interest (how engaged the participants were with the topic of the tool), ease of use (how user friendly and simple they found the tool to use) and practicality (how easily the participants felt the information could be transferred into practice). An average of these scores was calculated. This analysis was complimented with qualitative data from workshop discussions. In total, 53 separate tool scores were reported by groups for 33 tools[2]. Most groups used face-to-face workshops, but two groups conducted this step by phone. Each group then selected three tools for a more detailed qualitative assessment in a second workshop, to get a deeper understanding of the strengths and weaknesses of each tool. The results presented here are based on a synthesis of the qualitative feedback on each tool from all groups, which enabled key themes and critical success factors to be identified (see also Bliss et al., 2018). The names of the groups have been replaced with a letter (from A to L) to protect the anonymity of the comments.

In a final step, each group could select one tool to implement and evaluate in practice. This step was designed to give farmers the opportunity to do something practical and groups were free to choose a topic that was of interested to them. In total 11 trials were carried out, related to mainly to weed control, soil fertility and nutrient management tools. Six trials related to the use of machinery that was previously not used in the region or country, such as testing the roller crimper for terminating cover crops, testing of weed control equipment and an equal spacing seeder and one trial looked at

[2] 3 tools were evaluated in discussions, but no scores were provided, which explains the difference between the total numbers evaluated and the scores.

cultivars for cover crops. Four tested tools for diagnose of soils and rotation, such as the *Spade Test –* leaflet and using the nutrient dynamics model *NDICEA* on several farms. The process of practical tool testing in the field was documented with video diaries, which were edited into short videos shared on a 'farm news' page on the knowledge platform of the project *www.farmknowledge.org* . This online hub developed by the project brings together existing and new KE tools developed or translated in the OK-Net Arable project, including practice abstracts.

A series of exchange visits further enabled Farmer Innovation Groups to share experiences and knowledge on key topics of mutual interest, including intercropping and organic no till. A co-innovation workshop in Valence (France) in September 2017 enabled representatives of the groups to come together to share what they had learned and discuss emerging questions, with peers from other countries acting as 'advisors'. Feedback and reflections from these meetings, exchange visits and workshops were also documented (see Gócs et al, 2018) and provided additional insight into farmer perceptions and preferences for KE and the experience of being engaged in the Farmer Innovation Groups.

In the following section on results, we present the preference and feedback for tools covering the different topics and the feedback and preferences for different tool types. Preferences have been derived from the first choice (which tools were chosen to be evaluated by the groups) and the average scores for the tools, which give a qualitative indication complementing the feedback from the discussions with the group members that were reported. This is followed by a section on common themes that emerged from the feedback, which is largely descriptive, using quotes from the groups to illustrate points that the group have made. It should be also noted that the majority of the tools evaluated are in English, which may have influenced the results, although some groups chose to provide feedback on similar tools in their own language.

3 RESULTS

3.1 Preferences for topics

We presented the Farmer Innovation Groups with an initial offer of 30 tools, categorised in five thematic areas. Table 1 shows the number of tools that were chosen for evaluation in each theme. The average scores (Figure 1) indicate that in each topic, tools received lower average scores for 'practical' than for 'interest' or 'relevance'.

The highest number of tools evaluated by groups related to **soil quality and fertility** and similar topics, which was also identified as an important challenge by the groups (Cullen et al., 2016). The initial offer included many technical guides for visual soil assessment and earthworm activity and how to grow green manures to improve soil structure. The groups added three tools covering similar topics in their own language.

There was considerable thematic overlap of **soil quality and fertility** with **nutrient management** related tools; for example, tools related to green manure use were represented in both themes. Apart from technical guides, nutrient management also included websites and decision support (also called calculator) tools. One of the website tools, *Cover crop and living mulch tool box*, was evaluated by seven groups. The tool was well liked on first impression, further confirmed during workshop discussions.

Table 1: Number of tools selected and evaluated by theme

Theme	Initial offer	of which evaluated	New tools suggested by groups	Total number of tools considered	Of which evaluated
Weed management	6	5	3	9	8
Soil quality & fertility	6	6	3	9	9
Pest & disease control	6	1	1	7	2
Nutrient management	6	5	2	8	8
Cropping systems & crop specific	6	4	4	10	8
Total	**30**	**21**	**12**	**43**	**35**

