Reflections on co-constructing a digital adviser with stakeholders in agriculture and forestry

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Abstract: *Many EU and nationally funded research projects into land-based industries, such as agriculture and forestry, provide excellent scientific results. However, outreach and interpretation of these results into 'ready-to-use' farming and forestry formats is limited. A key challenge in agriculture and forestry, as in other disciplines, is taking a large body of research-based knowledge and making it meaningful to the user audience. Computer aided search engines and decision support systems potentially can offer cheap access to large repositories with relevant reports and publications, however these cannot substitute the expert-practitioner interaction that complex decision making often requires. This paper examines the process of developing a digital but knowledgeable 'assistant-expert'. This was developed within an action-research project and aimed to help practitioners and advisers in the field of agriculture and forestry find and share documents that respond to their specific queries. The paper focuses on the methodology which involved the continuous and iterative participation of the stakeholder community, involving project partners (domain experts, advisers) and practitioners. It pays particular attention to the role of the Case Study Partners and case study stakeholders in construction of an ontology on innovations in agriculture and forestry. This structured vocabulary, constructed using concepts provided by domain experts, advisers and practitioners, is a central element of the platform, and is unique, in that it aims to perform as a digital assistant-expert dialogue (helping to articulate queries and provide relevant solutions). The key opportunities and challenges in developing such a novel digital platform within a time-limited research are explored.*

Keywords: *agriculture, forestry, innovation, research outputs, stakeholders, ontology, search tool, semantics,research- translation*

Introduction

Research is a key dimension of innovation and offers significant opportunities for making farming and forestry smarter, more competitive and sustainable, by providing the understanding for advancing production while protecting ecosystem services. What Top and Wigham (2015 p54) call the "the highly important issue of how good science can become good practice" has occupied many commentators. In particular a key challenge for innovation in agriculture and forestry, as in other disciplines, is taking a large body of research-based knowledge and making it meaningful to the user audience (Baumbusch et al., 2008). Although a lot of information exists in journals, websites, this knowledge is not reaching farmers and other practitioners due to its unstructured, incomplete, varied formats, use of different terminologies for the same concept, and lack of targeted delivery methods. Thus as Walisadeera et al. (2015 p1) remark "finding the right information within the context in which information is required in a timely manner is a challenge. The information and knowledge needs to be provided not only in a structured and complete way, but also in a context specific manner".

There are opportunities throughout agricultural (and forestry) research now for providing and accessing data through increasing digitisation of society along with the increasing availability of internet and mobile technologies in agricultural communities (EU, 2015). ICT can facilitate the rapid collection, collation, storage and dissemination of data, thereby assisting the knowledge creation and diffusion process.

Additionally, while a lot of valuable research outputs continue to be generated, and practitioners are increasingly accessing research networks, the systems to enable widespread access and utilisation of such outputs is not keeping a pace (Antle et al., 2017, Sulaiman et al., 2012). The need for more effective tools, information systems, decision support systems (DSS), knowledge platforms and smart search engines has been identified if agricultural science is to be made accessible to practitioners[1] (Sulaiman et al., 2012). As Dayde et al. (2016 p1) remark "The issue of imbalance between the richness of available information and the ability of farmers to harness it in their decision-making process has received little attention so far".

Furthermore, the limitations in digital technologies are widely discussed. Scholars argue that although recent efforts to improve DSS use have focused on enhancing stakeholder participation in their development, a mismatch between stakeholders' expectations and the reality of DSS outputs continues to limit uptake. Critically, digital developments which utilise and interpret data, such as search engines, DSS and virtual platforms, neglect understanding of both the users' expectations and utilisation of them. Furthermore there is limited understanding of the processes by which users learn from these systems individually or collectively, or even learn and adapt their behavior as a result of using them (Janssen, 2017, Allen et al., 2017, Jakku et al., 2016, Eastwood et al., 2017). As such, while ICTS are an efficient tool for transferring information, their ability to improve the transferability of knowledge deserves attention (Roberts, 2000).

[1] 'researchers' as those using data and field knowledge, and producing expert knowledge, while 'practitioners' participate in experiments, contribute field knowledge, and access expert knowledge.

Researchers working in this field recognise that digital technologies and innovation need to incorporate user-input and feedback in their development and in so doing allow a dialogue and a learning community to develop to share experiences. The opportunities for practitioner consultation, user-centred DSS design, and for incorporating social learning in virtual platforms are now recognised and more widely implemented (Lundström and Lindblom, 2018, Carberry et al., 2002, McCown, 2001). This is in accordance with new ways of supporting innovation processes which involve end-users[2] in the research process so as to facilitate the integration of formal knowledge into farming practices (Knickel et al., 2009). As Sulaiman et al. (2012) point out under-utilisation of ICTs could be due to a lack of appreciation of these contemporary concepts of communication and innovation.

According to Top and Wigham (2015) the proliferation of cheap decentralized computational power allows for collection, storage and dissemination of data on a large scale. This so-called 'basic e-science technology', in the form of Web applications and networks, makes the reach of the dissemination much greater. Computer aided search engines, a sort of DSS, can potentially offer widespread and cheap access to large research repositories with relevant reports and publications. In such systems the user usually enters a few search terms, the system returns a ranked list of documents and the user refines the search terms if needed. The usefulness of such systems for the practitioner in agriculture and forestry who is dealing with multi-faceted and context-related issues however is often limited. Frequently, they act merely as dissemination tools. In particular it is argued, they do not offer the chance for real or smart interrogation of the knowledge base, nor for any dialogue or interaction with the system. As Willems et al. (2015 p2) assert "Search tools are a very poor reflection of the expert-practitioner interaction one would expect" in an agriculture and forestry innovation domain. This, they argue, is because in standard solutions, background knowledge on the domain is missing in the interaction between practitioner and system. As such, although promising, search engines cannot substitute the expert-practitioner interaction that complex decision-making often requires. Furthermore, like other methods to organise information and knowledge, they do not always address context specific needs, where expressive relationships among concepts are required to represent knowledge (Walisadeera et al., 2015).

This paper describes the development of ask-Valerie, a search engine which aims to help practitioners (farmers and advisers) in the field of agriculture and forestry to find and share documents that respond to their specific queries. In doing this, the aim is to overcome the limitations of normal search tools by using an ontology for better knowledge management, which provides a vocabulary common to different stakeholders (for effective knowledge sharing) (Miah et al., 2014), and thus optimises the interaction between practitioner users and the expert system. ask-Valerie was developed within an action-research project working with stakeholder communities over four years. The paper reflects on the methodology which involved the continuous and iterative participation of the stakeholder communities, involving project domain experts, advisers and practitioners in ten diverse case studies across Europe. It asks specifically: What are the expectations of the stakeholders involved in developing the search tool? How effective is the process of co-constructing an ontology in creating a shared vocabulary? What sort of document base is preferred by stakeholders? How effective is the

[2] The term 'end-user' or 'user' is used to denote a (potential) user of translated information, it is acknowledged that end-users can also be involved in other knowledge processes.

tool's query editor in steering question articulation? In doing this it aims to contribute to our understanding of the processes whereby users interact with the tool and utilise the data and information outputs.

Relevant concepts for digital tool development

The main concepts of relevance to the development of a more interactive and responsive searchable system, as proposed here, are discussed in this section.

