Digital tools co-creation to ease the dialog among farmers' communities with diverse visions. A practical case with conventional and organic farmers in CAPSELLA

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Abstract: *Information and Communication Technology (ICT) currently dominates the debate on innovation in agriculture. Digitization has the potential to impact on agriculture as tractors and chemicals did during the 1950s. The direction of this impact is largely unpredictable because ICT is a neutral and enabling technology, where defining the challenge (e.g. sustainable systems vs yield maximization) is as important as working on the technical solution (e.g. using a specific sensor type). For enabling digitization to serve key sustainability challenges of nowadays agriculture, a debate among end-users groups with different starting perspectives (e.g. organic and conventional farmers) is needed. We report a case of interaction between organic farmers (from Italy and Greece) focusing on community based agro-biodiversity management and conventional farmers (from Netherlands) involved in precision agriculture practises. The objective of the case study, within H2020 project CAPSELLA, was to use the co-creation process for an application as proof of concept about the possibility to use digitisation as a neutral framework in which diverse farming cultures can dialog and learn how to benefit from digital opportunities to reach common sustainability aims. During the co-creation experience, different positions and visions of the two groups were evident. Nevertheless, the initiative worked as an open space where the involved actors realised a practical link between the two domains which is shown by the converging topics covered by the two applications developed. A qualitative and a sensor based soil quality assessment and management tool derived from the process. The two tools can be integrated in order to be useful to both farmers' groups.*

Keywords: *local knowledge, high tech farming, integrated tools, co-innovation, CAPSELLA project*

Introduction

ICT development has enormously increased the amount of data collected and available: from long-term measurements and experimentation, nowadays several dedicated dataset repositories dedicated to the agricultural sector are available in public and private institutions in EU. As a result of EU policy to open these repositories, more of these data have become available and connected with data processing and analysis techniques. These data have most relevance for farmers, when they are connected to their local observations. The exploitation of open research and experimental data in combination with the farmers' local observations and the parallel processing of them by targeted ICT tools can support practitioners in reaching their farming systems managements objectives.

Several studies showed that engaging end-users through a participatory approach enhances the successful uptake of ICT tools (Cerf et al., 2012; Van Meensel et al., 2012; Anastasios et al., 2010, Matthews et al., 2008, Lindblom et al. 2016). The development of ICT tools needs to be more user-centred, allowing the targeted end-users to co-design the application and to be involved directly in the whole process. The discrepancy between the tools offered and the way farmers make decisions explains often the low level of use of decision support tools and this is a main driver that conducted several researchers to advocate for participatory design methods (McCown, 2002; Carberry et al., 2002; Breuer et al., 2008; Jakku and Thorburn, 2010). Apart from increasing adoption, these participatory processes are also likely to enhance co-learning process resulting from the development of the application (Thorburn et al., 2011).

We present a case of co-designing ICT applications with farmers from Greece, Italy and Netherlands in the framework of the H2020 project CAPSELLA (www.capsella.eu). This experience is framed within the general objective of developing new models of participatory innovation in biodiversity-based agriculture working with open software, open data and open hardware. CAPSELLA belongs to the Collective Awareness Platforms for Sustainability and Social Innovation (CAPS) co-financed by the EU for fostering digital innovation in European society. The approach applied for supporting the transition to sustainable farming systems comprised bottom-up co-design of ICT tools based on open data with end-users and participatory validation to drive the tools and data infrastructure development. We tested the effectiveness of a co-design process with farmers for developing tools that combine open data analysis and local knowledge and observations. This process was powered technically by the data infrastructure platform developed within the project. The technical platform and environment for innovation and invention arranged in CAPSELLA allows for access to various types of data (predominantly open), open software and tools facilitating the development and co-creation of opportunities in the agri-food sector.

In our case study we did not consider farmers as a homogeneous end-users group, in order to enhance the co-learning possibilities arising from the development of the application. Instead, we included a group of farmers (from Italy and Greece) focusing on community agro-biodiversity management and a group of farmers (from Netherlands) who are directly involved in precision agriculture. The two groups had the task to develop, together with the agriculture and data scientist of the project, an application solving one of their challenges at field level. The challenge to solve was not given at the beginning of the process in order to a completely user-centred approach. Our hypothesis was that ICT, as neutral and enabling technology, could support at the same time: (i) organic farmers, expert in applying biodiversity based innovations, to better benefit from digitisation and (ii) conventional farmers, taking a lot of effort in optimizing their practises, to emphasise their effort in biodiversity conservation. We used the co-creation process for a digital application to solve a problem at field level as proof of concept about the possibility to use digitisation as a neutral framework in which diverse farming cultures can dialog, learn how to benefit from digital opportunities and find context-adapt solutions towards a common aim of farming systems sustainability.