Source: Own data

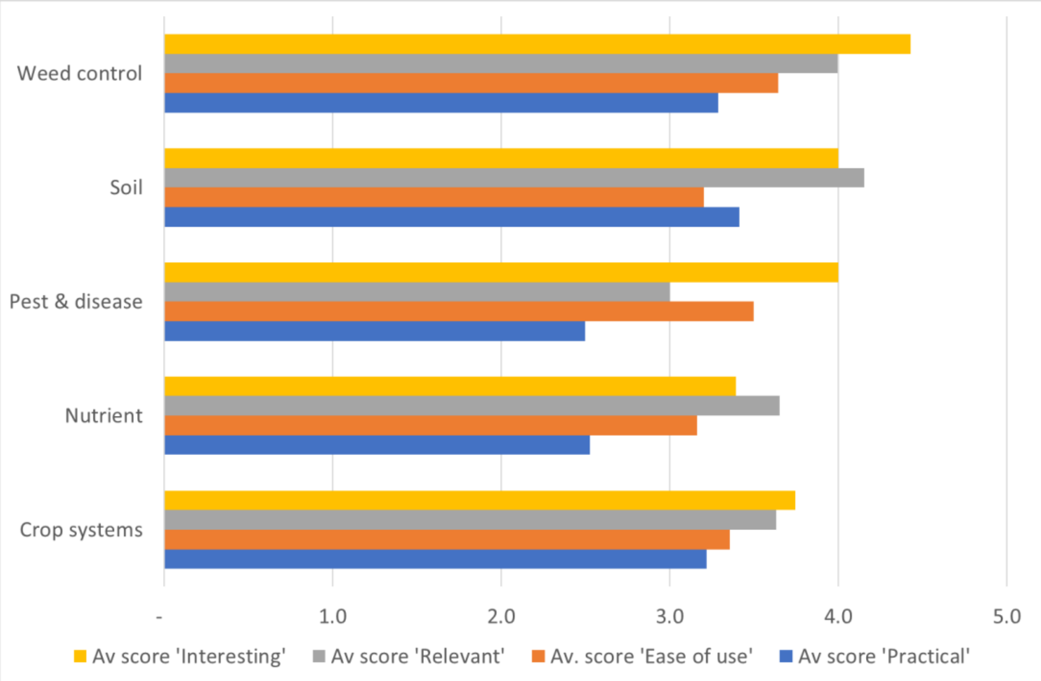
Taking both topics together, the tools found most relevant were relating to green manure/cover crops, visual soil assessment and building soil carbon. Tools on nutrient management were considered relevant but were not liked overall and may not have been meeting the farmers' needs.

Weed management tools were also popular, which corresponds well with the importance of weed control as a challenge for most of the Farmer Innovation Groups (see Cullen et al., 2016). This category included several videos, mostly related to reduced tillage. Tools on mechanical weed control received high scores, in particular those comparing different machinery, but the farmers also commented that such information goes out of date quickly with new developments. The feedback indicated that the groups would like to see some tools that provide information on weed biology and lifecycles to support improved management. Moreover, it was clear that more tools should focus on an integrated approach to weed control, which includes preventative and cultural control as well as direct methods such as mechanical weed control.

The category of **Cropping systems and crop specific** included tools that were both related to specific crops (e.g. cereals or lupins) and to the design of the cropping systems, such as rotation planners and websites with general information about organic agriculture. Most of the tools in this category were only evaluated by one or two groups.

The least popular category by far was that of **Pest and disease control**, where only one of the tools originally suggested was evaluated and one additional tool was suggested and evaluated by one group. The two tools that were evaluated (one atlas and one app) support the diagnosis of pest and disease and include recommendations for prevention as well as curative approaches. Farmers liked that tools showed the life cycles of pests with the support of good visual information. Tools that tackled specific pests or diseases were not relevant to all groups and some forecasting tools only have relevance in a specific region.

Figure 1: Average rating of knowledge exchange tools by topic*



* Scores for interesting, relevant, ease of use and practical are based on 33 scored tools (using a five-point scale (1 = low, 5 = high)

Source: Own data

3.2 Preferences for different tool types

All the KE tools were characterised as a tool type (format), with the tool offer being dominated by Leaflets/Technical guides. The choice of tools evaluated in Table 2 and Figure 1 show a clear preference for videos, whereas websites where least preferred.

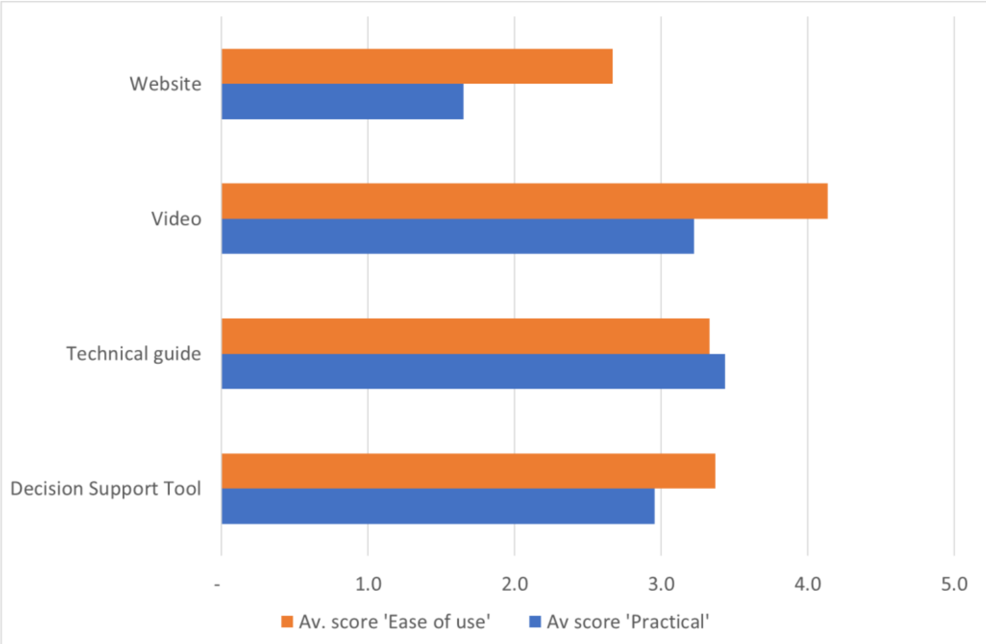
Table 2: Tools formats and preferences of the Farmer Innovation Groups

