Evaluation of the performance of the Soil Quality APP (SQAPP) for the greater Albaida region

iSQAPER Interactive Soil Quality Assessment

TEMPR

WAGENINGEN UNIVERSITY & RESEARCH

Evaluation of the performance of the Soil Quality APP (SQAPP) for the greater Albaida region

Team 113

TEMPR
Pim van den Berg
Cleveland Rex Steward
Marti Vidal Morant
Emily Ongus
Thijs van der Zaan

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Final Report

Authors
P. van den Berg, C.R. Steward, M. Vidal Morant, E. Ongus, T. van der Zaan

Commissioner
Prof. Dr. C.J. Ritsema.

Supervisors
Dr. Ir. L. Fleskens
D. Stoltenborg MSc

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This report has been produced by students of Wageningen University and Research as part of their MSc programme.

Foreword

This report is the outcome of a commissioned study under the EU Horizon 2020 iSQAPER project. The report is a pilot study of the Soil Quality App (SQAPP) tested in the greater Albaida region located in the Valencia and Alicante provinces, SE Spain. SQAPP provides information on the soil quality status in relation to the soil threats and provides recommendations for remediation or improvement. The following study evaluates app performance and ultimately delineates clear, actionable recommendations for improvement.

Acknowledgments

The report has been made possible with the guidance of the Soil Physics and Land Management Group of Wageningen University and Research. We would like to thank Prof. Coen Ritsema for making this project possible. Furthermore, we would like to assert our gratitude towards Didi Stoltenborg and Luuk Fleskens for supervising us and Bert Bruins for coaching us. Colleagues from Universidad Miguel Hernández de Elche (UMH); Jorge Mataix and Vicky Arcenegui for providing us with valuable lab data from their own assessment. Finally, we would like to thank Maria Jesus Morant Pineda for putting us in contact with many farmers and all the farmers that participated in the research.

1 - Introduction

1.1 - Background

Unsustainable use of agricultural areas causes soil degradation (Oldeman et al., 1991). Degraded soils are more prone to soil threats which can result in a vicious circle of soil degradation. For the European continent there are several soil threats identified; the main ones include soil organic matter decline, soil compaction, soil erosion, soil salinization, pollution, sealing and landslides (Van Beek et al., 2010). These threats have been an increasing concern in the European Union (EU) (Glæsner et al., 2014; Montanarella, 2007) with several soil protection strategies as a response, e.g. EU Common Agricultural Policy (Bowyer & Keenleyside, 2017). However, the impact of such strategies remains debatable (Glæsner et al., 2014). Soil degradation together with climate change (Olesen & Bindi, 2002), a growing demand for food due to a growing population (Godfray et al., 2010), and an increase in meat consumption due to a changing diet (Popp et al., 2010) puts heightened pressure on agricultural productivity. This pressure on agricultural land and the ineffectiveness of current European policies calls for new or revised strategies related to land management to reach a more sustainable use of soils.

To reach a more sustainable use of agricultural soils in Europe, the European Union, the Chinese government and the Swiss government, funded the iSQAPER project as part of the European Union Horizon 2020 programme for research and innovation. iSQAPER has been initiated by several European and Chinese organisations. The project is being coordinated by the Soil Physics and Land Management (SLM) Group of Wageningen University. The project's core mission is the protection and promotion of soil quality to ensure sustainable agricultural productivity. In support of this ideology, the main objective of iSQAPER is to provide an "interactive soil quality assessment in Europe and China for agricultural productivity and environmental resilience providing decision makers with science-based, easy to apply and cost-effective tools to manage soil quality and function" (iSQAPER information system, n.d.).

ISQAPER wants to achieve this objective by integrating existing soil quality data into an open access information system in the form of a mobile app, the Soil Quality Assessment Application (SQAPP). Currently SQAPP is still in its beta. SQAPP provides users with soil quality information anywhere in the world using data aggregated from several global datasets, primarily from ISRIC's Soilgrids (ISRIC, n.d.). The provided data consists of a range of physical and chemical soil quality indicators and associated soil threats. Additionally, the app provides management advice based on the aforementioned data and field characteristics. The expectation is that farmers can act on this knowledge to manage their soils more sustainably. Furthermore, it could inform policy makers about regionally specific soil threats and protection measures and therefore aid in the formation of soil protection legislation. This will lead to an overall higher quality of soils that are less susceptible to soil threats and ensure longevity of the agricultural systems that depend on them.