Methods

Participatory methodology applied

The participatory methodology applied in our case study was structured in five steps:

(a) Target community structure definition

Our case study was carried on with the support of farmers from Esapoda association (network of organic horticulture farmers from Veneto) in Italy, Aegilops (Network for Biodiversity and Ecology in Agriculture) in Greece and ZLTO (Southern Agriculture and Horticulture Organization) in Netherlands. Esapoda and Aegilops are two small organizations with a strong link to the organic agriculture and agroecology movements. About 16.000 farmers in the provinces of Brabant, Zeeland and South Gelderland are members of ZLTO, that represents the interests of agriculture entrepreneurs working in these areas. An active group of farmers working on precision agriculture is associated to ZLTO. The involved farms from Esapoda and Aegilops associations are small organic farms, focusing on horticulture and local cultivars use and conservation. The precision agriculture farms from ZLTO are conventional large farms producing field crops.
The first step of the process consisted in interviewing the coordinators of the networks taking part to the project. These interviews were conducted understand their structure and activities.

(b) Community requirements collection

We used focus-groups and dedicated workshops to collect the requirements and needs of the collaborating farmers communities. The meetings were planned for understanding the challenges that could be addressed with ICT tools. The farmers were asked to share their concerns and difficulties related to data access and use and the programmers helped to translate such issues into concrete topics for ICT tools. An agronomist facilitated the dialogue between farmers and programmers. The outcomes have directly influenced the way CAPSELLA has set up the pilots (the what, when and how) as well as the generic functionalities that our platform and data infrastructure should have (with an emphasis on authentication and authorization issues). Based on the needs collected the consortium developed personas (archetype users) for each community (characteristics, information types & data they have access to, information types & data they would like to access, challenges they have identified). A first meeting included both groups in creating a rich map of their most pressing issues at field management level. This was used to agree on the topic on which to create the two ICT tools.

(c) Tools co-design

Given the topic selected during the community requirements collection, the tools properties were designed with a continuous dialogue among farmers, agronomists and programmers. During the design phase, the dialogue between farmer group, agronomy and data scientists was kept ongoing for being able to combine end-users' needs and technical feasibility. The process was parallel and independent for the organic farmers (involved farmers in Italy and Greece) and the precision agriculture farmers (group in Netherlands) until we produced a working prototype for each application.

(d) Feedback from the communities

The prototypes were tested with the communities in dedicated field trials. The feedback from the farmers helped to detect the results of the participatory process and the success in integrating Open data with local knowledge in two concrete solutions. Moreover the resulting demonstrators of the two parallel pilots (with conventional and organic farmers) were exchanged among the groups and counter-evaluated.

(e) Feedback from end users that did not take part to the co-design process

The involvement of external farmers in the testing phase provided an overview on the possible impact of the tool out of the target communities.

Agronomic issue addressed and technical implementation methods

Soil health management was detected as a crucial activity about which to raise awareness and to develop ICT tools for in the first two steps by both farmers groups. This issue has been addressed at temporal and spatial level in the following activities: (i) at temporal level, with a pilot that aims to support soil health self-assessment and evaluation of soil organic matter dynamics as result of farmers practices using open data on soil and weather; and (ii) at spatial level, with a pilot that aims to support farmers in precision farming management of organic fertilisation using parcel linked Soil Scan data. The first pilot was named Soil Health and was conducted with the organic frames group and the second Compost in Precision Agriculture and it was conducted with the conventional farmers.

