FARM: A Prototype DSS Tool for Agriculture

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***Abstract*—Agriculture is a field that needs to be supported by technological tools. Digitalization in agriculture is the future of farming, and such support is a vital component of economic, social and environmental sustainability. Digital tools can assist not only big farming ventures but also small companies or individuals. Decision Support Systems (DSS) aim to reinforce decision analysis and decision-making. Such tools can allow farmers to better monitor the health of their livestock and crops. In the Erasmus+ Project FARM, we investigated the needs, drafted the specification, and designed a DSS tool with the aim to help in achieving better efficiency and improving the quality of decision-making in agriculture. We present our methodology, including a questionnaire survey for collecting the requirements, creating the design of the system database and system architecture, and developing the prototype tool in two levels, i.e., low fidelity and high fidelity. We conclude with a discussion of the prototype validation.**

***Index Terms*—Decision Support Tool, Agriculture, Digitalization, Software Prototyping, Small and Local Farmers, Dashboard**

I. Introduction

Digitalization in agriculture is the future of farming [1], and as such, it needs to be supported by technological tools. The possibility to increase the level of information available to agriculture workers is directly linked to sectorial investments, economic and environmental efficiency and sustainability, food healthiness and safety, and the ability to compete in the international market area. Support for agriculture and rural development remains a vital component of economic, social and environmental sustainability. Based on [2], digital farming technologies are expected to help transform current agricultural systems towards sustainability. The sector of agriculture faces the challenge in terms of sustainable management of natural resources, depopulation and contributing towards economic development. Scientific development complements this challenge by focusing on knowledge sharing and fostering technology and innovations in agricultural development.

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There is a huge difference in European agriculture concerning technological development and organization. Especially Decision Support Systems (DSS) and their usage are not widely known throughout Europe. A DSS is an information system aiming to reinforce decision analysis and decision-making activities by collecting and analysing amounts of data and compiling comprehensive information that can be used to solve problems in decision-making. Such digital tools can assist not only big farming ventures but also small companies or individuals. Based on [3], technology may promise to improve the conditions for vulnerable farmers. DSS-based tools have the potential to allow farmers to better monitor the health of their livestock and crops, and as such is of great importance to support local and small producers with accessible DSS tools.

Considering this, the Erasmus+ FARM project was focused on innovative approaches to farming that took advantage of the new digital technologies based on synergies between information management and communication for development. In the context of this project, we investigated the needs, drafted the specification, and designed our own DSS tool prototype with the aim to help in achieving better efficiency and improving the quality of decision-making in agriculture with our focus on small and local producers and their needs. The prototype demonstrates all the important characteristics and functionality that can be included once the tool gets developed. It is essentially an operational model of the application system implementing certain aspects of the future system [4]. A full software design process was followed and completed, providing all details needed to enable the full development of the tool in an immediate next step.

With our DSS tool, we aim to support the local and small farmers by (i) collecting global information otherwise spread over the internet, such as weather data with different parameters like temperature and humidity, and plants information like the best weather condition, recommended watering and fertilisation frequency and more, (ii) enable farmers to record their activity log like date, time and frequency of actual watering and fertilising, or crops amount collected, (iii) combine and process the above data altogether to support them extract results and take decisions, (iv) provide them further information about plants that exist worldwide and the conditions to grow them, weather data in general, and more, (v) assists them by providing reminders and notifications for watering and fertilising based on their established schedule routine, or on recommendations from the global database.

In this paper, we present our tool by discussing the initial research and the mapping of EU DSS tools and then presenting the detailed development methodology that we followed and the prototype produced, as well as the prototype validation.

Methodology. A step-by-step methodology was followed to effectively design the DSS Tool, from recognising the user needs to developing the tool prototype. The Methodology is demonstrated in Figure 1. Our methodology included five

Fig. 1. DSS Tool Prototype Development Methodology

important steps. During the requirements step, a questionnaire survey was conducted to collect the user needs. Then, we drafted the specifications of the tools based mainly on the results from the requirements analysis. Subsequently, we continued with the design of the system database, flow, and architecture, the development of the prototype tool, and the validation of the prototype.

Structure. In the following sections, we explain in detail our methodology and present all the design elements and the developed prototype. We conclude with the results of the prototype validation.