Data, information and knowledge

For search engines it is assumed that the knowledge needed to provide answers is contained in a set of digital documents which comprise the document base. Such documents are sourced from, and represent, data, information or some form of codified knowledge. In agriculture and forestry these might range from scientific data, scientific papers and reports, to models, practical factsheets and technical recommendations which represent the different extent to which the data and information has been translated[3] (through analysis, interpretation, modelling, synthesis, summarising).

Different levels of knowledge (e.g., data, information, knowledge, wisdom), knowledge types and knowledge modes have been extensively described and classified in the literature (Joshi et al., 2007). Although these terms are often used interchangeably they represent concepts which are qualitatively different. *Data* are the qualitative or quantitative values obtained from observations and measurements. Information comprises facts, interpretations and projections which reduce the uncertainty faced by decision makers, it is defined as data that have been arranged into meaningful patterns. It is how people understand information and attribute meaning to it, or the application and productive use of information, that turns this information into knowledge (Garforth et al., 2002). Hence knowledge is contextual, and there are local differences between the rules and stocks of knowledge (Joshi et al., 2007).

These distinctions imply a processing or transformation of information into knowledge and have implications for transferring 'knowledge' via digital tools. While data and information is independent of context and can easily be relayed using such tools, they have to be contextualised in order to become relevant or provide useful knowledge for individuals to act on. Although this depends to a large extent on the format of the information (i.e. paper, factsheet, video), there is still a challenge for search tools to create a system which can facilitate such contextualisation. Although conventional search engines can disseminate information, they need to incorporate some interactive exchange and negotiation of meaning to replicate the true communication processes that enable this contextualisation (Sulaiman et al., 2012).

[3] Here we use the term translation to describe the process whereby science becomes part of useful knowledge for decision making, in agriculture it is equivalent to turning knowledge into action (Valdiva et al., 2014; Ingram et al., 2018)

According to those commentating on transferring knowledge, differences between the use and the supply of knowledge needs to be reconciled and a 'degree of resonance' found (McNie, 2007, Joshi et al., 2007). Citing Boisot (2002), Joshi et al. (2007 p223) states that this "requires both the transfer (i.e., sending) of knowledge from the source agent, and the internalisation/learning of that knowledge by the recipient agent. Thus, this transfer of knowledge depends not only on the type and complexity of the knowledge but also on the attributes and behaviors of the human agent sharing that knowledge". Furthermore, knowledge conversion is a social process, knowledge evolves and is transformed through the process of transfer. Knowledge transfer through socialization consequently contributes to the creation of new knowledge (Roberts, 2000). This points to the need to involve potential users in tool development. Specifically for search engines this highlights the importance of enabling a form of dialogue between users and suppliers to allow effective communication and expression of questions and answers.

The nature of knowledge whether it is codified or tacit has implications for methods for transfer. Codified knowledge is easily replicated and transferred, tacit knowledge is more difficult since socialization requires co-presence and co-location between transmitter and receiver (Roberts, 2000). Although ICTs are more suited to transfer of highly codified and standardized knowledge, developing a search engine that can mimic the socialization of knowledge creation is a future possibility. Some scholars claim that ICT can be used to facilitate tacit to tacit knowledge, Boisot (2002) for example argues that new methods of communication allow information which could once only be reliably transmitted face to face to be shared globally by a large number of people. However Roberts contexts this pointing to the importance of trust and shared social and cultural understanding. Given these insights it is important to gain an understanding of the search engine users' information contexts and needs, this is referred to as domain specific knowledge.

Problem articulation

Understanding how practitioners, as potential users, ask questions, articulate issues, and define problems is an important element of any search or decision support tool. Researchers have highlighted the subtle differences in practitioner problem articulation. In the context of advice provision Kvam (2017), assessing different farmer problem definitions and the relationship with advice, found that the problems identified ranged from very well-defined to ill-defined. As a result they argued that the problem formulation process and characteristics of the problem emphasise the need for purposeful and understanding-oriented communication. Information seeking behavior, language and specificity of articulation and problem framing changes depending on the purpose of the search, for example, whether it is for problem detection, problem solution, new practices, or opinions (Eastwood et al., 2017, Ingram et al., 2018, Willems et al., 2015, Allen et al., 2017, Solano et al., 2003). As such, how questions or queries are articulated or framed by search engine users is likely to vary significantly and needs to be considered in tool development.

However, articulation of questions and problems, and the how the response to these is expressed, has not been widely studied in a digital or search engine context. As Willems et al. (2016) point out replicating the normal expert-practitioner interaction is a challenge many current systems are not up to. They argue that "Ideally, experts relate scientific findings to applications by discussing possible implementations with practitioners in the field. In these discussions, the practitioner's background, the precise problem context, possible solutions and further actions are clarified." How to imitate this interaction in a search engine to facilitate the dialogue involved in asking and answering questions needs further exploration. In this respect using a common vocabulary, as described next, is important.

Ontology

An ontology, described as a conceptual modeling technique, has the potential to improve the structuring of knowledge particularly for well-defined domains. The use of an ontology to model knowledge can lead towards the development of a solid, contextually relevant cognitive base that enables effective knowledge representation for a specific problem domain (Miah et al., 2014).

Haverkort and Top (2011 p121) define an ontology as "a controlled and shared vocabulary that describes concepts and the relations between them in a formal way, and has a grammar for using the vocabulary terms to express something meaningful within a specified domain of interest". Critically it can provide the basis for experts and practitioners to define a common language to express questions and answers and provide the platform for using the modelled domain knowledge (ontology) in such a way that allows an effective dialogue between user and digital system (Willems et al., 2015). The advantage of this is that all possible stakeholders are able to understand the data expressed by this ontology and that software applications can process them automatically (Haverkort and Top, 2011). In an ontology multiple alternative names (labels) can be attached to one concept, allowing for the definition of synonyms. Different types of relations can also be defined, such as *is-a* relations providing for the creation of hierarchies (e.g., *sandy clay* '*is-a' soil*). The network of relations determines the formal semantics of the associated concepts, allowing applications like search engines to act in an informed and intelligent way. This can provide the basis for an effective search engine. Such advanced e-science technology, such as semantics, can greatly improve the findability of data (Top and Wigham, 2015). Although ontologies exist in the domain of agriculture, such as Thai Rice ontology and Soil Science ontology, these tend to be sector specific or for researchers and few address practitioners' information needs in the local context (Walisadeera et al., 2015). Furthermore, in creating ontologies for agriculture, there is a tendency to rely on experts to determine and structure the knowledge. The potential of farmer centered ontology in providing information in a context-specific is becoming recognised (Walisadeera et al., 2015).

User input

The importance of involving stakeholders in the development of digital tools is well recognised (Jakku et al., 2016, Allen et al., 2017). User involvement can range from traditional testing, feedback or consultation, for example, applying user-requirements analysis, to modern techniques of user-centered design, in which software is built in direct contact with the end-user in short iterations. In the latter approach, user-needs and requirements guide and modify the development in each iteration (Cockburn, 2006). In the wider realm of business, Beguin et al. (2012) identify three broad types of designer–user interactions. In agriculture, there are many examples of user-consultation applied to different extents in DSS development, from intensive long term participatory research and construction (Carberry et al., 2002) to shorter term consultation within projects with multiple iterations (Ingram et al., 2016) to one-off feedback. Janssen (2017) argue, in the context of utilising large data sets for agricultural modeling, that development starts with an understanding of information required by various stakeholders and then works back from those requirements to determine the models and data needed to deliver that information in the form that users want. Furthermore studies have shown how users tend to take over the technology creatively, “reinventing devices through innovative applications” (Beguin et al., 2012 p158, citing Feenberg, 1999) ideally therefore a design process should aim to simultaneously articulate and match the specification of a technology by the designers to the inventiveness of the users, as revealed through its implementation.