Tool type	**Total No considered.**	**No. of tool evaluated**
Website or web-tool	9	4
Video	4	4
Leaflets/technical guides	21	20
Decision-support/calculation tool	9	7
Total	**43**	**35**

Source: Own data

Tools were scored for 'ease of use' – which took into account the user friendliness of the type, the instinctiveness of the layout and the energy it took to use them. This was considered particularly important as farmers are busy. Figure 1 shows that on average, videos were considered the easiest to use, followed by decision support tools. Interestingly websites were considered the least easy to use. Participants also provided feedback on practicality, for which the technical guides score similar to videos and website received a low score.

Figure 2: Average scores for ease of use and practicality of tools by type*



* Scores for ease of use and practical are based on 33 scored tools using a five-point scale (1 = low, 5 = high)

3.2.1 Feedback on videos

There was overall positive feedback on videos as a method of sharing knowledge, both from research and between farmers (see also 'Including visual information' below). The video type was well liked for ease of use and practicality, as a direct and simple way of learning from experience in the field – in particular the action of machinery: *"Videos are very direct and easy to understand"* (Group G); *"You can see the machines in action as if you were there yourself, … you can see it at work from all sides…"* (Group C).

Feedback suggests that videos should be short (2-8 minutes). For example, the 20 minute long video on *Mechanical weed control in vegetables* was considered too long and it was suggested to "***cut the film in different parts so you can look into the machine you are interested in***" (Group C). However, other videos, e.g. the *Tilman.org videos*, were criticised for being too general and simplistic, not covering the detail necessary for practical application. *"This is interesting as a kind of "first information". It`s not detailed, but well done as an entry into this topic. If somebody wants detailed information a video is not the right thing"* (Group G).

A few groups suggested that videos could be directly linked to other tools, such as technical guides that provide further details for practical implementation (e.g. soil types, establishment methods, timings, seed rates, machinery settings etc). Others suggested that providing a series of short videos on the same topic might allow presentation of greater degree of detail.

3.2.2 Feedback on technical guides

Technical guides scored higher overall than videos for practicality, namely due to the level of detail they could go into. As an example, the technical guide *Earthworms: Architects of a fertile soil* was evaluated by eight groups. The participants had quite different opinions: four groups found it interesting, easy to use and practical. They liked the presence of good pictures, clear subtitles and short texts and the overall format that can both be printed or read online. Other groups found the guide not so relevant, mainly because they found it to be too theoretical and overlapping with other tools they knew, or mainly aimed at beginners. Other sceptical comments included missing information about the effect of some machinery on the worms and the lack of a glossary explaining scientific terms.

It became clear that some groups preferred short technical guides of less than 20 pages that are clear and concise. One exception was a particular well-structured guide that made good use of visual information. The *Visual soil assessment: Field guide* is 84 pages long, but was considered to be useful because of the step-by step layout with photos, despite being seen as too long. On the other hand, the topic of the tool *Regionally adapted humus balance in organic farming* appeared interesting and relevant, but Group H, for example, found the tool not particularly practical to use because of the complexity and length and was uncertain about applicability to their conditions. The guide *Nutrient management in farms in conversion to organic* meanwhile received a mixed response, with one group finding it relevant and practical (Group D), whereas another (Group G) finding it complicated.

The colourful guide *Sort out your soil: A practical guide to green manures* was found to be interesting and practical, with sufficient detail about many green manure plants included. However, two groups (D and H) thought it was more for beginners than for experienced organic farmers and had some reservations about the transferability of the findings, whilst another group was doubtful whether or not growing green manure was feasible in their specific climate (Group I).

Longer guides, such as *Weed control in organic farming through mechanical solutions* (288 pages), were considered to be less easy to use because of long blocks of text with minimal use of visual information. However, one of Group H did report "*our experienced farmers read long materials, if they are well presented and relevant"*.

3.2.3 Feedback on decision support and calculation tools

The decision support and calculation tools (DST) evaluated included databases, software models and digital applications and whilst there was recognition of the potential, while some of those evaluated received very positive feedback, others did not come out so well. For example, the *Living mulch and cover crop tool box OSCAR* was rated highly by many groups. The user interface was considered to be easy to use, with simple check boxes supporting the toolbox to select cover crop species appropriate to one's own farm conditions and objectives: "*The software is self-explanatory and therefore very easy to use*" (Group D). There was an appreciation of their *"playful*" nature - the ability to test out new ideas and bringing together scientific knowledge for practical solutions. *"The participants found the criteria approach relevant, the tool is easy to use and playful. Moreover, it is adaptable to the system of each farm"* (Group B). The toolbox also has an associated wiki page, which allows farmers to add their own experiences with different cover crops. This function was appreciated, although many were not sure they would have the time to contribute and others felt that users should be able to interact directly with the toolbox itself rather than a separate wiki.