II. Background & Related Tools

We conducted an in-depth search, discovering and collecting information about all the relevant practical tools or theoretical research works applying technology in the agriculture sector in all European Union (EU) countries. Such tools aim to help improve farmers' productivity, efficiency and profitability. Different information about the tools was documented, including the following fields: Title, Location, Developer, Goals, Target groups, Literature, Logo and Images. Furthermore, the question *"Where is it used?"* was answered for each related work in terms of Soil Management, Water Management, Climate Change, Economic Aspects, and other aspects.

After research, 194 DSS tools were mapped and presented in an interactive online dashboard[1]. Within the dashboard all the tools are demonstrated in different formats, including a GIS map. Then an online catalogue of the ICT and DSS tools was created by selecting the most applicable ICT-DSS tools from the dashboard collection and catalogizing them. The selection was made based on the standards and criteria obtained from the feedback of the survey prepared for this part and shared with the stakeholders. Thus, the catalogue represents a specific description, including empirical values from the selected examples preceded by an introduction on the topic with an elaborated methodology and literature review as well as an insightful description of the ICT-DSS tools and their appliance. The catalogue was published[2].

The tools recognised exploit different technologies, including, among others, Data Analytics, Data Science, the Internet of Things, and Robotics. Most tools are applied directly to the actual farming activities, like [5] where a general purpose mobile robotic platform is transformed into a semi-autonomous agricultural robot sprayer; or are theoretical research studies like [6] in which they estimate the adaptation cost of agriculture to climate change or [7] where they assess, in a holistic manner, the sustainability performance of different farming systems. A tool similar to ours is [6]. However, it functions with data imported from sensors applied in farming establishments, something that is not possible for small or individual local farmers. Our tool aims to assist small-sized and local farmers by providing all the needed information directly from external resources or by collecting it from the farmers without requiring expensive sensor equipment and sophisticated set-up. Other DSS tools currently in the market include Agroclimate [8], DSSAT [9], and FarmLogs [10].

III. User Requirements & App Specification

Questionnaire and results. As a first step, we prepared and distributed a questionnaire to collect the user requirements and needs. The questionnaire consisted of demographic questions, as well as questions about the tools' desired functionality and content. The complete questionnaire can be found as a pdf [3]. It was handed out by project partners to stakeholders in the Agricultural sector in Germany, Spain, Lithuania, Cyprus and the Republic of North Macedonia. 32 responses were collected. Figure 2 shows an example question and the collected responses. After collecting the responses, we conducted quantitative and qualitative analysis. Based on the results, we were able to draft a user persona and decide on a broad set of decisions to be supported by the tool.

User persona. Our typical user is a small farmer. A persona of the system is George, a small farmer living in a rural village in Italy. George grows a variety of crops, such as olives, tomatoes, and wheat, on his small farm. He faces challenges such as unpredictable weather patterns, limited water resources, and the need to maximize yields and profits with limited resources. He also has difficulty locating the most relevant information about the plants he grows and combining them in a way that would be most useful.

[1]https://hsharzgeo.maps.arcgis.com/apps /dashboards/923e875221154c218a0c9f0e9a5fe22e

[2]http://dx.doi.org/10.25673/101259

[3]https://drive.google.com/file/d/1g28mHC4MCFal5g54kZxl7-CGVxjDoWBB

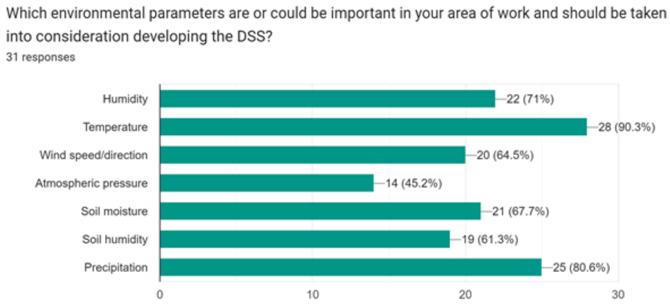

Fig. 2. Question for the content of the tools

George is looking for a DSS tool to help him make informed decisions about the frequency and the type of fertilizer and how to optimize his farming environment (soil, watering, etc.). He needs a DSS tool to provide him with real-time information on rainfall, temperature, and wind, and to also help him manage his farm more efficiently, as well as to improve his chances of success by enabling him to save information for each of his plants and his farming actions. George needs to be presented with different kinds of data combinations to understand in detail how all the information he added in the DSS, combined with weather information and information about the plants, can be helpful for him.