The Soil Health pilot is composed of four main components:

(i) Farm data. Farmers enter basic information about their farm into the platform through a web interface: location, soil data analysis (if available), crop rotation and agronomic practices;

(ii) Soil health self-assessment. This component includes a guide for doing and registering results of a spade test (qualitative soil status assessment method) through a step-by-step evaluation of the main soil features: structure, layers, biodiversity, crop-soil interaction;

(iii) Soil model. This function of the platform is based on the Rothamsted carbon model (Coleman & Jenkinson, 1996), one of the most widely used and validated models to estimate SOM dynamics in the soil. RothC model has been used to estimate the turnover of organic carbon in the soil at plot, field, regional, national and global scales;

(iv) Open data. Input of soil and weather data from the following sources: the monthly temperature and precipitation from the Worldclim 1 dataset (Hijmans et al., 2005); the monthly potential evapotranspiration from the Global-PET dataset (Zomer et al., 2007 and 2008); the soil data (clay content, organic soil matter, bulk density, erosion risk, compaction risk) will be derived from the European Soil Database v2 (Panagos et al., 2012) and from the soilGrids datasets from the ISRIC — World Soil Information (Hengl et al., 2014).

Compost in Precision Agriculture pilot worked on the precision spreading of compost according to the level of fertility of each area in a field. Compost use is an important measure to stop the decreasing organic matter content and related buffer capacity and biodiversity in soils in the cultivation zone. The application is limited by laws that prevent nutrient pollution of soil water.

The tool supports the farmers' decision making for applying compost on the places where it is needed most: on parts of the field where organic matter is minimal. To this end, the tool will help to apply more compost on poor zones in parcels. The compost application works in the following steps:

(i) Farm data. The farmer defines on which parcels the compost will be applied, the maximum quantity according to his experience on soil conditions and his decisions on what crop to plant. The maximum quantity of compost to use in the farm will be selected to comply with local legislation.

(ii) Soil health assessment. The information collected using DualEM soil scan is used to define 5 zones with different levels of organic matter content are defined, based on 5 levels of electromagnetic conductivity in the field. The tool measures the surface of field zones and shows the result in a map, that the farmer can check with his experience.

(iii) Optimising the application of the planned amount of compost. The application uses the farm data and the zoned defined by the soil health assessment for linking the application rate (kg/m2) to the total application (kg in total).

(iv) Actuation. The tool produces a task map for the spreading machine to apply the compost as planned.

The planning tool can be made available in more circumstances: e.g. the soil health assessment can be determined by farmers' observations, by exploiting the spade test from the Soil Health Pilot, instead of DualEM soil scan.

Results and Discussion

Target community structure definition

The co-design process is conducted with farmers from Greece, Italy and Netherlands. In the first phases of the process it was challenging to talk with farmers about data, especially referring to the activities of collecting and connecting data (Figure 1). A standard presentation providing technical information about data was not adequate for starting to populate the data infrastructure. We tried to solve this with each community independently, as the two farmers groups have a very different entry-point on the discussion about data management. Farmers from Esapoda and Aegilops associations were at their first experience with a data-driven project whereas ZLTO farmers already had expertise with precision agriculture tools application on-farm. After identifying the key personas (archetype users) in each community we started discussions with community representatives about what they do in their work and how. From the first step of interaction with the coordinators of the three networks, we have identified five main stakeholders types to take part to the co-design process: farmers, contractors, consultants, researchers and programmers. This helped the data scientist, supported by the agronomists involved, in defining the data needs that should be gathered for the project platform and applications. This preliminary process helped in raising awareness levels considerably about open data, especially in the organic farmers group from southern Europe. This was also a learning process for the other actors involved (basically agronomists and ICT experts) who could understand better the needs in terms of data ownership and the privacy restrictions required by the communities.