There was, however, also some more critical feedback. The tool was considered to be lacking in detail – for example it covered only individual species, whereas some users were more interested in mixtures and the interaction of species in mixtures and crops following the cover crop in the rotation. Users also felt it needed to include information on the practical management implications; for example, identifying an appropriate 'window' for the cover crop in the rotation, including sowing dates, seed rates etc. Some crops were also missing an indication of likely costs of the seeds and benefit in terms of yield and cost savings.

In contrast, other calculation tools were not considered to be easy to use in their current form and data entry in some cases was time consuming. For example, in relation to the N-flow simulation tool *NDICEA:* "*Very good, needs a considerable time investment. Could be useful if you have the time*" (Group J). Some data such tools require are collected on farms and the farmers would like them to link to existing farm management software. Some were found to have complex user interfaces and limited data input options not fitting for specific situations and there was some concern about the reliability of output data.

Group J was supported by a researcher to apply the NDICEA nutrient dynamics model on their own rotations at a field scale to deepen their understanding of what was happening in the soil below their feet. With local data on climate, and soil and management practices for one field over a rotation, the model calculated nutrient surpluses and deficiencies over multiple seasons. Modelling the current rotations highlighted some common issues between the farms in relation to organic matter balances and suggested that nutrients were being lost through leaching, harvest and breaking the ley in the autumn. One farmer found the process of working through the scenarios together with the researcher really useful, particularly to step back and reflect was a "*real eye-opener"* that stimulated much discussion in the group and also in international knowledge exchange workshops.

Although the majority of DSTs tested were not considered particularly ready for practice because data-input was complicated, or output was either seen as too academic and not of practical relevance or seen as not reliable, there was an interest in the future potential in supporting users to pull together large amounts of complex information to make decisions tailored to their own farms. The use of DSTs as an indication of the relative risk and opportunity of different actions, as well as inspiring new ideas and approaches, was considered valuable.

3.2.4 Websites

Examples of websites also received mixed feedback. The website *Knowledge platform for Agroecology* received most positive feedback. This resource is built around different agroecological principles and farmer testimonies for using them. Starting with farmer experience and practical examples seems to be a logical way to lead people into learning more in other, more detailed tools. The tool was liked by one group of farmers "*thanks to several videos of farmers telling their stories"* (Group F). Meanwhile, although appreciated for good overview of reduced tillage, the *Bioaktuell* website was considered to be more difficult to navigate and many were not able to find the more detailed technical guides contained on the site: "*Due to the different sections navigation is complicated.*" (Group D).

3.3 Emerging themes

A number of common themes emerge from the feedback on the various tool types, which have been summarised in Table 3 and are described further in this section

Table 3: Common themes in farmer feedback on KE tools

☺ **Well liked**	☹ **Less well liked**
Visual information – pictures, tables, diagrams, videos of machinery in action	Long streams of unbroken text. Lack of images that farmers can relate to
Contextual information - tailored to different regions/farm types	Generalisation of a practice without a sense of 'place'. Unreliable data
Farmer experience - case studies, tips, dos and don'ts	Theoretical concepts with lack of application in the real world
Honest account of what works and, importantly, what doesn't work	'Promoting' an idea and giving a one-sided account. Omitting negative results
Easy to use and to find relevant information	Time consuming and difficult to navigate
Clear, plain language/glossary for technical terms	Overly complex, technical language
Makes relevant practical observations/recommendations	Lack of recommendations that take into consideration other elements of the farming system
Includes numbers – economics, yields, seed rates	No consideration of the impact on factors critical to farm decision making
User friendly way to interact with other farmers, researchers and advisors	Underutilised forums and difficult log in

Source: Own data

3.3.1 The importance of farmer experience and practical implementation

'*The best way to learn about something is to speak to someone who is doing* it' (Group J).

The importance of farmer experience and practical implementation is clearly reflected in the farmers' feedback on KE tools. One of the most common elements was that the Farmer Innovation Groups value KE tools that include or are based on experience of another farmer who has tried the practice. Tools that included case studies of farmers sharing their experiences with different practices, including details of the context, what worked and what didn't, and data on the impact on yields and economics, were appreciated. For example: "*The participants…appreciated the case studies (farmers' examples) and the technical detail represented on the figures…the farmers found it very practical*" (Group K) in reference to the technical guide on *Mechanical weeding in arable crops*.

Farmers considered this specific information useful to help inform them whether a practice could be successful on their own farms. It adds a sense of 'place', in contrast to some technical guides, which generalised findings across many farm types and contexts. This was particularly true for the *YouTube channel* of a UK arable farmer. The farmer captures interesting insights and updates on his mobile phone as he walks his fields. Group J felt he is "*an ambassador for Organic Farming*" who is often innovating with new techniques – such as relay cropping and grazing wheat with sheep to control black-grass and shares his experiences. Watching such videos is "*Second best to standing in the field with him",* according to members of the group. Farmers valued the honest analysis of the advantages and disadvantages "*…will be honest about what works and what doesn't work which is really important*" (Group J). The farmer also provides updates over time, so that viewers can follow progress on innovative practices he is trialling.