1.2 - Study objectives

This study was commissioned by Coen Ritsema, chair of the SLM department and head of the Wageningen team responsible for SQAPP development and project management of the overall iSQAPER project. The commissioner stressed the need for a multi-actor approach in the development of SQAPP whereby farmers, scientists, practitioners, agricultural service providers and policy makers play a role in testing, evaluating, and improving the app. It was made clear that SQAPP has not been thoroughly tested in its current level of development, especially by the primary end-users envisioned: farmers themselves.
In meetings with the commissioner, a need for further verification of the global data used by the app was expressed, as was the necessity for direct farmer feedback on the usefulness and impact of the app and the information it contains. The opportunity was thus presented to explore what other information may be incorporated to better match the needs and interests of such end-users. Interest was also shown into seeing how different farmers from varying backgrounds and sectors of agriculture interpret the potential of such tool.

Based on the above points of discussion, the main issue that was identified was the lack of information on the performance and impressions of the app. The objective of our study was thus identified: to gain information on the accuracy of soil quality data, relevance of the information provided to the farmers, and overall practical functionality of the app.

1.3 - Study area

The study area is located in the region around Albaida, consisting of the South-West of the Valencia province and the Alicante province, as shown in Figure 1. This region lies in the Mediterranean climate zone. The climate zone combined with the soil types forms pedoclimatic zones (iSQAPER information system, n.d. & Toth et al., 2017). Most of the times during the summer, between June and September, there is a dry period that usually lasts 3 – 5 months. Contrary to the summer, the winter is characterized by intense rainfall events and contributes to a yearly precipitation of 300 – 500 mm (García-Orenes et al., 2009).

Figure 1: Study area of the research

The most common crops in the study area are citrus plantations, rain fed olive, vineyards, fruit and cereals (ISQAPER, n.d., a). The traditional agricultural practices entail intensive tilling and the use of inorganic fertilizers. Because of water scarcity, wastewater and salty water is often used for irrigation, locally leading to the loss of soil structure and aquifer contamination (Pedro-Monzonís et al., 2015). Recently, however, organic farming systems have been introduced, which use leguminous species that provide soil cover and animal manure to improve the quality of the soil. These soils are mainly developed on calcareous materials and on quaternary sediments (ISQAPER, n.d., a). Unsuitable land management practices and the highly irregular and occasional intensive rainfall can lead to increased rates of soil erosion and land degradation processes, leading to reduced soil fertility. Furthermore, soils in the project area generally have poor soil structure and low organic content (ISQAPER, n.d., a).

1.4 - Soil Quality APP (SQAPP)

There is a wealth of global soil information available and even a number of apps aimed at making this data more accessible to landowners and the general public. One of the most comprehensive is the “SoilInfo” app by ISRIC which makes use of many of the same databases to provide soil quality indicators and inform users of the properties of their soil (Hengl & Mendes de Jesus, 2015). SQAPP aims to expand upon the offerings of such tools by better tailoring information to specific decision-makers. It seeks to accomplish this by benchmarking soil quality in relation to farming systems and pedo-climatic conditions, linking soil quality to soil threats, and providing management advice on how to improve soil quality (iSQAPER information system, n.d.).

SQAPP pulls data from global datasets, with a resolution of 250m, based on the input location of the user. This data consists of information on the chemical, physical and biological soil properties. The soil threats are defined through existing soil threat datasets that have been altered based on the local conditions, e.g. slope, rainfall and land use. The app then provides recommendations, or agricultural management practices (AMPs) to improve the properties and threats that score the worst, while taking the local characteristics into account. A more detailed explanation of app processes is provided in annex B.

1.5 - Research questions

In response to the aforementioned issues, team TEMPR (Annex A) addresses the following research question and sub-questions:

How can the Soil Quality App (SQAPP) be improved based on its performance in the Albaida region, SE Spain?

Sub-questions:

- How accurate is the data provided by the app compared to data acquired through field measurement and lab analysis, for the greater Albaida region?
- How relevant is the information provided by the app to end-users in the region?
- How functional is the app as a tool for conveying information to local farmers?

2 - Core Concepts and Approach

2.1 - Soil quality

Soil quality has been a debated concept since its first utilisation in 1971 (Mausel, 1971). A recently published review (Bünemann et al., 2018) depicted the main arguments and struggles to consensuate a definition. A generally used definition of soil quality refers to it as "the capacity of a soil to function within ecosystem and land-use boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health" (Doran and Parkin, 1994).