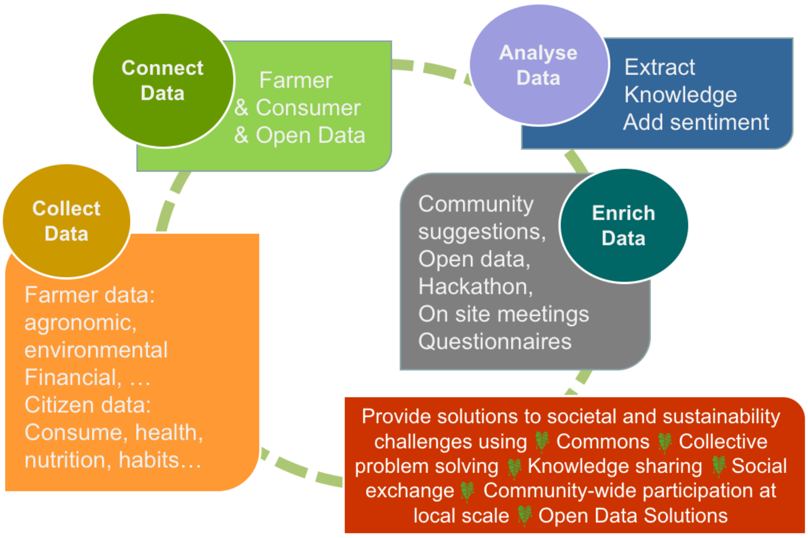

Figure 1. CAPSELLA Data Flow

Community requirements collection

The topic of soil health (meant as the holistic concept of chemical, physical and biological soil fertility) for the two pilots derived by the initial interaction phase with the communities that involved farmers from Italy, Greece and Netherlands in surveys, focus groups and workshops (Figure 2). The need for a platform for exchanging information about soil health threads, for monitoring the effects of fertilization practices on soil organic matter (SOM) dynamics was highlighted by Esapoda and Aegilops networks. This group of farmers uses organic fertilization and green manuring as core practises of fertilization. SOM cycle is at the center of their soil management strategy and having tools to monitor the impact of these practices on real state of the soil is fundamental for them. ZLTO showed the interest in having a tool to support the precise spread of compost on soil according to the level of SOM in a specific area. Compost is a voluminous product, so it needs to be applied where it's needed most. Speaking with and observing farmers daily practices it became clear they needed quick and easy way to know how to apply compost where it's most needed.

Figure 2. Rich picture produced by the discussion with stakeholders during a focus group in May 2016

The two topics were analysed by the researchers and programmers of the project. This process gave rise to the concrete pilots covering topics of interest for the farmers. These pilots were feasible for the users, in terms of the ICT content, the open data framework, and combining them with farm-specific data

Tools co-design

The target communities participated in the pilots structuring phase and the development of the actual applications with the researchers and programmers of the project. In the Soil Health pilot we focused with the organic farmers' group on soil fertility in time and we used open data on soil characteristics and weather conditions, together with the information coming from farmers self-assessment, for monitoring soil health as result of agronomic practices. In the Compost in Precision Agriculture pilot, in collaboration with the conventional farmers' group, SOM distribution in space was targeted and we used Electro Magnetic soil scan data for determining the organic matter distribution as a basis for calculating the optimum spread of compost.

Soil Health pilot (soilhealth.capsella.eu)

The result of this activity is a web platform on the topic of soil health. The core of the platform is a central spatial database storing farm data and spatial datasets (**Figure *3***).