Based on the above, we conclude, that the tool needs to (i) collect data from users about their farming habits and actions; (ii) collect data from external resources like a weather Application Programming Interface (API) and a global plants Database (DB).

Decisions To Support. Graphs will be the main tool to support the user in decision-making. Graphs can be a crucial tool for farmers as they visualise and analyse complex data clearly and concisely. Farmers can use graphs to monitor various factors in their farming operations, including soil moisture, rainfall, temperature, and crop growth. With the help of such graphs, farmers can make informed decisions and appropriate changes to improve productivity and optimise their farming techniques by examining the graphs' data. Graphs can also provide a historical perspective, allowing farmers to compare current data to previous years' data and find trends or anomalies that must be addressed. Overall, graphs are an important tool for farmers to use to assist them in managing their farming operations more efficiently, boosting profitability, and raising their chances of success. Different graph combinations are possible from the collected data from the farmer and the data from the connected external resources, while also generating and presenting important points such as average values. We decided on a set of parameters for X-Axis and Y-Axis, out of which the user will be able to choose and overlay. The parameters are:

1) X-Axis: Date; Temperature; Crops; Water; Soil.
2) Y-Axis: Crops; Water; Soil.

Some example decisions that will be supported by the above are:

- Based on weather data, for example, average temperatures, and crop collection data, which is the best season to grow specific trees?
- What is the optimal frequency of applying fertilisation on plants?
- How much water does each plant need? In what frequency?
- What is the estimated crop quantity for the season for each plant?

Based on all of the above, we concluded on the tool specifications, i.e., a list of functionalities to be developed, and we were able to proceed with the design.

IV. Tool Design & Prototyping

A. DSS Tool Design

Figure 3 demonstrates the overall system architecture. The prototype DSS tool was designed as a plugin for Wordpress-based web platforms. However, the tool can be re-designed to be suitable for integration into other kinds of platforms, in a straightforward manner. With the WordPress CMS (Content Management System), a User Accounts Management plugin will be integrated to take care of the user account-related functionality, such as registration, login and GDPR user rights. There will also be a weather API and a global plants DB both feeding the WordPress CMS environment with data. Then, all the main functionalities of the tool will be developed as a separate plugin, interconnected to the basic environment.

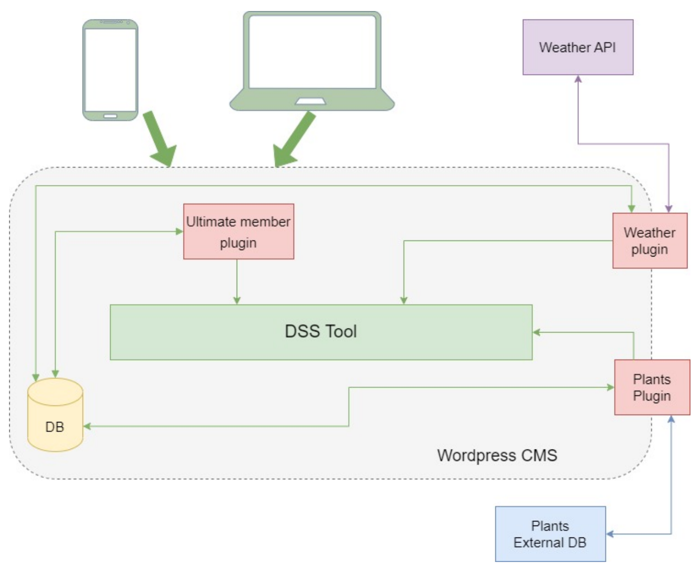

Fig. 3. System Architecture

All plugins and APIs will be connected to the tool's database. The database besides standard WordPress tables and tables used by the User Account Management plugin, will also include those of the designed DSS tool. We have designed the complete DB schema needed for this tool to function when developed into a full version.

The platform will work in direct interaction with the database from which it will request data through queries and receive back results to process and present to the farmer. The system will also interact with the weather API to make it possible for the farmer to see the weather data for the next seven days and also any predictions of very high or low temperatures, rain or snow, etc. Communication with the plants' information from the global DB will also be vital, for example in order to decide if current temperatures affect some plants and inform the farmer.

The DSS tool will be developed using web technologies, i.e. HTML, PHP, JavaScript and CSS. A search for Weather APIs and Global Plants DBs was conducted, and the results are demonstrated in an external pdf file [4].