Groups discussed that it was important that tools should give recommendations and consider the practical implications at a farm level – for example, regarding seed rates, tillage practices, drilling dates, species selection etc. However, the groups did not always agree what 'practical' looks like. One group scored the *Müncheberg visual soil quality rating* positively and commented "*The test is easy to perform and does not require additional expensive equipment"* (Group L), whereas another group found the tool *"A bit difficult, maybe too theoretical, no practical suggestions"* (Group H).

The FiBL technical guide *Earthworms: Architects of fertile soils* shows a practical step-by-step process for counting earthworms as an indicator of soil biological activity. "*The guide has a very helpful "so what" summary at the end to help with management practices…… It would be useful to have more information about the effects of specific machines/equipment (rotary) on earthworm populations ….and how to mitigate some of the less beneficial practices, as what's bad for earthworms may be beneficial in another context.*" (Group J). This illustrates that farmers are faced with the need to balance considerations for different parts of their farm when implementing recommendations and what works for one part of the farm may not do so for another. It appears that '*Sometimes [those writing the guide] forget that farms are businesses, we need to know if it is going to pay'* (Group J).

Farmers expressed an appreciation for an honest portrayal of the challenges and trade-offs experienced by those that have tried out the practices covered in the tools. Some KE tools were viewed as trying to 'promote' a certain practice and not cover potential set-backs and disadvantages. For example, in response to the US based video *Bringing the dirt to the doorstep* on reduced tillage, one Group B reported "*The farmers …were sceptical about impartiality of the results: they suspected the authors to present only the successful results*" (Group B).

The group members found examples where a technique had failed under certain conditions to be as useful as where it had been successful. During practical testing, the Farmer Innovation Groups in Bulgaria and Italy both tested a roller crimper to destroy cover crops and create a mulch into which the following crop could be directly drilled. The trials in Italy showed relative success, but by contrast the trials partially failed in Bulgaria. The group attributed this to a late sowing date, soil compaction and lack of rain during the growing season but would like to carry out a further trial in future. In the discussion at the common workshops in France it was highlighted that it is essential to be clear about the different contexts in which the practice had been used to understand the difference.

Whilst many organic farmers in Europe are interested in reduced or no-tillage systems, they do want to see more trials under their own conditions to judge whether it could work for them. An exchange visit to Austria invited members of some of the Farmer Innovation Groups to meet US researchers to talk about their experience. The direct exchange allowed the opportunity for two-way learning, as the advisors and researchers engaged in the process also gained new knowledge and insights. Bringing together farmers and scientists and organising national and international exchange visits, farm walks and on-farm trials all play an important role in the innovation process.

3.3.2 Including visual information

Another common theme in the discussion of several different tools was the appreciation of photos and visual information, which was expressed in the preferences for videos but also in response to technical guides. The tool *Mechanical weeding in arable crops* received positive feedback for combining short sections of text with photographs showing the mode of action of a finger weeder and weed control interventions in the rotation. *"Although it is quite a lot of information the layout makes it easy digestible. You can read it as separate leaflets. There are lots of practical case studies, pictures and practical tables*." (Group C). Guides that contain photos, diagrams and tables are seen as more useful than long streams of text.

Photographs were also used to convey essential information on crop health, crop establishment and soil condition. For example, the *CroProtect App* was rated positively for its visual content: *"Photos [in the App] are helpful visual cues for identification of pests in the field*" (Group J). Additionally, visual information can help to overcome language barriers: *"even without translation or with only some small keywords, you can learn a lot from a video"* (Group C).

3.3.3 The importance of detail about context and 'place'

The OK-Net Arable project aimed to share tools between countries and many groups tested tools not particularly developed for their specific soil, climate and socio-economic conditions. Several of the farmer groups fed back that many of the tools were too general or not appropriate to their specific conditions.

The video *Bringing the dirt to the doorstep* on the challenge of weed control with reduced tillage is based on case studies in the US that the farmers did not consider to be relevant to the European farming systems. Participants in Farmer Innovation Group B found it difficult "*to transpose the results to French pedoclimatic conditions because (i) there was a lack of context information in the video and (ii) the experimentation is set in the US*".

Similarly, in response to the *Living mulch and cover crop tool box OSCAR*, one group commented: "*Highly relevant for the soil fertility issues raised by the farmers. However, it seems too generic and does not offer specific solutions (cover crops) for the Marche region*" (Group F). The same group commented on the rotation calculation tool *(ROTOR)* that it does not cover important details: "*…the tool does not take economic aspects of the cropping system into account and it seems specifically* *suitable for the Baltic area, so rather far from the agro-ecological characteristics of the Marche region. This makes its practical value very low"* (Group F). Commenting on the technical guide *Mechanical weeding in arable crops*, another group highlighted the need to adapt to local conditions: *"In all details it needs to be adapted into the Hungarian agro-ecological and farming conditions"* (Group I).