Another important dimension of user-involvement is that it can help to develop and enhance learning in a community of users. Medema et al. (2014) suggest that digital techniques can offer significant opportunities for effective and innovative ways of facilitating multi-loop social learning, both in the way information may be transmitted and stored, as well as the deliberation of new knowledge, ideas and perceptions. However, opportunities for stakeholder inputs often have to be balanced with effort. As Hochman et al. (2009) points out for the FARMSCAPE decision support tool, the effects were achieved in large measure because of the intensive effort which scientists invested in engaging with their clients. Such intensive effort is time consuming and economically unsustainable and there remains a need for a more cost-effective tool.

The interlinked concepts of what constitutes data, information and knowledge and how to exchange and contextualize them; problem and question articulation; structuring and managing knowledge in a domain (ontology) to assist this questioning; and the role of stakeholders in tool development, are all relevant to the development of a digital tool, specifically ask-Valerie, as discussed next.

Constructing ask-Valerie

The project

The challenge in the VALERIE project was to make innovative research output in the agriculture and forestry domains accessible to end-users. The project, which ran from 2014-2018, covered six thematic domains with a focus on sustainability and profitability, these included: sustainable soil and water management, integrated pest management, recycling of biomass, supply chain optimisation, and ecosystem and social services from agriculture and forestry. Partners included: agricultural and soil scientists (domain experts), computer scientists, social scientists, and Case Study Partners (CSPs) who are advisers and intermediaries. A co-innovation methodology underpinned the project. This entailed an iterative process in which partners in VALERIE and stakeholder communities participated. Ten CS participate in six countries across Europe (Table 1) provided the platform for this iterative process. Cases were organised around a particular supply chain, a farming/forestry sector, or a landscape, and so covered different scales and dimensions. A CSP for each CS facilitated and coordinated the stakeholder community. The CSPs and stakeholders had a central role in both developing ask-Valerie as well as identifying innovation and information needs and testing innovations in the field.

The ambition

The aim was to construct a search engine which can help practitioners and advisers in the field of agriculture and forestry to find and share documents that respond to their specific queries.
The ultimate ambition was to create a digital but knowledgeable ‘assistant-expert’ or ‘digital adviser’ which can serve as an intermediate between experts and practitioners, optimising the effectiveness of the interaction between them. An important challenge identified for the project was to use the modelled domain knowledge in such a way that the system is able to have an effective dialogue with the user. According to project partners “in such a dialogue, the initial

question of a user (farmer, adviser) may be vague and broad, or very specific. If the idea of an assistant-expert is to work it needs to translate the users' question into terms in which solutions are formulated, independent of a particular language, and help the user (farmer, adviser) to narrow down or broaden the questions, or suggest alternative lines of thinking" (Willems et al. (2015). A further goal of ask-Valerie was to extend beyond a search tool towards an interactive ask-Valerie learning community.

Given this ambition it was essential for the computer scientist and domain experts to work with potential users throughout the development of the tool. This provides a better understanding of users' information contexts to identify what information is required and what are the innovation needs. The core elements of the system to achieve this are described next.

Table 1 Case study details

Name	**Case study (CS) partner & country**	**Topic**	**Stakeholders**
Catchment scale resource use efficiency	GWCT UK	Sustainable farming at landscape scale	Environment agency, NFU, NGOs, professional nutrient management group, agric. levy boards
Soil management in livestock supply chains	GWCT UK	Sustainable soil management in livestock production	Farmers, advisers, supply chain, NGOs
Sustainable forest biomass	TAPIO Finland	Sustainable forestry management and smart use of biomass	Researchers, forestry organisations, forest owners, ash processers, policy makers
Agroecology: managing plant protection	CETIOM France	Sustainable cereal cultivation	Farmers, technical institutes, agricultural chambers, machinery companies
Innovative arable cropping	ACTA France	Reducing herbicides use in arable crops	Technical institutes, agricultural chambers, farmers, research institutes, storage agencies
Sustainable forest management and ecosystem services	USSE Spain	Improving the economic and environmental performance of forestry in Navarra	Forest owners, municipalities, forest authority and extension service, value chain organisations
Improving milling wheat quality	Cadir Lab Italy	Fertilisation, IPM and fungi control in sustainable milling wheat supply chain	Farmers, wheat-stocking cooperatives, seed companies, pesticide companies, wheat-buying companies
Drip irrigation management in tomatoes and maize	Cadir Lab Italy	Sustainable water and nutrient management	Farmers, cooperative for tomato transformation, public experimental station
Sustainable onion supply chains	DLV Netherlands	Improvement in onion quantity and quality	Farmers, seed companies, packers, exporters, suppliers of fertilizers and pesticides
Sustainable potato supply chains	DLV Poland	Sustainable potato production for the French	Farmers, processing and exporting industry, suppliers of

		fry industry	fertilizers and pesticides, experimental station and research

Constructing the main elements of ask-Valerie

Firstly, at the core of the platform is the **ontology**. The partner domain experts and CSPs in the project defined a common language to express questions and answers. While the practitioner and the expert have some common background, as they work in the same domain, differences exist in the level of expertise and terms used. This means that they not only have to choose a shared natural language, but also a corresponding set of words and grammar, understandable for the system. They also have to identify relationships between the concepts. To do this an ontology was created that organises terms in a taxonomy (e.g., 'wheat' and 'barley' are specific types of 'cereal'), and defines synonyms as well as closely related concepts (e.g. 'Phythophthora' is related to 'potato').

Domain experts and CSPs (acting as potential users of the ask-Valerie system) were asked to provide relevant concepts in the agronomic and forestry domains (for the 6 themes of the project), place these concepts in a hierarchy using ROC+[4] and identify concepts that are related in another way (Koenderink et al., 2008) . Domain experts and CSPs were trained and made their inputs in workshop sessions, or remotely at the beginning of the project. Domain expert can identify the range and scope of information available, while CSP can identify the breadth of information required by practitioners. CSPs initially used their personal vocabularies, they then collected specific context specific terms identified by stakeholders in CS meetings, these were supplemented by terms collected throughout meetings, as innovation needs were identified in a parallel exercise (Ingram et al., 2018). Domain experts and CSPs also translated ontologies into national CS languages. Thus CSPs drawing on stakeholders vocabularies co-constructed the ontology with domain experts.

A second element involved creating the **document base**, the domain experts and CSPs selected a collection of relevant reports, papers and other outputs within the domain of interest to the 6 themes and to the case studies; they are selected for their potential to help farmers/advisers to find the innovations relevant to their problems and questions. These documents originate from Horizon2020 thematic networks, the EIP-AGRI website, CORDIS, national and regional advisory services, levy boards, universities, journals, and national repositories (guided by CSPs). The experts 'translated' the documents into the shared terminology and identified relevant sections. They also made the documents available for the system to access.