Soil quality is often assessed by the evaluation of a set of indicators. Since a single indicator cannot predict soil quality, a combination of those are usually selected aiming to describe different soil properties. Generally, the inclusion of a minimum set of indicators referring to soil physical, chemical and biological properties is considered essential. However, one must take into account the existing trade-off between complexity and accuracy: including too many indicators can restrict the aggregation of an overall soil quality index (Bünemann et al., 2018). A solid body of indicators describing the three groups of soil properties should be the aim to describe soil quality.

The materialisation of the soil quality concept into indexed values is a complex subject. Here, the benchmarking of what is an adequate or acceptable score for an indicator or index becomes more subjective. Finding a reference soil with optimum indicator values is not always possible, since soil properties are determined by the soil type and local climatic conditions. In their review, Bünemann et al. (2018) state that very often native undisturbed soils, selected as reference, may not always score better for certain indicators on agricultural productivity or environmental performance. Additionally, what may seem as optimal according to expert opinion, may not be for farmers or other land users (Andrews et al. 2003). Experts, decision makers, and land users may not have the same requirements for soil quality indices, and divergent understandings of its meaning and relevance may further entangle the standardisation of a common assessment procedure.

The app summarizes output into biological, chemical and physical properties as indicators of soil quality. It then translates these information into soil parameters and threat levels needing attention and provides recommendations. This was highlighted in our analyses of relevance , this is further elaborated in our results and discussion.

2.2 - Accuracy, Relevance and Functionality

Our analysis of app performance is focused on the accuracy and relevance of the information provided, as well as its functionality as a tool in the hands of end-users.

Accuracy

Accuracy as a concept can be defined as the difference between the estimated value and the true value. In order to determine accuracy, quantitative measurements of data are necessary. This is expressed by knowing or estimating the actual (true) value , (Walther and Moore, 2005). As such, the accuracy in this case can refer to the ability of the app to report information to the best estimation of the true value. This was done by checking on the accuracy of the app output using our VSA.

Relevance
The relevance of the information provided by the app can be analysed using the concept of actionable knowledge as stated by Cash et al. (2003): “Science and technology must play a role in sustainable development whilst effectively managing the boundaries between knowledge and action in ways that simultaneously enhance salience, credibility and legitimacy of the information produced”. Actionable Knowledge as a concept defines the boundaries of stakeholder participation in the decision making process and fostering solutions together (Geertsema et al., 2018).
The concept of actionable knowledge will be channeled into our study’s investigation of relevance. Relevance, in the context of this study, is used to describe the meaningfulness of the information provided by the app and subsequent action through adjustments in management practices by the end-users. This was tested via communication of the recommendations to the farmers during farmer interviews. We also assessed the recommendations provided based on various levels of suitability to the specific farmers’ context.This is further highlighted in the results and discussion sections.

Functionality
Functionality, in the present assessment, can be defined as the effectiveness of the app as a medium, the accessibility of the language used, and the usability of the tool. Within the concept of usability, Iwarsson and Ståhl (2003) suggest four components that need to be satisfied: a personal component related to human functioning, an environmental component related to barriers within the environment that may inhibit action, an activity component related to the activities that need to be performed, and, finally, an analysis of the three aforementioned parts ensuring individual and group preferences are met within the targeted environment. That means, that the functionality of the app is not only limited by the design of the interface, but it also encompasses the socio-environmental context in which the user is placed, as well as the individual attitude towards the technology.

2.3 - Approach

In seeking to understand the accuracy and relevance of the app, our study assesses how soil properties, threats, and suitable management practices are uniquely interpreted and reported by the application, by field measurements and observations, and by farmers and landowners themselves. The diagram below illustrates the categorical information sought from these three distinct sources, forming the core of our study:

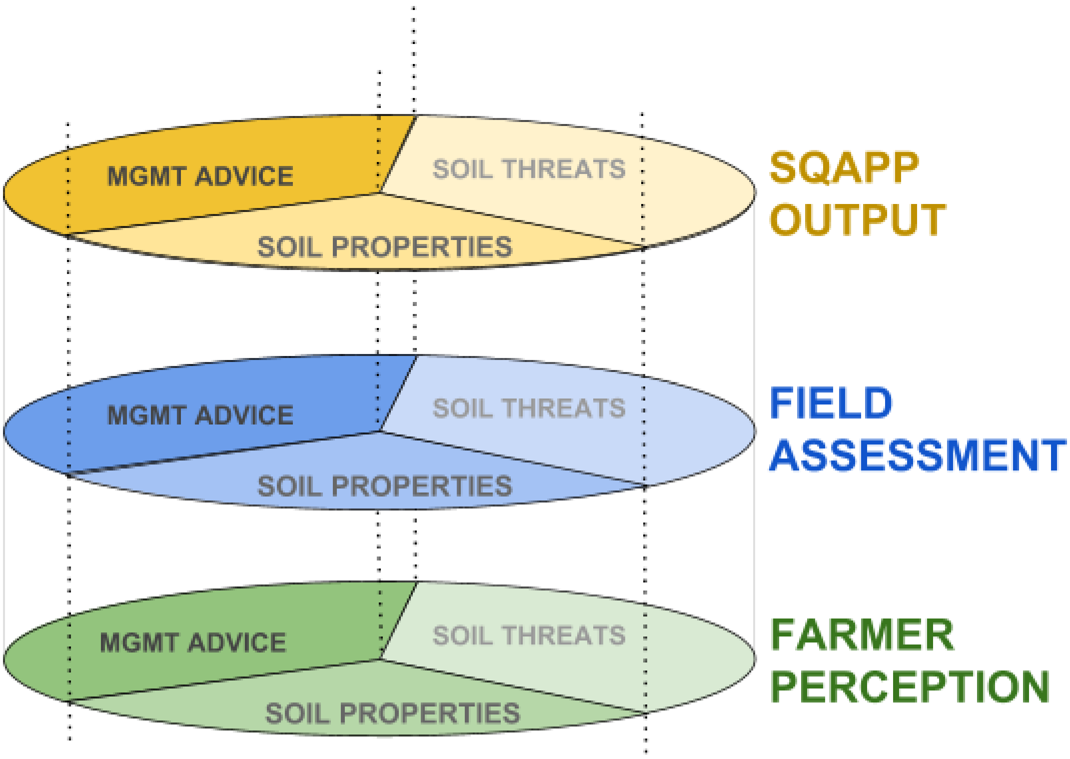

Figure 2: Categories of information sought from three key sources (SQAPP, field assessment, and farmer perception)

The differences in how this information is interpreted at each level (SQAPP, scientific analysis, and farmer perception) is central to understanding the accuracy and relevance of the app - concepts which are defined above. As the app was designed to close the gap between scientific data and end users, the practical functionality of the app as a tool toward conveying this information and achieving this goal will also be assessed.

3 - Materials and Methods

To assess the accuracy, relevance and functionality of SQAPP local information had to be compared to the app's predictions. Since the accessibility of existing field data is limited, field visits were conducted in the Albaida region. During the field visits the app was run for that location, soil measurements were taken, and the landowners were interviewed.

3.1 - Accuracy of reported soil data and threats

The first objective of the study was to assess the accuracy of soil quality parameter and soil threat information provided by the app. The information targeted by this portion of the study is illustrated in Figure 3 below:

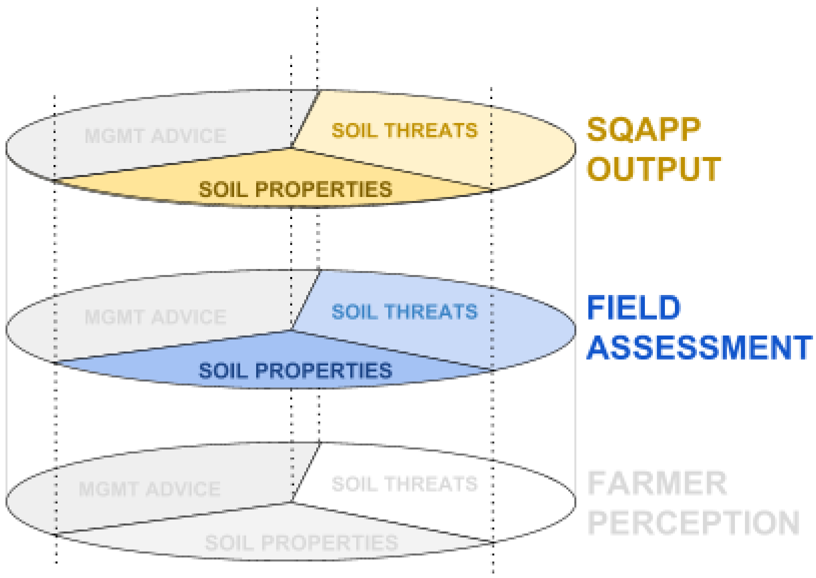

Figure 3: Information targeted in accuracy assessment (in colour)

Visual Soil Assessment (VSA)

Since we did not have a laboratory at our disposal we performed in-field soil measurements using a Visual Soil Assessment tool (VSA) as described by ISQAPER (Alaoui & Schwilch, 2016) to assess soil quality. The app provides a sizeable list of soil properties and threats as shown in Annex B. With our VSA we were able to assess a handful of these through direct measurements and some indirectly via empirical relationships. The properties and threats we were able to assess in this fashion were bulk density, texture, percentage coarse fragments, pH, electrical conductivity, water erosion and wind erosion. All the properties and threats assessed with the VSA are listed below. A detailed description of our method for data collection for every single property and our sampling method is provided in annex C. Critically, we first validated our VSA by comparing it to lab data provided by Universidad Miguel Hernández or obtained from farmer cooperatives. This VSA validation is not a result of our study, but is a necessary step to legitimise using our field assessment to judge the app's accuracy. See annex F for a table of visited farm sites - those used for validation are clearly delineated therein.