Details such as soil type, rainfall, establishment method, position in the rotation are all critical to help farmers make the decision of whether a practice is suitable for their farm or how they may adapt it. As every farm is different, it is unlikely that farmers will adopt a practice exactly as it is presented in a tool, but providing more details helps them to interpret how the practice could fit into their own situation. For applied knowledge, such as practices for weed control, cover crops and reduced tillage, information about the local context was found to be critical, whereas the groups found knowledge that covers more 'fundamental' topics, such as soil biology and soil monitoring techniques might be transferable, irrespective of the local context.

4 DISCUSSION

In the project, groups of organic farmers in several EU countries used KE tools that were presented on a common platform. The evaluation of tools in the OK-Net Arable project by farmer groups was an attempt to move beyond the linear model of innovation, where practices are developed by scientists, disseminated through intermediaries and then used by farmers, towards an integrated model of KE and contributing to the question how this knowledge exchange can be carried out across borders and by using the internet.

One important question when talking about taking KE online is the question whether, for what and how frequently organic farmers use the internet. In a survey of organic farmers as part of the OK-Net Arable project, Ortolani and Micheloni (2016) found that only about 30% of farmers in their survey considered the internet to be an important source of information, with time being the most significant barrier. The proportion is higher among younger farmers and the increasing use of smartphones will extend the time periods during which farmers can access the Internet to look up technical information. This stands in contrast to a study in the South West of England which found that 89% of farmers use the internet in the context of the farm business management for sending e-mails, reading farming news online and to apply for government grants (Buttler and Lobley, 2012), although only a 9% used internet discussion boards and 6% used internet blogs. Since the sector of KE is developing very fast, there is a need to repeat surveys to get up-to-date insights into farmers and advisors use of the internet and digital tools.

In the same English survey, farmers were also asked to name the three sources they trusted most in terms of the knowledge imparted. They cited advisors and other farming professionals (52%), the farming press (36%), business professionals (31%) and farming friends (29%) (Buttler and Lobley, 2012). This stands in slight contrast to the preferences of the organic farmer groups in the OK-Net Arable project, who appear to trust other farmers more than farming professionals. This may be a reflection of the shortage of farming professionals that are well trained and qualified in organic farming in several of the countries in which the groups operate. Trust in groups that learn together develops through mutual support, so that both positive and negative experiences from trial and error can be explored and learning emerge from a shared interest in a problem or challenge (Moschitz et al., 2014). There is, however, also evidence that agronomist-farmer encounters that are underpinned by trust, credibility, empathy, and consultation could provide an effective context for knowledge exchange—potentially facilitating farmers' transformation to more sustainable management practices (Ingram, 2008).There is a need to consider what factors farmers value in KE tools and face-to-face KE and how and if these factors can be included when taking KE tools online.

4.1 What tool formats are preferred?

Each tool type (leaflet/technical guide, video, website and DST) has relative advantages and disadvantages and provides a slightly different function. Some are also better suited to certain types of information. For example, videos can work better for introductory information and inspiration, whereas technical guides provide detail for practical implementation. Moreover, different users are likely to prefer certain formats over others and therefore providing a range of options is important to be able to reach as wide an audience as possible.

The generation of web-hubs, like the *knowledge exchange hub for agroecology*, create the opportunity for combining different formats in a single location, for example by linking to farmer profiles and videos. This is an idea that has been considered in the design of the knowledge platform of the OK-Net Arable project (*http://farmknowledge.org*), where videos are used as, and connected to, other tools. In this way, videos can be an easy-to-use 'hook' and inspiration for farmers to then delve deeper into existing information to learn how to apply certain practices on their own farms.

Our results also show some recognition of the potential of digital Decision Support Tools (DSTs), which synthesise information in a way to support farmers in making decisions – those assessed included databases, software models and digital applications. According to Rose et al. (2016), such tools are designed to help users make more effective decisions, by leading them through clear decision stages and presenting the likelihood of various outcomes resulting from different options. However, whilst decision-support tools may have potential to tailor management practices to the specific context of each farm, in their current form they frequently lack this detailed information about location and experience-based knowledge to support decisions (Rose et al.,2018). Our findings therefore suggested some scepticism that in their current form, DSTs could replace the ability to consider different types of contextual knowledge, such as the tacit knowledge of each farmer, the historical rotations, weather and soil types. They suggest a role in supporting farmers, rather than trying to replace the farmer or advisor in making decisions. "*Farmers and agronomists require decision support not decision making because they are the ones that decide what is most appropriate for their local conditions*" (Bruce, 2016 p90).

Finally, DSTs and online tools that force farmers to be more office-based in their decision-making ignore the spatialities of decision making and the workflow on farm (Rose et al., 2018). Another consideration for future tool development is to consider the value in user centred design (UCD). For example, Rose et al., (2018) suggest that engaging users in the co-development of Decision Support Systems, including taking a decision support assessment prior to building and launching a product, may enhance usefulness and uptake.

It is likely that e-learning could also be a useful online KE tool, but the farmer groups did not evaluate any e-learning tools systematically. The OK-net Arable project developed a facilitated E-learning course that introduces some of the KE tools on the knowledge platform in five different thematic modules. The course was taken by 70 participants from 23 countries and evaluated largely positively and is now offered as self-learning course *Challenges of Organic Arable Farming* on the knowledge platform (see Mohamad et al., 2018). This experience suggests that e-learning should be explored further. However, further research would be needed to get better understand why farmers prefer certain tools and interactions and how this can be used to improve KE in organic farming.