A third element was the **annotation**, this is at first manual and them automated The scientific experts select new documents from reliable sources, and use their own expert knowledge to indicate the useful elements for practitioners. A practitioner can enter a question into the system and receive answers extracted from the documents, this personalizes the question-and-answer process. The research results can become a targeted transmission of knowledge specifically applied to the practical problem which a practitioner faces, rather than a universal dissemination.

[4] Ontology construction is a laborious and expensive process so a ROC+ (Rapid Ontology Construction) method was used to facilitate this activity. The ROC+-method consists of five steps: (i) entering of concepts into the ontology, (ii) identifying synonyms, (iii) use existing ontologies to suggest per concept in the ontology other possibly relevant concepts, (iv) create the hierarchy between the concepts, (v) indicate relations between concepts

The selected documents in the database were automatically annotated using the domain ontology, and afterwards manually checked by the same domain experts. As such the ontology was used to take a 'fingerprint' (make a semantic index) of all documents in the document base. Given a user-query, the best matching documents should then be easily found. This provides the algorithm for the interaction needed for the digital adviser concept to work.

A further element was the **query editor**. This feature aimed to help the user (practitioner) to formulate a question as a formal query to the ask-Valerie knowledge base. The query should capture the meaning of the question. The system aims to help the practitioner to use the shared language (ontology) to articulate his/her question. The premise is that a query editor can suggest alternative directions to explore, and helps the user to zoom in or out of certain details or presents suggestions for expanding or narrowing the search, offering alternative search directions by showing slightly different concepts or synonyns or relations (based on ontology). It should also be able to translate selected terms into queries to consult the document repository. The intention is that when a query is entered ask-Valerie selects snippets/fragments from relevant documents and ranks them. The user can then take action with this information or reformulates his question. The documents that fit with the user's question are presented using their titles, along with selected text snippets and the logo of the document owner which can be clicked on for access.

Finally the interactive element was designed in which users can suggest new documents (e.g. those found by other search engines) and add new terms to the ontology, The interface for this **ask-Valerie learning community** was designed to enable users to connect with each other and share retrieved documents and experiences, and to find experts/advisers on specific topics.

Stakeholder involvement in the development of ask-Valerie

ask-Valerie has been developed through a series of iterations involving progressive stages of design and development by the project partners responsible with input and feedback from supporting partners, the CSPs and stakeholders over the project period. The CSPs played an essential role, not only providing their own technical and practical expertise, concepts and perspectives, but also by liaising with their stakeholder communities in multiple participatory meetings.

In the iterative process in the CS, the search tool concept was first introduced in early CS meetings in which the views and **expectations of the stakeholders** were sought and noted and potential users identified. These were reported in CS reports. Following this three main methods were used to collect CSP and stakeholder input and feedback to support the development of ask-Valerie (see Figure 1).

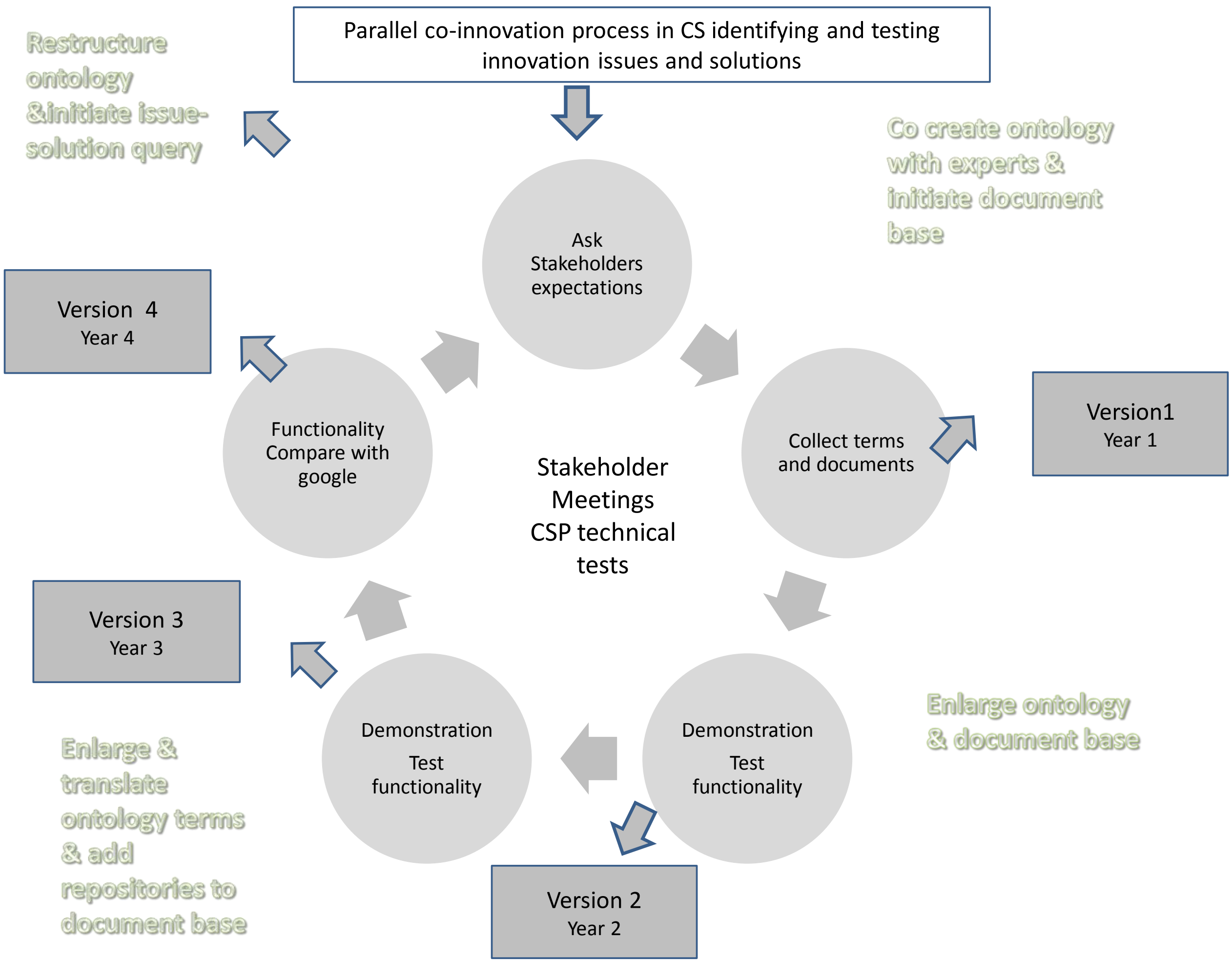

Figure 1 Stakeholder and CSP involvement in ask-Valerie development

The **first method** comprised a series of technical tests and demonstrations of the software undertaken in the CS with stakeholders over the duration of the project. As part of this three technical demonstrations and tests were conducted with CS stakeholders for Versions 2, 3 and 4 respectively. These tests were facilitated by CSPs who collected stakeholder feedback (according to standard protocols). Key issues raised were provided to the partners developing ask-Valerie so they could make the necessary adjustments. The evaluation methods were based on descriptive (analysis) methods. The tests concerned functionality, mainly usefulness of search outputs with respect to search terms, ranking and snippet features; the user interface (search features, queries, filters), the document base and the type and language of the document. In the demonstration/test of Version 3 the stakeholders also identified missing features and listed these as either 'must have' and 'like to have' features. The test of Version 4 was undertaken with a smaller selected group of stakeholders in each CS. The aim of this test was specifically to evaluate the usefulness of ask-Valerie by comparing it with a commonly used search engine, Google; this was done, using standard protocols, by searching for specific queries and scoring the outputs and snippets provided by each. A preliminary task in this exercise was for CSPs to list the criteria they used to judge the usefulness of the search outputs. All these test results were reported in CS meeting reports which have provided the empirical data for the analysis in this paper.