B. DSS Tool Prototyping

As explained before, prototypes are draft versions of the product, enabling users to explore the features that the final product will have. By default, a tool prototype and a tool design are flexible enough, allowing future development in different platforms, incorporating different material or data, connecting to different resources, e.g. databases, and subsequently, integration of the respective tool in different environments, providing transferability. Prototypes can range from paper drawings (i.e. low-fidelity) to ones that allow users to interact by clicking or using some features (i.e. high-fidelity). We implemented both. We now present the developed prototypes.

Low-Fidelity Prototypes. The Low-Fidelity Prototypes were hand-drawn using a tablet and a stylus. Low-fidelity prototypes are also known as throw-away prototypes, so we did not use any specific tools. Low-fidelity prototypes show the basic features of each screen without describing any functionality. Figure 4 shows an example screen of the low-fidelity prototype, i.e., the user dashboard.

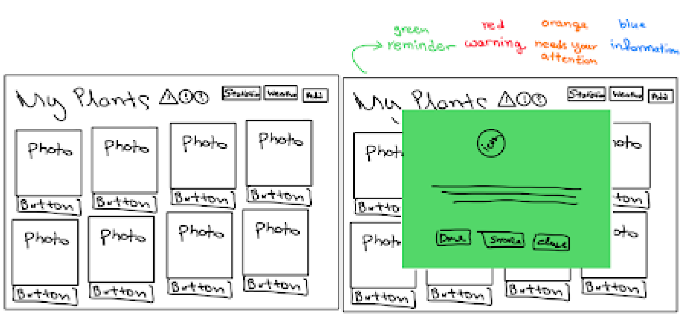

Fig. 4. Low-Fidelity Prototype User Dashboard

High-Fidelity Prototypes. High-fidelity prototypes can be implemented either horizontally or vertically. We did horizontal prototyping, implementing the interface for all the screens of the tool without them being fully functional. However, all planned functionality is demonstrated. The Prototypes were created by using proto.io, a tool for creating interactive prototypes. The main goal while designing the prototypes was a clear and easy user interface since our target group is small farmers. The functionalities that were designed on the prototypes are:

1) User dashboard: As shown in Figure 5, through the user dashboard the users can see all their plants and more information about each one as well as general notifications. There are three types of notifications: warnings, reminders and information. The users can also add more plants and see the weather from the dashboard.

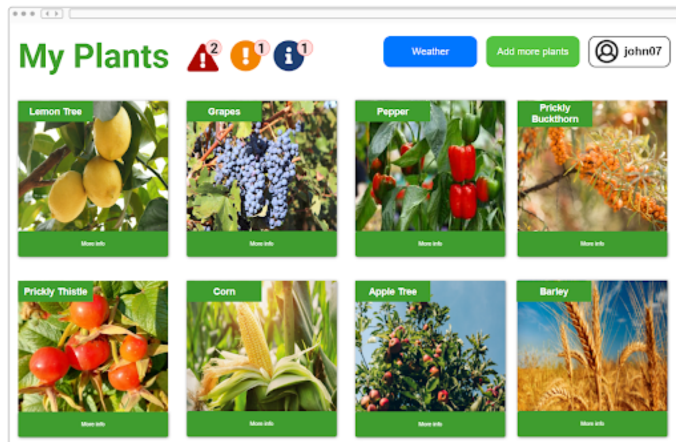

Fig. 5. High-Fidelity Prototype User Dashboard

2) Add more plants: Figure 6 shows that the users have the ability to add more plants on their dashboard. The tool provides a small description of each available plant as well as a more detailed one for the users to decide which plant they want to add to their dashboard. There are three ways of searching among the available plants: (i) search by typing the name of the desired plant; (ii) search by ticking one or more of the following group of plants: Trees, Flowers and Herbs; (iii) advanced search. On advanced search, there is a possibility of adding the type, humidity and PH of soil as well as climate and season.

3) Weather: The users can see the weather forecast. This functionality helps the farmers to estimate and prepare properly for their plants.

4) More information about each plant: The users can read a detailed description of each plant along with information about watering, fertilising, plant diseases, climate and soil.

5) Set reminders of individual plants: The users can add reminders about watering and fertilising their plants. These include adding date, time and possible reminder repetition.

6) Add information about individual plants: There is a possibility for the users to add information about the date and quantity in litres each time they water their plants, the date and type of fertiliser, the date and kilograms of crop collections, and dates of pruning and soil changes/additions.