4.2 Keeping it practical

Weed control, soil fertility and nutrient management were the two most important thematic topics that groups chose for tool feedback and practical trials, which corresponds well to the most common challenges reported by the groups earlier in the project (Cullen et al., 2016). Our results show that the farmers value practical experiences in KE tools, related to the agronomic conditions (soil, climate, seed rates) and costs and benefits that help to inform their decisions whether or not a practice is useful for their own farm. The farmer decision-making process is strongly influenced by practical, but also by legal means and financial factors (Blackstock et al., 2010). They appreciate succinct tools that clearly outline practical implications and recommendations, but this does not mean that they are looking for information that has been generalised to apply to all conditions. Understanding how certain practices have been applied in different contexts (soil, climate conditions, farming systems), the specific field operations that were performed (machinery, cultivations, position in the rotation etc.), the impact on yields and farm economics are all details that the farmers found valuable but lacking in many of the tools. Also, often missing were honest accounts of negative impacts – what didn't work and why – which was also considered to be very useful. Many of those elements that farmers felt were missing in existing KE tools are exactly those they valued in direct communication with other farmers, advisors and researchers. This may be one of the reasons why farmers express a strong preference for farmer-to-farmers KE rather than KE tools written by researchers. According to a study with small-scale farmers in four European countries, apart from independence the combination of tacit and codified knowledge is important for credibility of source (Sutherland et al., 2017).

4.3 Providing a context and farmer experiences

Overall, many of the tools were considered to present practices without a sense of place or reference to the contexts in which it could work or not. Farmers pull together information from many sources to gain knowledge of their own systems. This is often hindered by lack of research relevant to their own context – e.g. soil type, farming system, agroclimatic conditions (Röling, 1990).

Scientific knowledge is always embedded in specific contexts, but many tools seek to be broadly compatible across farms/regions/countries. As such, information tools developed by scientists for farmers are often considered to provide a placeless '*view from nowhere*' (Rose et al., 2016 p14). Our findings confirm the conclusion of Rose et al. (2018) that farmers value knowledge that is contextualised. They value experience in the field and the opinions of advisors and other farmers that know the farm and put less trust in scientific recommendations where the context is not clear/realistic (Rose et al., 2018).

This value of location-based knowledge may thus be one of the critical success factors of direct farmer-farmer KE and careful consideration is needed as to how this can be provided online. This is an area to improve in future tools, perhaps adapting tools to be relevant to different regions or farm types. Despite the need to synthesise results and keep tools relatively succinct, researchers creating KE tools should be mindful of the tendency to over-generalise information. Providing case studies and background to the trial sites is an important detail that farmers appreciate. However, this also depends on such research outcomes being available for organic agriculture - highlighting a significant research gap.

Overall, feedback from farmers reinforced that they are unlikely to adopt a practice directly as scripted in a tool. Instead, they tend to refer to information tools once they have already explored ideas by talking to others, and then 'interpret' how that information may be relevant to their own situation. "*For farmers and advisors using tools, decisions will be a hybrid of different forms of knowledge*" (Rose et al., 2018 p15).

4.4 Providing visual information through videos and images

In our results, the farmers expressed a clear preference for visual information. This may be related to the fact that humans are neurologically wired with an overwhelmingly visual sensory ability (Brown, 2014 p222) and that pictures are not only more effortless to recognise and process than words, but also easier to recall (Dewan, 2015). It is likely that farmers are used to using visual cues in the field every day to make decisions about the condition of their soil, crops and livestock and so also relate well to seeing practices in action in other places. Visual information could be used more widely in other online tools. Careful selection of practical images and other visual information (flowcharts, diagrams, infographics) in written guides, websites and Decision Support and Calculation Tools could improve their practicality.

The medium of the video in particular opens up a huge opportunity to take experience online and is, as one farmer put it "*second best to standing in the field*". There is also potential for sharing updates on demonstrations and trials – both on farm and at research stations for example in the form of video diaries or vlogs. Direct dialogue can permit feedback to the research community on what is appropriate and realistic and thus increase research impact (Bruce, 2016) and give rise to new insights and solutions. This could be an opportunity to engage other practitioners in an online co-innovation process, in which they are able to interact, ask questions and make suggestions to those running the trials. However, the experience from the knowledge platform of OK-Net Arable has shown that it is challenging to engage users in online interaction and trials would need to have sufficient staff time resources to engage with such online interactions. With improving smartphone technology, it is increasingly possible for farmers, advisors and researchers to make their own videos and share these online through platforms such as YouTube, opening up a new space for dialogue. Some farmers may do this for altruistic purposes, but most will need to see clear benefit to investing time in sharing their experiences (Bruce, 2016).

Videos can be used to film in-field KE activities – such as farm walks – sharing those discussions with a wider audience. Social media can also be used to bring questions and answers to on-farm events from remote participants.