The **second method** used to inform the development of ask-Valerie comprised a series of small technical tests with CSPs in between CS stakeholder meetings. These involved CSPs completing a prepared questionnaire in project meetings, dedicated workshops, smaller tests in Skype mini-workshops and remote exercises facilitated and analysed by those constructing the search engine. A **third method** was for the authors to collect feedback in a series of reflective interviews with CSPs throughout the project, and discussion during project meetings and in other project activities. This feedback was then passed onto the partners developing ask-Valerie. Analysis of this interview data is presented in this paper.

In parallel with these activities the tool consultation and validation and internal evaluation was constantly being carried out by domain experts who examined the correctness and relevance of the ontology terms, checking the concepts used and the relationships throughout using specific meeting and standarised criteria. The CS meeting reports and CSP interviews together with the authors observations provide the empirical basis for the results, as reported next.

Results

ask-Valerie versions and development

To date there have been four versions of ask-Valerie. Some of the key advancements in each version, in response to the feedback are shown in Figures 2 and 3 Stakeholder involvement in the development of ask-Valerie has provided vocabularies to build the ontology, and feedback to the developers as potential users. In particular comments concerning the language and the document base have led to significant changes and improvements, whilst issues raised about functionality (searching and ranking) and presentation of results have been progressively addressed in each version. More significantly, in response to some experiences with functionality, the team developing ask-Valerie, together with project partners, reconceptualised important features of ask-Valerie.

The results drawing on analysis of the CS reports and CSP interviews, are presented first for stakeholder expectations, then provide some insights into how the distinctive elements of ask-Valerie (document base, ontology, functionality (of algorithms for query editor and digital adviser), were developed with stakeholder participation (Figure 3).

Expectations

The CSs were diverse and the stakeholders within them cover a range of roles and expertise (Table 1), consequently expectations, where expressed, were mixed, reflecting the type and context of the CS and individual stakeholder characteristics. However, stakeholders generally liked the idea of ask-Valerie and appreciated the ambition of the tool. In one CS (Agroecology

CS in France) arable farmers identified the need for improved access to research but discussed the limitations of information sources on the internet remarking, for example that: “queries show too much irrelevant information. It is time consuming to find what you seek”; “Documents found (e.g. report, scientific article) are too long, too scientific”; and “Participatory internet sites (e.g. agricultural forums, Wikipedia) raise the question of the validity of the information because nothing is checked”. This prompted questions like “Will ask-Valerie provide validated information?” and “Does ask-Valerie offer other sources of information than on innovation? Will we have access to more general agronomic information?”

The comments suggest that a more targeted search tool is needed, but also demonstrate farmers’ concerns about the validity and credibility of information from search engines in general and specifically about the format of outputs, and their practical applicability. However, regarding the first point, stakeholders in two other CS proposed that some form of interactive tool in the form of an internet wiki would be preferable to a search engine per se as this could link and enable information sharing in the agricultural community. In this respect they valued social interaction and peer experience and recommendations above any concerns about validity.

Considering the format and content of outputs, the need for practically applicable materials was emphasised in a number of CS. In the Wheat supply chain CS in Italy, for example, the stakeholders said that did not expect or need specific innovations from research outputs using ask-Valerie, they agreed that they just need “pragmatic solutions, usable in their territory”. They were also particularly interested in providing innovation opportunities to actors throughout the supply-chain, from the field to the processing factory, including seed production and lot storage. An exercise in the first CS meeting identified each stakeholder groups’ different information needs from ask-Valerie and their current sources of information showing a clear differentiation.

In other CSs, such as in the Potato and Onion supply chain CSs, professional farmers and advisers are already accessing scientific articles and information using search engines and have the highest expectations of ask-Valerie. For the Potato CS in Poland the CSP highlighted the need to demonstrate the added value of ask-Valerie to the stakeholder group, who will use Google as their bench mark. The farmers in this group can be highly educated people, who know where to find research information. The CSP described the stakeholder group as “critically positive”. They found the ambition of ask-Valerie interesting but, there was he said “a little scepticism about whether it can do what it promises. These stakeholders actively search for solutions for their problems; if ask-Valerie can help in this search it will be highly appreciated”. All stakeholders and CSPs remarked that they would be very interested in finding results from European projects and other national projects which might be relevant to them, for example Italian wheat growers were interested in wheat research in France. Thus the document base proposed was promising for them.

With respect to potential users, this was related to characteristics of individual farmers and advisers, current level of innovation support services, and format, language and content of the research output. Overall it was felt that advisers, rather than farmers, would be the most likely users, as farmers spend less time searching for documents online, although this depends on the CS context. In France, rather than farmers and advisers, technical experts were identified as the main users. Potential use was also connected to the level of existing innovation support, some CS stakeholders were already well connected to information. Stakeholders in supply chains, for example, tend to be well supported by their sector which provides up to date technical information. In other CS, established relationships with projects, agronomists and intermediaries enhance farmers' ability to find information, as the CSP of the Agroecology CS in France explained:

> "In our context, our stakeholders … already have access to very innovative projects. … they know the technical Institutes website to grab the information that is useful for them. So they already have access. It is not the case and the rest of France, it is not representative at all. They are very isolated, farmers, may find ask-Valerie more useful for sure".

Ontology

The ontology was built using domain expert, CSP and stakeholder terms and relations. Early contributions from the CS helped to capture the range of vocabularies used by practitioners as well as their information contexts and needs. However, as the project progressed the CSPs and stakeholder took a marginal role as the domain experts became the main drivers of the ontology. As described below this was in response to fundamental issues that emerged with respect to the relations architecture of the ontology.

CSPs took different approaches to collecting terms for the ontology from their stakeholders. In the Wheat CS in Italy, for example, an exercise was carried out in the first stakeholder meeting to identify innovation issues and research needs with a poster trail, after this all content written on the posters were read and compared to the list that was entered in the ROC+ system by the CSP earlier. In this case CSP felt that it was not necessary to add any more terms as it was complete. The process was considered useful as the CSP found some connections that they had not thought about before such as "fertilization" and "grain quality", "monitor" and "wheat bugs", "NIR" and "guidelines", etc. The CSP reported that the recurrent terms of the stakeholder meetings were "supply-chain improvement", "quality assessment" and "sorted storage" of the grain lots, which reflects the stakeholder group composition. The CSP reported that they had some problems in translating the language for these terms and in particular terms like quality typologies of wheat varieties for their different uses over the supply-chain: "Strong bread making varieties", "Bread making varieties" and "Biscuit making varieties". This is a one of the main issues they identified related to the key-term list because of its importance not only for agricultural practices but also for the market.

In the Potato CS in Poland an exercise in small groups was carried out in consecutive meetings, in which the groups listed "all terms that came into their minds". The CSP did not present the ontology made previously by the CSP and domain experts because, as he said, "I didn't want to lead them in a certain direction". Different stakeholders came with stakeholder specific terms, related to their business. For example, suppliers of potato seeds has concerns about seed quality, identifying terms like "Rhizoctonia" and "Fusarium" (common diseases). On the other hand, representatives of the processing industry listed terms like "tuber shape", "length", and "disorder". Given that there is a connection between these terms, the CSP noted that it was beneficial to have all stakeholders together to create all relevant terms and connections for the ontology.