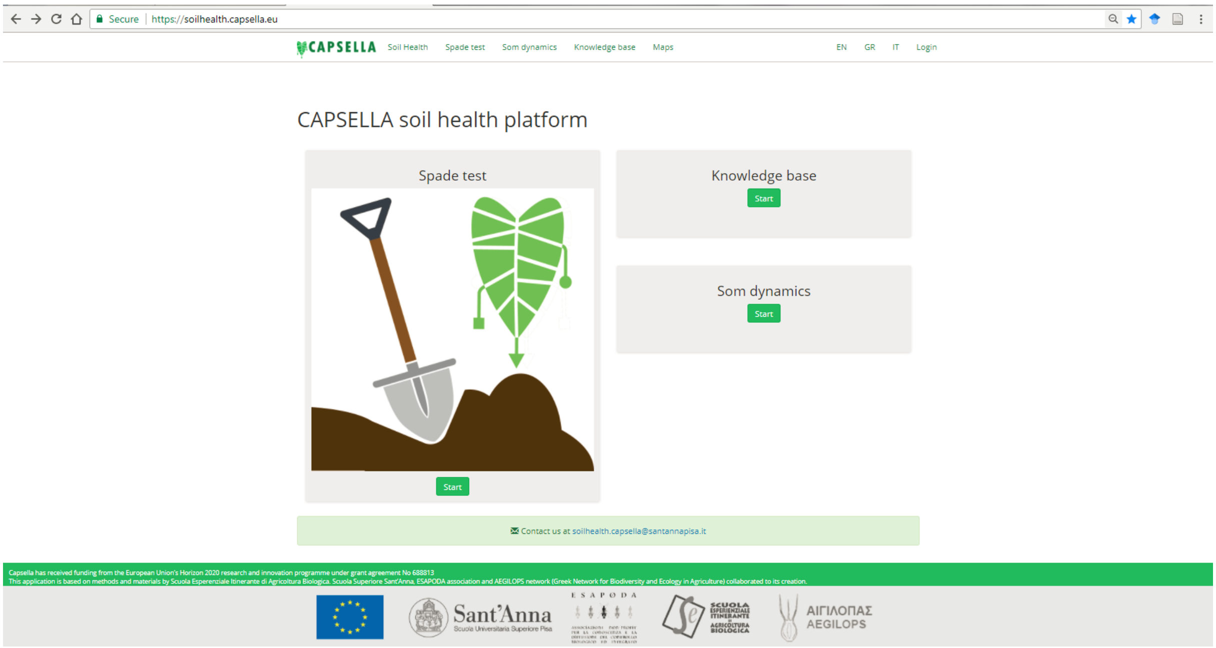

Figure 3. Home page of CAPSELLA platform on soil health

A set of web services are developed and used by the web-app to access data and tools. All the spatial data are available using the Web Map Service and Web Coverage Service standards, allowing the users to request weather and soil data for a specific location. The web service receives all the needed data from the RothC model and results are saved in the CAPSELLA database. A responsive designed web-app is the interface with the tools. The app can be reached online using a web browser from a desktop or a mobile device. The device obtains the user location using geolocation but the user can also click on a map to access a different location. The app queries the soil and climate web services to collect all the available information from the open datasets. The user can confirm a pre-defined scenario or edit the climatic and soil data, and then access two functions: spade test and SOM dynamics. The spade test function (Figure 4) guides the user through an easy touch-enabled interface to define the soil features for different layers. At the end, summary results highlighting the positive and negative features are given and shared, eventually adding comments and a short description of farm practices (Figure 3).

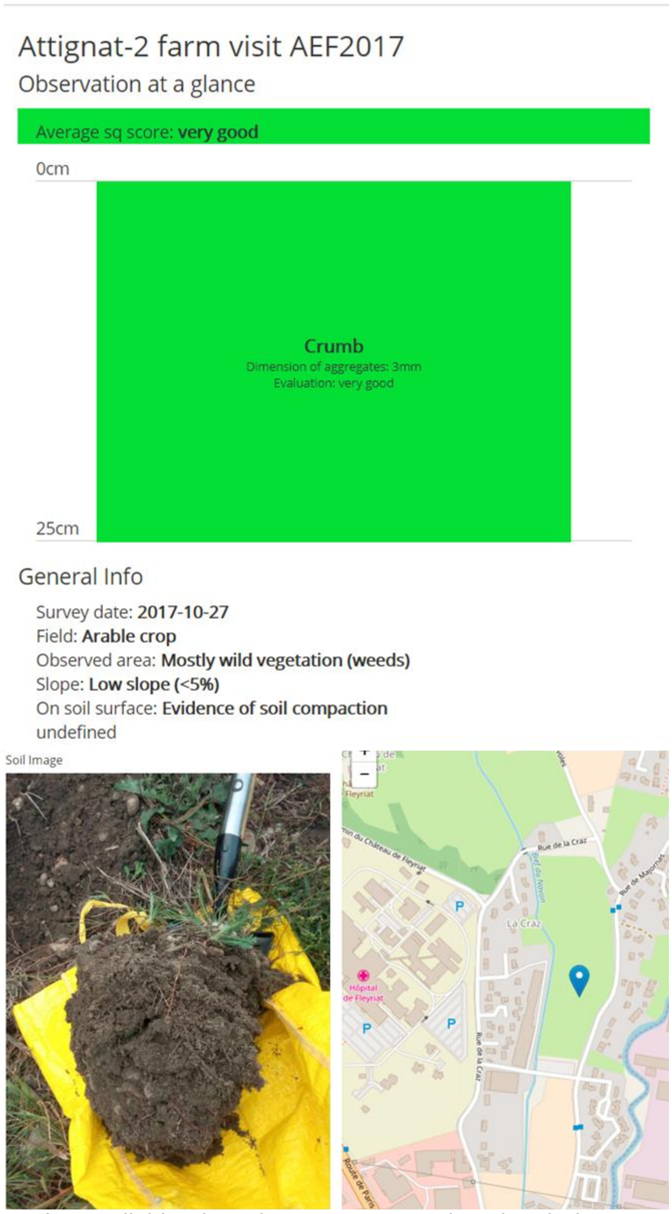

Figure 4. Example of information available of spade test entry saved on the platform

The SOM modelling function allows the user to select predefined crops and farming practices, or edit them with specific data. A preliminary list of scenarios is available in the CAPSELLA database. After choosing the scenario, RothC simulation of the SOM dynamics in the following years is run, showing the charts of SOM content and the nitrogen units available from SOM mineralisations. A map interface allows the users to search across farms, practices, spade tests and soil simulations.