[4]https://drive.google.com/file/d/1UkhByZ5Qi8HJUxPbPqePptoaQktdHr5d

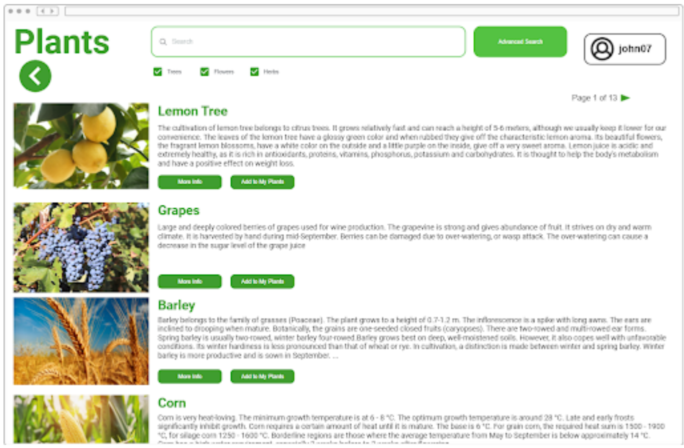

Fig. 6. High-Fidelity Prototype Add More Plants

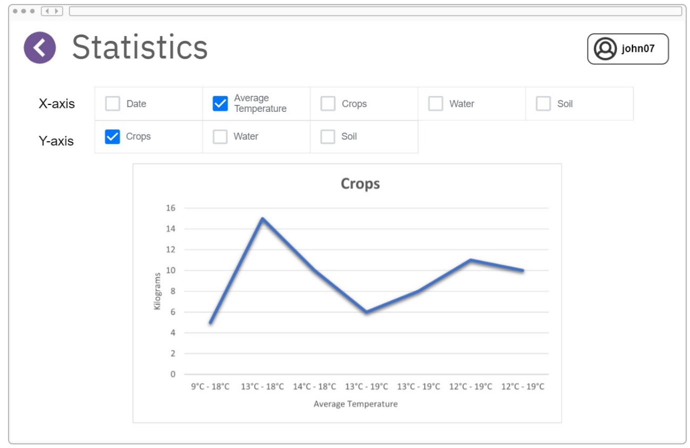

Fig. 7. Graph showing watering and crops over time

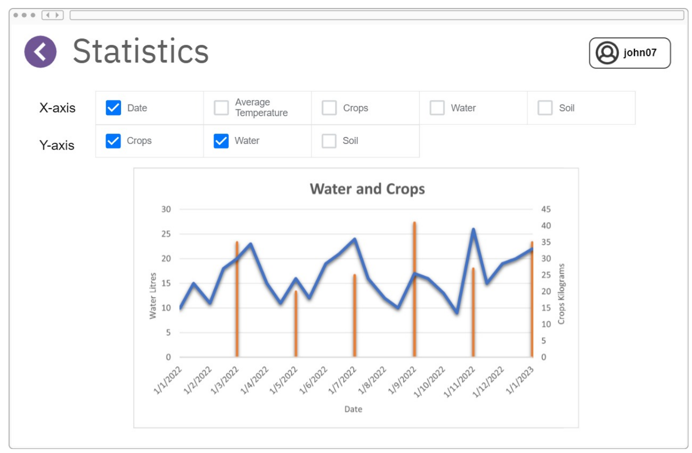

Fig. 8. Graph showing crops on average temperatures

7) History of individual plants: Each plant has its own historical data of watering, fertilising, crop collection, pruning and soil. Each input includes the date and time of the event along with some extra information - litres of water, type of fertiliser etc.

8) Statistics: This is the most important functionality, with which the users can see combined data about their plants in the form of graphs. As we previously explained the tool will have a connection with a weather API so we have information about the weather for the past, present and near future, and with a plants DB, as such having information about the plants required watering, fertilisation and so on. These comprise the first source of information. Additionally, there are specific screens on the tool where the farmers can add information about the watering of each plant, the fertilization, the crop collection, the pruning and the soil. This is the second source of information. For watering, the tool asks how many litres of water the farmer used and the date and time of the watering. For fertilisation, the tool also asks the type of fertilisation used so that later on, the farmer can compare the different types of fertilisation. Some examples of graphs can be crops over time, crops at different temperatures etc. The user selects the parameters to be included in X-Axis and in Y-Axis. The graph on Figure 7 presents how many kilograms of crops were collected at different average temperatures. Another example of a graph is shown in Figure 8, where the users can see their history of watering on different months together with the kilograms of crops they collected on specific dates. This graph will help the farmers to locate the optimal pattern of watering in order to have the largest crop collection. As stated before, these graphs help in decision-making.