As the project progressed the ontology was expanded from 1,746 terms to 6,253 from Versions 1 to 4. Some CSPs reported that they had exhausted the number of terms collected with stakeholders so did not continue with this activity after the initial exercises. However, as the tool was subsequently developed and tested, all partners became aware of the importance of the ontology in the construction of ask-Valerie. This was expressed both in terms of overall functionality and the domain terms. In the Potato CS in Poland, for example, the importance of spending time developing the ontology was highlighted by the CSP who found that important terms were still missing:

> "Too late in our project I understood the real importance of the ontology. What amazes me is that there have been many more terms incorporated into the ontology. So there has been a lot of effort apparently in developing the ontology. But too many crucial terms for my case studies are not there".

In particular it became apparent that while the list of terms was important, it was identifying the correct relations between the terms that was critical for the ontology and tool functionality. CSPs attributed some problems in finding documents to poor ontology development. The CSP in the Agroecology CS, France noted difficulties, for Versions 2 and 3 they remarked that they were still unable to find relevant answers, saying:

> "When you write the question of farmers on a very specific subject you can't find it. This is the case for English and in French language. With the ontology we realise now that there are some weaknesses. We realise now how crucial the ontology is."

For this reason it was sometimes felt by CSPs that there was little progress made between versions. In turn this led some to question the value of ontology construction. Again in the Potato CS the CSP described how ontologies were a completely new concept for his stakeholder group and that it was not easy to convince them that working with ontologies had added value compared to clever use of existing search engines like Google. The CSP remarked:

> "My little knowledge and lack of experience on this subject might be one of the reasons. But also the fact that we could not show any relevant output did not help to convince the people that ask-Valerie will work and will supply interesting information and solutions".

Partners developing the tool planned for the ontology not to be a static entity but to be continuously expanded and enriched to stay relevant for answering practitioners' questions. To make this process as user-friendly as possible, CSPs and stakeholders were encouraged to add new ontological terms at any time when using ask-Valerie. However, this facility also created some issues as in some cases the added terms were not uploaded to the system, in other cases there was issues of quality control (correct relations) of such contributions.

In response to all these issues, and as part of the continued development of the ontology, the partners and domain experts, who were constantly reviewing the ontology, significantly restructured the relations component, revising or even removing some of the stakeholder terms and relations. As the project progressed the CS input was progressively modified and reduced.

Document base

Preliminary stakeholder consultations identified some limitations in the proposed tool with respect to the relevance of the documents in the document base for the potential users. In the early stage of development a systematic search of CORDIS and EU or national project reports revealed few that provided research outputs with a suitable format or content the documents identified as relevant to the domains. As such the domain experts sought research outputs from scientific repositories and these were largely scientific articles in English. However in many CSs, these were not considered appropriate for farmers and advisers. Instead their preference was for summarised or synthesised (translated) research outputs in the form of technical notes or factsheets. Furthermore, CSPs reported that documents in English were not suitable for most potential users outside UK. The exception was the more professional farmers in high value supply chains and for agricultural project managers, technical officers who work with advisers, and agriculture/agronomy students, who can understand these documents.

In response to these concerns a priority was set for CSPs and domain experts in each country to gather relevant ‘practical’ documents (factsheets etc.) in their native languages, and to identify national repositories of these which could be linked to ask-Valerie. At this point CSPs each selected 100 documents relevant to their case studies, they also used the facility to upload their own practical documents to the document base. This led to an expansion of the document based from 710 documents in Version 1 to 3,905 in Version 3 and the prospect of many tens of thousands through linked national repositories in Version 4. The number of languages rose from one to six by Version 4. In turn this required an expansion of the ontology and a need for the CSP to translate the ontologies into native CS languages. Overall this process, widely welcomed by stakeholders, took a many months and delayed opportunities to test the functionality of ask-Valerie with stakeholders (Figure 2).

Insights were also gained from the parallel co-innovation activities in the CS in which different forms of ‘translated’ (synthesized, summarized scientific papers) material were evaluated by stakeholders. These co-created fact sheets provided a bench mark of what stakeholders preferred and were themselves added to the document base.

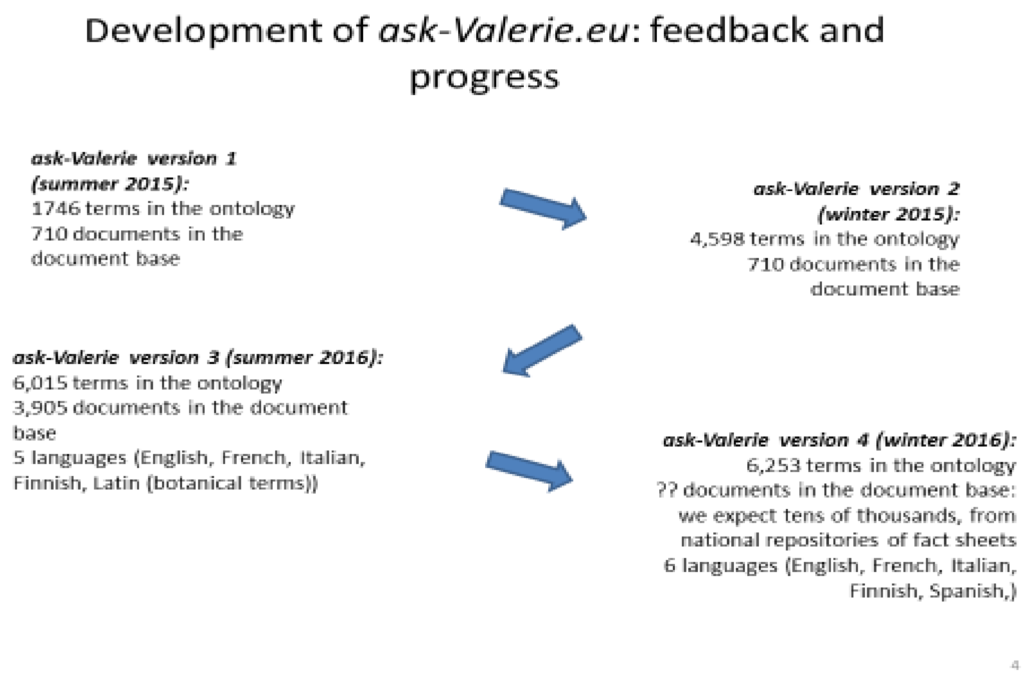

Figure 2 Changes in ontology terms and documents in progressive Versions of ask-Valerie

Functionality (of algorithms for query editor and digital adviser) feedback

Once the document base and ontology had been expanded and the ontology translated, demonstrations and functionality tests were conducted with CSPs and stakeholders. In these the CSPs reported that the stakeholders understood the potential and they gave positive feedback on the functionality of the tool. All stakeholders particularly liked the ability to search and access documents in different languages and appreciated these revisions. In the Onions CS in the Netherlands stakeholders liked the query editor, and the possibility to add documents and new terms to the system is seen as an interesting feature.