Compost in Precision Agriculture pilot (capsella-pilots.madgik.di.uoa.gr/compost-calculator/#/)

The compost calculator web application exploits the CAPSELLA infrastructure for storing and retrieving its datasets. The geospatial datasets describing the involved parcels are disseminated through OGC geographical web standards, the Web Map Service (WMS) and consumed by the web application (Figure 5).

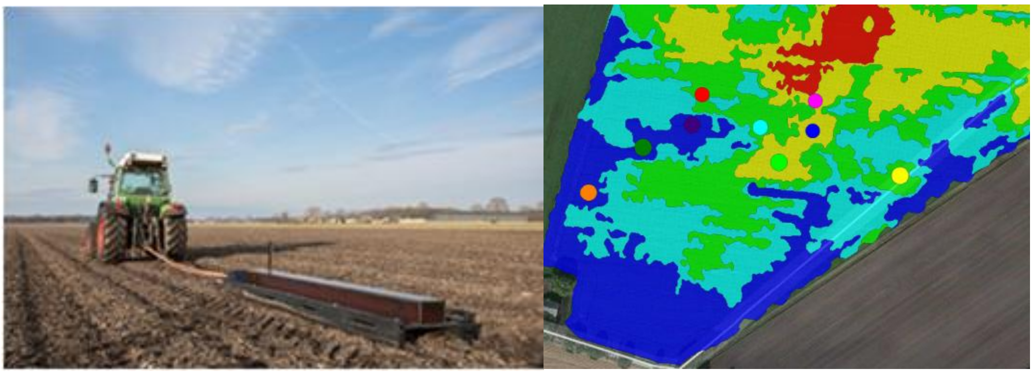

Figure 5. On the left, a tractor scanning the soil with the DualEM sensor. On the right, soil scan result of the pilot field in Netherlands in 2016.

Through a simple to use User Interface (UI) the farmer can provide the required input as this has been described in the previous section and automatically get a proposal for the compost application together with the produced task map (Figure 6). The resulted task map is stored in the CAPSELLA infrastructure and can be later used by the farmer or contractor who spreads the compost, if authorised. In addition, farmers can save the results and exploit it using additional tools.

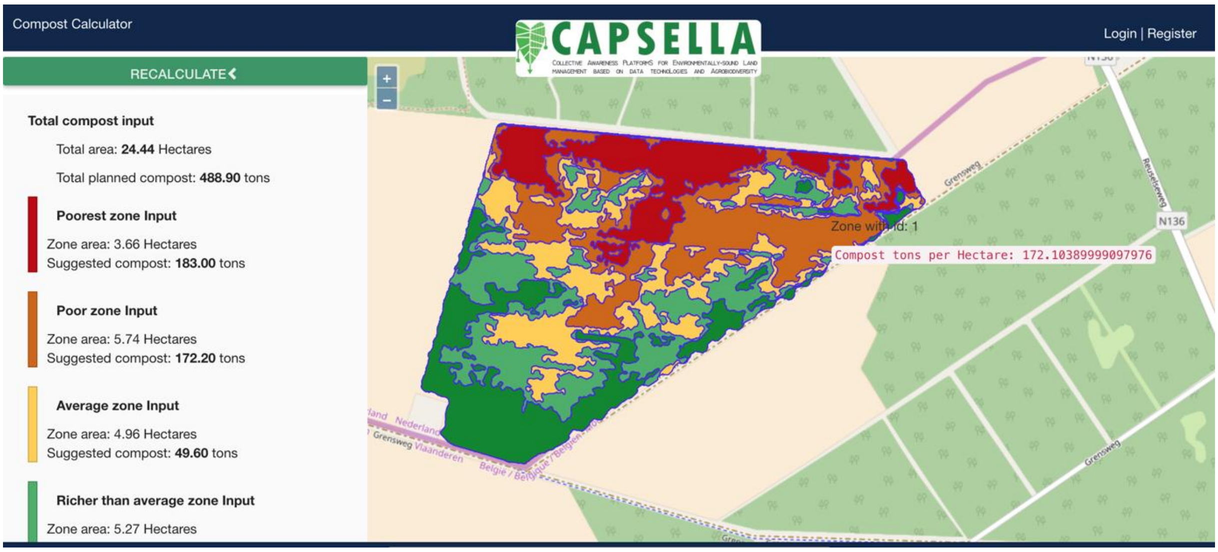

Figure 6. Compost Calculator Results Page

Advanced releases of the tool at the end of the project (June 2018) are planned to exploit open data related to soil health and the dynamic evaluation of the soil organic matter produced by the soil health pilot so as to be able to provide indications for any parcel on the application of fertilization / compost.