List of indicators assessed in VSA:

- Bulk density - Silt content - Sand content
- Clay content - Course fragments - pH
- Electrical conductivity - Compaction - Water erosion
- Wind erosion - Acidification - Salinization

Lab data

Due to limitations in scope and extent of our VSA data, we sought additional soil data in the form of laboratory soil analyses. Data for 6 farm plots was acquired from Universidad Miguel Hernández (UMH). Their dataset included information on nitrogen, phosphorus, organic matter, pH and electrical conductivity.

Laboratory soil data was also obtained by contacting individual farmers and farmer cooperatives. A consultant in Villanueva de Castellón, for example, was willing to share lab data for 2 plots. The scopes of these lab studies varied and only partially aligned with parameters highlighted in the app. As with our VSA data, our assessment of accuracy was therefore limited to those parameters shared by both the lab reports and the app. The locations of the acquired lab data and VSA measurements are mapped in figure 4. Below is a list of VSA properties that we were able to validate using lab data.

- Silt content
- Sand content
- Clay content
- Electrical conductivity
- pH

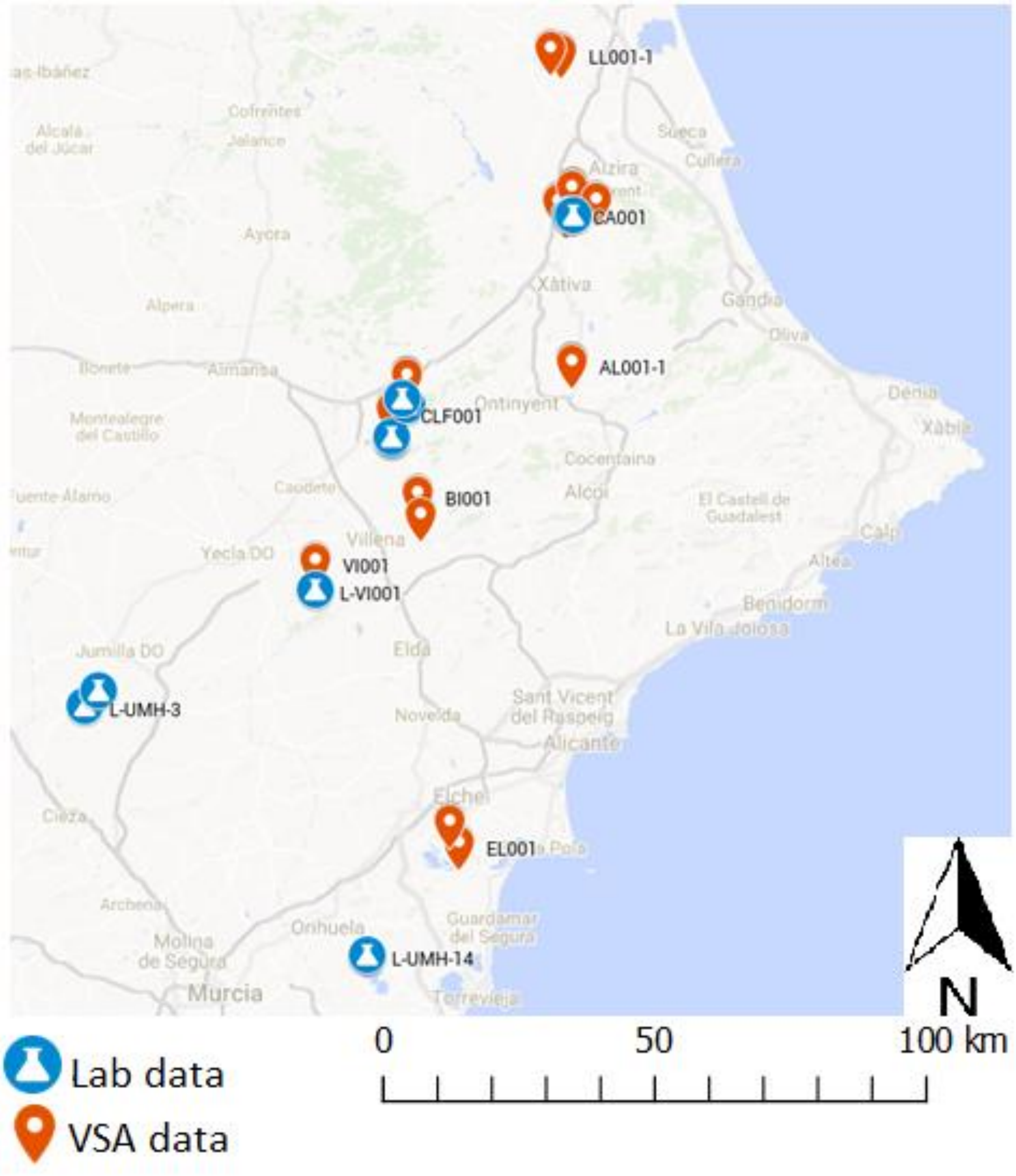

Figure 4: Locations of gathered VSA data (orange pins) and lab data (blue circles)

App runs: properties & threats

The above collected data were compared to the soil properties and threats provided by the app to determine the accuracy of the app data. Lab data were prioritised over VSA data in this process when multiple values were available.

To assess the accuracy of the app data, we consider the average difference between the app's prediction and measured data or lab data. The standard deviation of differences between the app's prediction and measured data has additionally been determined. For most indicators, we simply calculate the absolute difference between lab/VSA and the app's predictions. However, since the absolute differences in nutrient availability of the soil are generally very small, percent (relative) difference gives a better impression of the magnitude.

In formula:

$$Average\ Difference\ = \frac{L-A}{L} \times 100\%,$$

Where L is lab/vsa data and A represents the app's predicted value.