In general, CSPs said that the query editor functions, broader, narrower and related terms are appreciated by stakeholders because they allow a “complete search”. They tested the tool by progressively refining and defining their question and by following the alternative search directions offered. Early queries were broad and generic, the tool supported them to refine these. Also their question or query articulation behavior replicated that used for other search engines, which was based on key word searches rather than questions about solutions to specific problems. However they learned to adapt their questioning. As the tool developed they recognized synonyms familiar to them and identified errors to be corrected in these as well. CSPs and stakeholders also identified several detailed functional features concerning the interface that they wanted changed as well as commenting on how the search results are presented (abstracts or snippets), ranked and sorted. However overall the ability of the system to find relevant documents was a main concern and masked any specific feedback on the query editor feature, and on the potential of ask-Valerie as an intermediary or digital adviser.

In the final technical test, overall relevance and practicality were the most important criteria identified by CSPs and stakeholders in deciding the usefulness of the search outputs. The tool performed well against Google in some respects, for example the majority of queries performed on ask-Valerie returned snippets and outputs and two-thirds of the queries in ask-Valerie identified at least one useful result. In some CSs Google listed multiple documents but they were not considered relevant and furthermore they were not always publically accessible. The main reasons that snippets and outputs did not receive a high score from the tester were lack of relevance to the query, or they were not considered to have a practical application.

To address the aspect of relevance and practicality, and to develop the digital adviser concept, the partners next started to develop an advanced feature building on the notion of innovation issues and solutions, in the search function. Concepts that represent ‘solutions’ (innovations) are linked to the particular problem they aim to resolve. The intention is that this allows the query editor to mimic the role of the adviser interacting with the practitioner, for example, for a specific crop disease it points to innovations (methods, products, etc.) that may help to control the disease. This development however was curtailed by the end of the project.

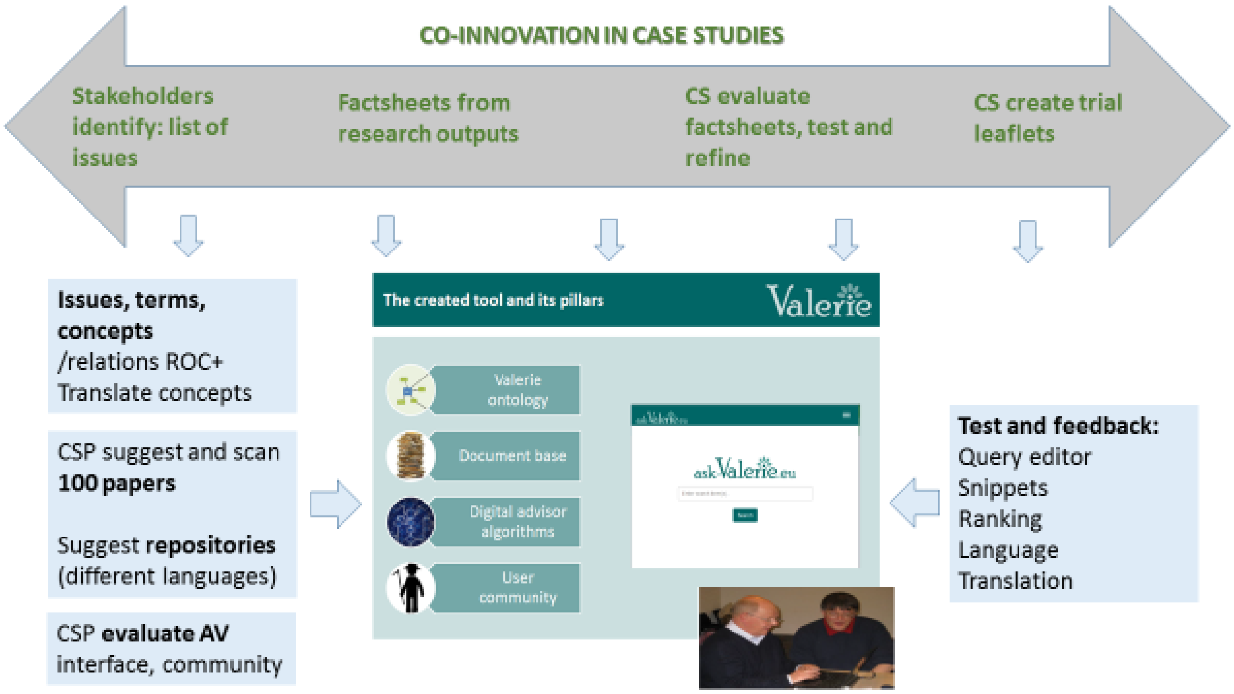

Figure 3 CSP and stakeholder role in developing ask-Valerie

Tensions and managing expectations

From the stakeholder perspectives they have appreciated contributing to the development of the tool and have welcomed improvements and development as the tool progressed but there have been some tensions. Whilst they acknowledge their role is important for development, there has been frustration amongst stakeholders when prototypes have not functioned well. There has also been some disappointment when feedback had not been sufficiently addressed between test versions due to the delays and significant demands on the computer scientists in the project.

In the Wheat CS in Italy it would appear that the technicians and advisers were the most critical and demanding of ask-Valerie, and the farmers were more positive and curious. In terms of the project iterative methodology the Potato CSP noted:

> “Of course they [stakeholders] are, to a certain extent, willing to contribute to the development of the system that is what they have done so far. But we should realise that the frequency at which we can show progress in ask-Valerie is not very high. This is no problem as long as we can show significant progress each time we meet them”.

This was also the experience in the two CS in Italy where the CSP remarked:

> “Yes, the last meeting [was particularly difficult]. Because we were showing them something that was not ready yet. It was like driving the prototype of a car and the car

> doesn't start. It is like a metaphor for the car, this is a beautiful Ferrari, but without wheels".

The CSPs who were the "face" of ask-Valerie in the CSs had to manage the expectations of the stakeholders, and to demonstrate progress and ultimately deliver the search tool as promised in the CS kick-off meeting. They have managed this through a variety of means, sometimes 'protecting' their stakeholders by using small groups of colleagues or experts to test the tool as they can understand that "I'm not demonstrating ask-Valerie I'm asking you for feedback so we can improve the system". The CSP remarked that that they would also have appreciated longer and more in-depth technical tests in every project meeting.

Discussion

This paper has revealed a number of insights into the process of creating an ontology-based search engine by working with experts and stakeholders. These insights are not only relevant to this project and specific tool but have wider significance as they can be applied to other contexts where practitioners are involved in tool development in trans- and inter-disciplinary projects.

Firstly, there is frustration among some of the stakeholder community with current search engines. They find that the information is fragmented, of questionable utility and validity and often inaccessible; many therefore welcomed the ask-Valerie ambition. This supports the argument that smarter farmer-centric search engines based on ontologies are needed to link practitioners to the large number of research outputs available (Walisadeera et al., 2015).

Secondly, the research found that the novelty of the approach, drawing on ontological developments in IT and applying them to agriculture and forestry domains, required a flexible and iterative approach by the project partners and stakeholders. As such the feasibility of, and the means of achieving the vision[5] for, ask-Valerie was constantly reviewed and critiqued by partners throughout the project in an on-going reflective process. In turn this needed good cross-partner communication and a shared conceptual understanding, ambition and set of expectations. This aligns with Joshi et al. (2007 p323) views on Information systems development; they note that "To successfully build a large and complex system, team members have to continuously communicate and learn from each other regarding different issues ranging from the capabilities of the new system, application-specific algorithms, and architecture of the computers to articulating the intentions of the customers". Beguin et al. (2012) also note a dialogical processes between designers and users which involves user adaptation of tools and requires reflexive approaches.