Feedback from the communities and from end-users not participating in the co-design process.

Each tool was fine-tuned and tested within the target community, with the community not taking part in the development within the project (the conventional farmers for the Soil Health demonstrator and the organic farmers for the Compost Calculator) and with external farmers (both conventional and organic) not involved in the co-creation process. In the development phase, the collaboration of the different stakeholders involved proved very useful, on one hand to make clearer to the farmers the potential of ICT tools and open data and, on the other hand, to highlight for the programmers the details about how the end-users expect to interact with the tools. The results of this process in both pilots, highly appreciated at the testing phase by both groups, show the bridgeheads for fruitful cooperation between worlds that may otherwise seem distant (conservation of traditional knowledge, open data use and high tech soil scans).

Bridging two development lines, phase by phase. How the case study contributes to the discussion on open data use in agriculture

The project was developed in the framework of Collective Awareness Platforms for Sustainability and Social Innovation (CAPS). Having as a challenge the sustainability of agriculture, CAPSELLA was designed to create bridges between the biodiversity based agriculture domain and the ICT world. The Soil Health Pilot was developed with two farmers associations strongly grounded in the domain of organic agriculture and agrobiodiversity conservation (Fig. 7). The techniques and network in the Compost in Precision Agriculture pilot originated from the projects on technology for smart agriculture, connecting ICT and machines. Examples in this line are Future Internet, Smart Agrifood and Internet of Farm and Food 2020. Precision Agriculture techniques can support agrobiodiversity and soil health management, therefore the Compost in Precision Agriculture pilot was incorporated in CAPSELLA (Fig. 7).

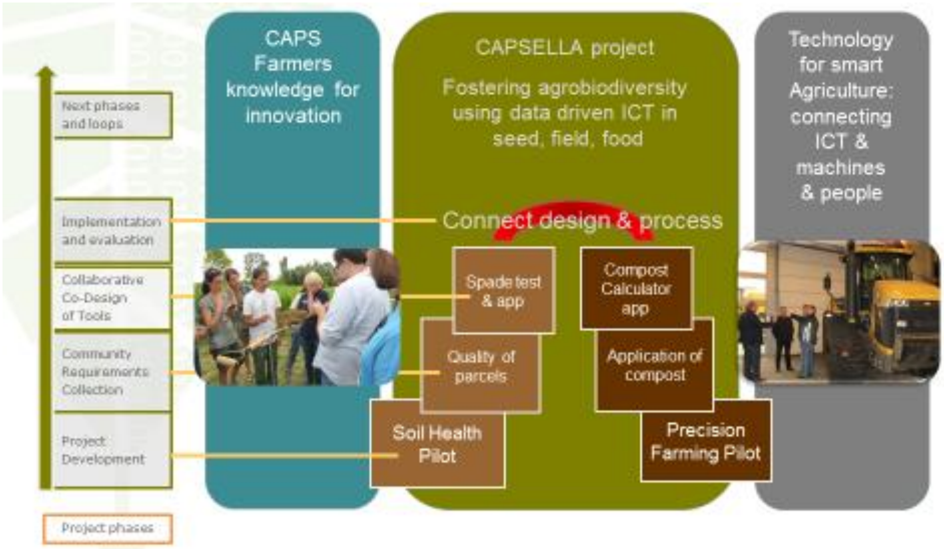

Figure 7. Schematic representation of how CAPSELLA contributes to the discussion about social innovation in CAPS (Collective Awareness Platforms for Sustainability and Social Innovation), open data infrastructures and technology for smart agriculture

In the case study presented we have farmer communities that are the epitome of the precision agriculture and smart farming, and others that implement only organic farming practices. We worked with farmers from Northern and Southern Europe. It was a major challenge for the project to bring these two worlds together. During the project, the differences between the two farmers' groups was evident. The power of high tech investments of big companies in the digitisation domain can conflict with the market position of smallholder farmers and as such with the general position of farmers about ICT tools' usefulness. Nevertheless, the project worked as an open space where the involved actors could realise a practical link between the ICT and agrobiodiversity management domains. In the precision farming community, the challenge was to make precision techniques profitable and accepted. In line with the goals of the project, for the assessment of soil quality, open data about it were unlocked for farmers and enriched with easy-to-do soil tests (spade test). At the same time, for high tech farmers soil quality was assessed by Electro Magnetic Conductivity soil scan.