Soil threats, on the other hand, are classified based on the level of the threat, which, for most threats, relates to certain soil quality indicators. The app has a classification system to determine whether a threat is low, moderate or high. To assess the accuracy of this classification, we subject our VSA/lab data to the app's classification system, and check whether the threat level is the same as predicted by the app. The overall score of all samples show us how accurate the app predicts soil threats. To identify the threat level of erosion by wind and water, we use alternative methods, proposed by Stocking (2013) and University of Hertforshire (2011) respectively. Due to time and material limitations, we were unable to assess app performance when predicting organic matter decline, nutrient depletion, contamination, and biodiversity decline.

3.2 - Relevance of app content

Relevance of app content to farmers in the region was explored using two distinct strategies: First, per app run, an assessment of the recommended agricultural management practices (AMPs), were reviewed for suitability and feasibility using an elimination method. The second means of assessing relevance was carried out by conducting semi-structured interviews and characterizing and comparing farmer interpretation of soil quality, soil threats, and management as well as seeking direct feedback on app output for their land.

3.2.1 - Contextual assessment of summary and management advice

Management recommendations provided by the app were critically assessed for all sites visited by the project team. We assessed the different recommendations using an elimination method into 3 different levels to find the most relevant AMPs for our study area. First, the recommended practices were assessed based solely on field characteristics without regard to farm-specific context. In doing so, the applicability matrix used by the app in assigning recommendations is tested. Second, farm characteristics were taken into account and physical suitability of the recommendations are assessed based on specific farm context. For example, the current irrigation and conservation practices are taken into account. Last,the recommended practices were assessed on their ability to improve the soil properties and remediate the soil threats given in the summary of the app, this was done alongside the cropping system of the specific sites. This assessment was based on our expert view and literature. The knowledge targeted via this methodology is represented by the following portions of our diagrammatic framework:

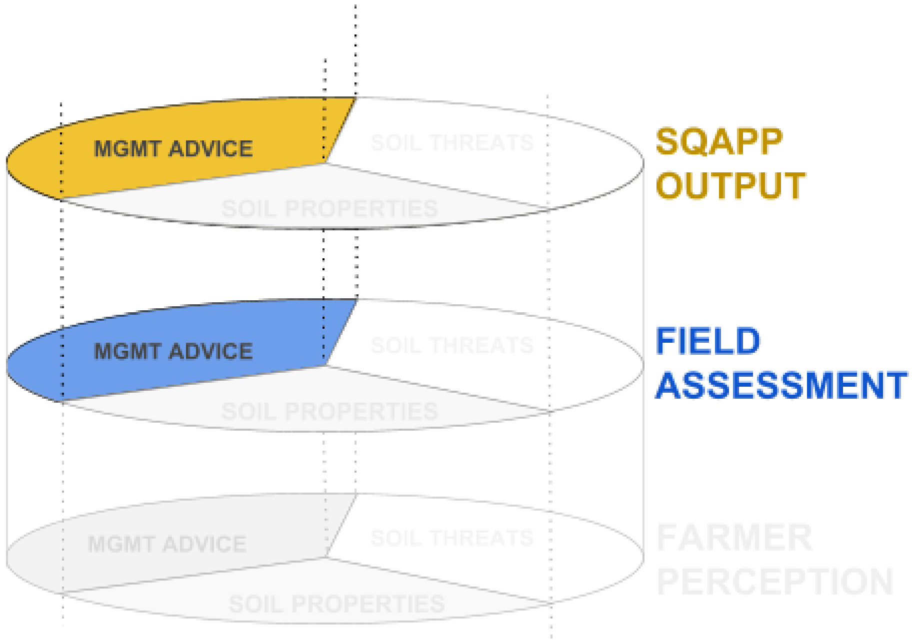

Figure 5: Information targeted in contextual assessment of summary/management advice

3.2.2 - Semi-structured Interviews

The second part of the assessment of the relevance of app content was carried out by holding 12 semi-structured interviews. The purpose of the interview is to gather information on the opinion of the farmers on soil properties and threats of their field. Furthermore, information about the management practices is gathered. This information was first recorded and then the results of the app were discussed. The opinion of the farmers on the given values for the soil properties and soil threats were recorded. After that the app's proposed recommendations and the general idea of a soil quality app were discussed. This information is represented in figure 6 below:

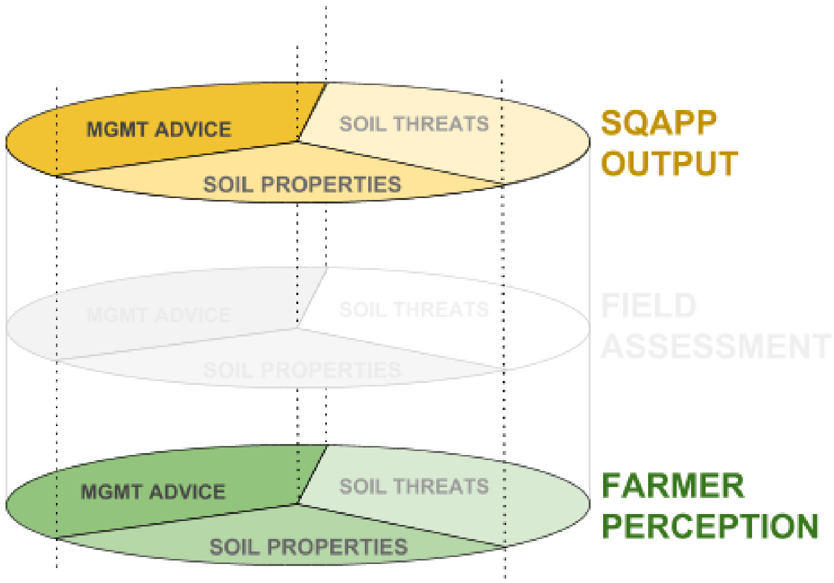

Figure 6: Information targeted via farmer interviews (farmer perspectives and feedback on SQAPP output)

A list of the soil quality indicators used by farmers used to describe their soil quality were produced. The indicators were proposed by the farmer without guided questions. Some of these indicators may be in line with the ones provided by the app, while others may not. Similarly, soil threats perceived by the farmer were outlined. In order to obtain the information on soil threats, guided questions on the threats considered by the application were formulated. All responses were recorded even if the definition of soil threats by farmers did not match our own. The recorded farming practices were used to provide indispensable contextual background and enabled comparison with app recommendations and insights into adoption dynamics.

The outputs of the app were presented to the farmer, and the consensus between the farmer opinion on soil properties, threats and recommendations were analysed. First, the level of agreement on each category of soil properties (physical, chemical and biological) for all the farmers were combined. Second, we presented an analysis of the mismatch between what the app perceives as a soil threat and the farmer perception. Any difference between farmer perceived threats and the app were qualified as mismatch if, either the farmer perceives it but not the app (and vice versa), or if the app does not provide data for a perceived threat by the farmer. It has not been considered a mismatch when the app perceives a threat but the farmer is not able to agree or disagree on that output. Very often, the app gives a value for a given threats, such as erosion in tons per hectare. However, farmers are unable to produce values to compare with. In that case, the app qualitative information on the threat (low, medium or high risk, for instance) were used to compare. Finally, each of the recommendations given by the app were qualified on the likelihood to be considered as a future AMP by the farmer or not. Additionally, we recorded if that particular recommendation is already in practice or not.