The responsiveness of the tool developers to stakeholder and CSP input was a particularly positive feature of the tool development, however, this has created a considerable amount of work and delayed the tool development. In turn, this brought some tension and frustrations in the CS in terms of meeting stakeholders' expectations. This raises questions about finding an appropriate balance between allocating sufficient time to tool development and spending more

[5] i.e. to use an ontology to improve the structuring of knowledge for the agriculture and forestry domains according to context of the users; to create a shared vocabulary between experts and stakeholders to express questions and answers and therefore imitate an expert-practitioner dialogue; to use the domain ontology to annotate digital documents and provide an index so that best matching documents to answer a query could be found

time in the early stages of co-constructing the ontology architecture, against testing early prototypes with users. These observations are equally pertinent to other short term projects tasked with information management or decision support tool development requiring participatory user input.

Thirdly, the significance of the ontology to the effective working of ask-Valerie and its potential as a digital adviser became clearer as the project progressed. Considerable effort went into creating the ontology and this was effective in terms of assembling large numbers of concept and terms from domain experts, CSPs and stakeholders. Domain experts met frequently and reviewed and validated the ontology. However, despite this, all partners recognised that there were some deficiencies in the functioning of the ontology. Some CSPs came to realise "too late" how important the ontology was, possibly suggesting that they did not fully understand the concept or the stakeholders role in ontology creation. While some CSPs reported that they had exhausted term collection, others noted that crucial terms they had proposed were missing and as a result searches failed to find suitable documents in some tests. Furthermore in some CS the supply chains terms suggested were hard to define and to relate to other more technical or scientific terms; revealing the different arenas in which the experts and the stakeholders operate.

Domain experts and partners developing ask-Valerie realised that whilst the number of terms was high, the relations between them were not accurately expressed (and therefore the semantic index was not optimal) leading them to significantly revise the ontology at a late stage with some adjustment and exclusion of earlier CSPs and stakeholder inputs. This questions the extent to which stakeholder terms and relations were retained in the "common vocabulary" which was always seen to be at the core of ask-Valerie in that it aimed to "remove the ambiguities and vagueness of natural language in this domain" (Willems et al., 2016). It also questions future opportunities for users to add terms and concepts which was part of the vision of a dynamic ontology.

The basis of ask-Valerie, using an ontology for structuring and representing problem specific knowledge (e.g. decision making realities in a farming context) into a knowledge repository (Miah et al., 2014), requires dedicated time and effort. (Walisadeera et al., 2015 p143) support this saying "Organizing information so that it can be queried in a context-specific way is more resource intensive as it requires procedures, methods, staff, and professional expertise to provide this information". The experience developing ask-Valerie reveals a tension between the need to build and test an ontology systematically over a period of time and the users' demand for some evidence that their time is being used effectively in building a functioning tool. Full buy-in and understanding is needed early in the development process, as well as evidence of incorporation of CS feedback, otherwise participation fatigue sets in if stakeholders perceive their involvement gains little reward (Reed, 2008). Here the CSPs play a key role as gatekeepers or intermediaries in reconciling differences between tool developers and stakeholders. Other approaches for constructing an ontology have been described, for example, secondary data and preliminary farmer interviews were effectively used to identify important factors (farm environment, types of farmers, farmers' preferences, and farming stages) that needed to be considered when delivering agricultural information and knowledge to farmers in particular contexts in Sri Lanka (Walisadeera et al 2015). While suited to local problem solving this approach would not have been suitable for the large scale term collection that ROC+ enabled.

Fourthly, early adjustments to the document base were made in response to concerns about relevant formats and language. The reorientation of ask-Valerie towards practical documents in native languages was a major part of the ask-Valerie development and was highly appreciated by the stakeholders and CSPs. As Sulaiman et al. (2012) noted the value of information provided by ICT applications greatly depends on its local relevance, and this was the case in ask-Valerie, by offering both access to national repositories and concurrently translating ontologies to allow effective querying and searching, local relevance was offered. By being responsive to stakeholder comments the partners reoriented ask-Valerie towards a more useful tool with an extensive and relevant document base in six languages. The importance of being able to locate practical rather than scientific documents was emphasised and the benefits of drawing on stakeholders' evaluation of different levels of scientific translation in the co-created factsheets was noted. However, as noted above, the ontology is key to the way that knowledge in a document base is represented and structured, and critical to finding relevant and useful search results.

Fifthly, with respect to functionality, the query editor features were appreciated. As expected, how questions or queries are articulated by stakeholders varied greatly. The query editor helped users to refine questions, it supported and steered problem formulation and question reformulation. Also the synonyms and relations suggested enabled a shared language to be 'spoken' between the experts and stakeholders. However, the query editor is not yet able to imitate the interaction or dialogue between user and adviser. Ultimately this facility was judged on the usefulness of outputs, that is their relevance and practically oriented information, and in a number of cases this was still found to be wanting. The potential for achieving some form of interactive digital adviser will only be realised when the ontology improves. As part of this efforts to develop the concept of innovation issue and solution matching, as a way of enhancing the digital adviser function, continue. Meanwhile although the aim to combine the ontology, selected digital documents and dialogue to progress from standard search solutions has been achieved, it is not yet approaching the advisory capabilities of a human adviser, nor replicating the socialization process of knowledge exchange (Roberts, 2000). Although Boisot (2002) claims that electronic communication can potentially enable co-presence without co-location, the experience with this tool development is that this is still an ambition to be achieved.

Finally, the gap between stakeholders' expectations and ask-Valerie ambitions and outputs was apparent, both in early consultations and later tests with stakeholders. The stakeholder perspectives extend to the wider system (for example a supply chain) in which they operate where problems and solutions are multi-dimensional, whilst in the experts' view scientific outputs alone offers the solutions. Allen et al. (2017) described a similar gap in DSS development where stakeholders held whole-system views, and had diverse expectations, problem scoping and evaluation of outcomes which did not align with conventional DSS outputs. This corresponds with previous research which has found that DSS users require different types and complexities of information depending on the context, the application e.g. the temporal and spatial scale, the level of detail, users' level of current understanding and uncertainty currently faced, coupled with user characteristics such as preferred learning styles and existing local knowledge (Allen et al., 2017).

Conclusion

The increasing use of digital and emerging technologies may offer a number of innovative opportunities to developing and transferring knowledge. Providing tools that can access research data intelligently and cost effectively is important in agriculture and forestry and will help these domains to effectively mobilise knowledge resources and so improve innovation, sustainability and thus gain a competitive advantage. As Roberts (2000) notes the rise of the the knowledge bassed economy is closely related to the ICT revolution.

This paper describes an original and innovative approach to capturing a large body of research-based knowledge in agriculture and forestry and making it accessible and meaningful to the users. It reveals the complex process of building an interactive search engine based on a shared vocabulary between experts and stakeholders, and the need for constant iteration and partner consultation to ensure that project and stakeholder expectations are reconciled. With respect to this it reveals the tensions and limitations of developing an ambitious tool within a time and resource limited project.

The potential of developing a search engine using an ontology is clear however time and effort need to be devoted to the process together with sustained user involvement. The lessons from construing ask-Valerie align can be widely applied to other contexts.

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