4.5 Seeking opportunities for dialogue and co-innovation.

Bringing farmers, advisors and researchers together in the Farmer Innovation Groups of OK-Net Arable and through international exchange visits and workshops led to the production of new ideas and insights that perhaps would not have emerged otherwise. Farmers were motivated to test the tools in practice and share their findings with others on the farmknowledge.org knowledge platform, in videos and as practice abstracts. Members of different groups were able to interact in meetings and discuss openly what worked and what didn't and how that related to the context – soil type, slope, rainfall etc. sharing ideas and experiences.

In this sense, the Farmer Innovation Groups can be seen as 'boundary organisations', i.e. organisations that work on the boundary between science and farming exemplify this convergence of knowledge and roles (Carr and Wilkinson, 2007). They provide a new space for farmers, advisors and scientists to interact. This in turn enables movement away from a linear process of knowledge transfer from science to practice towards a co-innovation process, enabling researchers to learn from farmer experience, deepen their understanding of what is realistic on farm and all actors to learn from each other. This experience therefore reflects previous findings that such processes constitute a powerful force for stimulating innovation and co-production of new knowledge (Carr and Wilkinson, 2007; Almekinders, 2011).

However, despite the momentum generated by Farmer Innovation Groups meeting on exchange visits, there was reluctance to continue these discussions online. This confirms findings of Buttler and Lobley (2012), who also found farmers reluctant to visit internet discussion forums. Similarly, the opportunity to interact with the discussion forum on farmknowledge.org was not taken up, and the language barrier and the lack of a critical mass of active users were mentioned as reasons (see Gócs et al., 2018). An alternative to seeking to establish forums or integrate other interactive functions into online tools could be to tap into existing social media networks. Utilising these forms of online communications also offers the opportunity to bridge the gap between actors separated spatially (e.g. in different organisations) and/or by perspective (Klerkx and Proctor, 2013). Building on established relationships and user profiles may create a more interpersonal experience and tap into a critical mass of people using these channels. Finding new ways to integrate discussions on these channels with platforms such as farmknowledge.org remains a challenge for the future. Experience with the www.agricology.co.uk website hub in the UK, which integrates social media channels (Twitter, Facebook, YouTube and Instagram), suggests that using the handle @agricology can sometimes encourage users to ask each other questions or engage in polls and discussions. #AgrichatUK is another peer to peer twitter home for weekly discussions on specific farming topics. Similarly, social media channels that enable discussions in smaller focus groups have also shown promise. A group of farmers from the UK and France that met on an OK-Net Arable exchange visit on intercropping chose to set up a *WhatsApp* group to enable ongoing discussions and informal chats, the sharing of photos, updates and anecdotes from their own trials.

5 CONCLUSIONS

Online Knowledge Exchange (KE) tools can play a valuable role in bringing together knowledge and experience on good practice in organic arable farming in Europe and contribute to improving yields. Topics chosen most frequently for evaluation in workshops and in practice include soil quality and fertility, nutrient management and weed control corresponding with the topics identified as key challenges by the group earlier in the project. For weed control tools integrating preventative with direct methods were discussed favourable. Only a few crop specific tools and tools related to pest and diseases management were evaluated, which maybe a reflection of the tools presented rather then the importance of the topic.

Critical considerations for those developing online KE tools are to:

- Include farmers' experience about a specific practice, for example through case studies and farmer profiles
- Provide clues about the context: when did it work/not work
- Include visual information – photos, graphics and videos
- Support co-innovation through farmers interacting with the research results/researchers

There is no silver bullet in relation to tool formats and a range of tools are necessary to support farmers to take new knowledge into action. Videos have potential for capturing field experiences, such as trials and demonstrations, but technical guides may allow more detail and fundamental knowledge to be conveyed.

Sharing case studies, tips, successes and failures in online KE tools can support farmers to judge for themselves how a practice may work on their own farm and make use of the fact that farmers trust the experience of another farmer. Furthermore, providing more details of the context in which a practice has worked or not worked in an honest way, including the climate, rotation and other on farm management practices, is also valuable. The final decision whether or not to try or use a new practice lies with the farmer. Decision Support Tools should be co-developed these in collaboration with farmers and could help in tailoring scientific information to individual farm contexts. Adopting a a user centred design approach for future tool development is likely to enhance usefulness and uptake. Tool developers should also consider including information on negative impacts and situations in which practices failed. Details on the implications for management, economics and yields would also be valuable. Integrating more relevant visual information such as photos and diagrams in tools could additionally improve the ease of use and practicality for the farming community. Online KE opens a whole new space for co-innovation between farmers, researchers and advisors. Further studies could seek to analyse the processes involved in digital co-innovation approaches, including the how social media can be utilised in contributing to knowledge exchange between farmers and farmers and researcher. However, despite the considerable potential, online KE tools should not be expected to replace face to face in-field KE. The farmers engaged in the project hugely valued the opportunities for international face-to-face exchanges that were created during the project and were inspired to reflect on their own practices. This in turn has the potential to improve organic arable yields. Online KE tools, supported by social media channels to enable discussion and allow feedback and informative chats, can complement this face to face in-field KE and together they could play an increasing role in improving best practice in organic farming in Europe and beyond.

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