Further to the above, we have provisioned for responsive design of the tool, and we have designed as well all the screens adjusted to mobile phones. Figure 9 shows the dashboard mobile design.

V. Validation

After the prototype development, an evaluation was conducted with users. A task-oriented evaluation questionnaire was used where users were asked to follow specific steps and, by using the prototype, fulfil certain tasks and then respond to questions. The steps included using the prototype to accomplish tasks such as:

> *"Add a new plant to your collection of plants" by following the instructions below: 1) From the main screen, try to add a new plant to your collection of plants. 2) Get more information about any of the available plants. 3) Search for "lemon" to see the different types of lemon plants. . .*

After finishing the tasks, participants were asked to answer the evaluation questionnaire. The first section of the questionnaire consisted of five demographic questions. Then, the following two sections included questions from the Technology Acceptance Model - TAM satisfaction questionnaire [11], as well as questions from the User Experience Questionnaire - UEQ [12]. Questions related to TAM (7-point Likert scale) aim to observe how acceptable the technology is to users. It includes questions for perceived usefulness and perceived ease of use. Perceived usefulness is defined as the tendency of users to use or not use an application to the extent they believe it

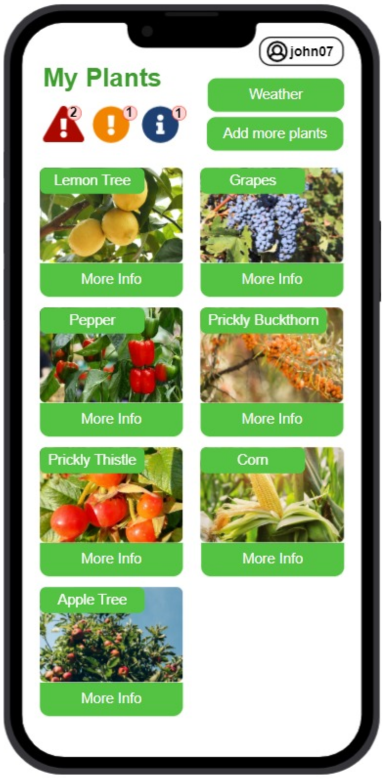

Fig. 9. High-Fidelity Prototype User Dashboard on Mobile Screen

will help them perform their job better, while perceived ease of use refers to whether the application is easy or hard to use.

The UEQ was developed by usability experts with the aim of evaluating user experience and usability with products (i.e. software products). It allows users to quickly assess their interaction with the product, as well as their experience with it. UEQ includes usability aspects, as well as aspects related to effectiveness and efficiency. The questionnaire included all 26 questions of the UEQ.

In terms of the results, 7 participants responded to the evaluation questionnaire. All participants answered that using these tools would enable them to accomplish agricultural tasks more quickly, and most participants (85.7%) that it would improve their performance in doing so. The majority also responded that these tools would enhance their effectiveness (71.4%) and it would make it easier for them to accomplish their agricultural tasks (85.7%). All but one participant stated that it would be more difficult to accomplish their agricultural task without the use of the tools, while another one thought it would not make any difference. All participants found the prototypes, and therefore the potential tool to be easy to use, clear and understandable.

In terms of the UEQ, the scales of the questionnaire cover both classical usability aspects (efficiency, perspicuity, dependability) and user experience aspects (originality, stimulation). From Figure 10 it is observed that in all categories, our tools were above average and, most times, good or excellent.

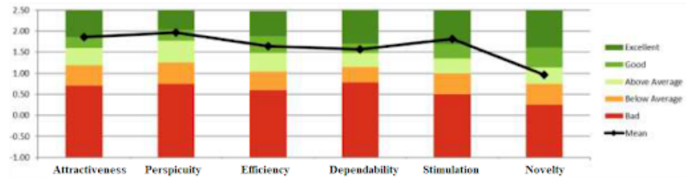

Fig. 10. UEQ Results

VI. Summary

In this paper, we have presented the prototype DSS tool for small and local farmers that we have developed through a user-centred methodology. The tool does not require sophisticated equipment or set-ups to collect data, like other similar ones. In future work, we plan to do a more extensive tool validation and mainly to develop the tool into a fully-functional version.

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