Based on the aforementioned methods, a high tech tool has been developed for optimal compost use and to support soil fertility management. It has been enriched, made useful in more circumstances and made widely available with the integration of qualitative, farmer's lead methods. The two communities were encouraged to provide ideas about how to integrate and generalize the two tools combining the demonstrators. The flexible way of gathering data applied in the data platform, with diversified privacy and sharing schemes according to the type of data, helped farmers thrust, install, and use the demonstrators according to their local conditions. The ICT experts involved in the process became neutral actors linking the two communities. This has encouraged a holistic approach by both groups, rather than farmers keeping specialised roles according to the type of farming system they come from.

We therefore consider as a major success of our bottom up and participatory approach that both groups were satisfied by the demonstrator developed and they are now interested in the integration of the precision farming and the soil health pilot. A joint trial took place in the Netherlands, to check in practice the difficulties and opportunities of merging functionalities of both applications into a new, single one. The farmers in the meeting showed enthusiasm for the combination: it gives them an opportunity to turn their concerns into insights in the health of their soil and to use modern techniques to implement improvement measures. This new combined application cannot be developed in the lifetime of the current project, as resources and time are limited, but we expect the development will continue, because involved farmers are very much interested.

As described before, the communities determined the lines of pilot development, within the objectives and scenarios of the project. In the Soil Health Pilot, soil quality at field level was central; in the Compost in Precision Agriculture pilot, the application of compost was chosen. Both pilots actually focussed on improving quality of soil at field level, one looking at its spatial and the other at its temporal dimension. In the design and programming of tools, the Soil Health Pilot started with retrieving data on individual fields from open data, detailing them with observations (spade test) for specific fields. The Compost in Precision Agriculture pilot started from sensor data, combining them with open data like field boundaries, and introducing both in a calculating tool. Together, we realised tool prototypes that have similar functions and design. At the same time, we worked on the realisation of CAPSELLA ambition to share open data structures and interfaces and to promote their usefulness among farmers. In this way, connectivity between the precision compost calculator and soil health tool was relatively easy to accomplish. For the later loops in development, integration has concrete advantages: the open soil data and spade test are interesting additions to the Compost in Precision Agriculture pilot, and the calculating tool and other parcel data are interesting for the Soil Health pilot.

Our case study contributes to the current discussion on how public initiatives can enhance the positive exploitation of open data, when we are able to engage farmers in a practical way on a challenge that they identify as important. This means striving for data oriented tools that farmers can really use and appreciate. Because of this, from the start of the project, we asked farmers to collaborate in the collection of requirements, in the co-design and in the implementation/evaluation. The appreciation of the communities shows that our case study can be used as a practical proof of effectiveness of co-design processes both for avoiding uptake problems of ICT tools and for supporting collective awareness mediated innovation in biodiversity based agriculture. Looking at the process until the development phase, we can highlight a good integration among the stakeholders involved and a continuous interaction that is promising.

Conclusion

Organic farmers showed interest in ICT solutions supporting their activities. The co-creation project brought to the publication of an open access and open source tool that can be used by their associations as well as by other organic farmers. Precision agriculture farmers understood the need to integrate local knowledge with external information (e.g. coming from open data) and are already making use of the web-service deriving from the project. Information coming from open data in the CAPSELLA application is complementary to the existing knowledge and practices of the farmers and do not substitute farmers' decision-taking process. This information rather improves their decisions and empowers local knowledge with additional information coming from external sources. Cooperation with farmers, and efforts to use open data concretely with them in agriculture, brought tangible results and concrete ICT applications in our case. The positive experience of interaction with conventional and organic farmers at the same time enable us to propose the spreading of co-creation and innovation initiatives for linking professionals from ICT with diverse farmers' communities, to more effectively dialog and take actions on the agriculture sustainability challenges. The CAPSELLA project approach of co-creating innovation with the use of digital tools can be applied in other contexts and with other farmers' communities.

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