3.3 - App functionality

3.3.1 - Expert opinion

Throughout the study the research team has interfaced with SQAPP extensively. This provided ample opportunity to reflect on the app based on our own direct experiences. These experiences, both positive and negative, were distilled into recommendations for improvements.

3.3.2 - Questionnaire

The iSQAPER project targets farmers as key end-users of the app. It is important that the app is a functional and understandable tool for farmers. To assess the functionality of the concepts used in the app, farmer questionnaires were held through sending out questionnaires by mail and by distributing hard copies through farmer cooperatives. Unfortunately the app was only available in English at the time the questionnaires were held and the respondents did not get a chance to test the app themselves. The questionnaires consisted of 4 components: The first component was about the general background of the farmer. This data was meant to be used to identify possible trends in the rest of the data, however sampling size was too small to identify any trends. The second component was about the practicality of a mobile app. This component had questions about the possession of phones, use of phones, and reception. The third component was used to assess the terminology used in different parts of the app. This component consisted of a list of terms used in the app and the farmer could score his familiarity with these terms. Finally, there was a component with some open ended questions about points of improvements for clarity and completeness of the terminology. It was considered to add a section about the graphs and layout used in the app, however the questionnaire was already quite long and we figured that this is not the most important part to be assessed. A total of 19 questionnaires were returned. The information in the returned questionnaires were summarised and analysed to identify trends and potential points for improvement. The format of the questionnaire is provided in annex I.

4 - Results & Data Analysis

4.1 - Accuracy

4.1.1 - VSA Validation

Validation for our VSA methods was carried out by comparing our measurements with lab data at 6 sites. This is a rough validation, due to limitations in quantity and scope of comparable data sets. The result is a general understanding of the dependability of several indicators from our VSA. Not all parameters measured in our tests overlapped with available lab data and thus several cannot be validated using this method. The conclusions on validity of VSA measurements are displayed in the table below. Because validation of the VSA is not the main focus of this report, only the level of validity will be shown here.

Table 1: Validity of the parameters of the VSA measurements

Parameter	**Validity**
Clay Content	Low
Silt Content	High *
Sand Content	High *
Coarse Fragments	Inconclusive
pH	High
Electric Conductivity	High
Bulk Density & Compaction	Inconclusive
** Validation showed high validity of VSA data, but method should be questioned since clay content validity is low*	

As can be concluded from the table above (Table 1), some soil properties could be measured with reasonable accuracy (high) and others were consistently mismeasured (low), while we lacked lab data to validate our method for other properties (inconclusive). This needs to be taken into account while drawing conclusions from this data. A more thorough discussion of validity for each of the VSA measurements, as well as graphical depictions of this analysis can be found in annex E.

4.1.2 - App Accuracy: Soil Properties & Field Characteristics

30 app runs were conducted in order to assess the accuracy of soil parameter and threat reporting by SQAPP. Field measurements were conducted for 19 sites via visual soil assessments and laboratory data was assembled for 11 sites. Both types of data were available 4 sites, allowing a wider range of parameters to be assessed. A map of these locations is available in Figure 4. This section will present the accuracy of most indicators provided by the app, together with identified trends. Discussion of these results and how deviations may be linked to land management will follow in section 5. For each VSA we

perform or lab data set we analyse, we calculate the difference between indicator values and those predicted by the app. The accuracy of the prediction will be assessed by calculating the average and standard deviation of these differences. A summary for each of the indicators and relevant field characteristics will follow. More detailed data and graphical representations of this analysis can be found in annex F.

Slope

The app showed its ability to predict slope angles in practice. Our analysis shows an average deviation of 1.41% compared with our field measurements, with a standard deviation of 1.4%. The app's predicted slope deviated between 0% and 4.15% from the measured slope. The difference between the measured value and the app's prediction usually ranged between two percent, except for three test sites.

Rainfall Data

Rainfall data was compared with data from another source (*climate-data.org, 30 years of rainfall data*) for 11 points all over Spain. Our analysis shows an average difference between the sources of 111 mm/year for all sites, with an average a deviation of 17%. Subjecting these data to the rainfall classification system of the app shows that the sources result in a different classification in 4 of the cases. Neither consistent underprediction nor overprediction was observed for this indicator.

Soil Particle Distribution

The app predicts a percentage of silt-, clay- and sand particles in the soil. Our VSA provided a % range for each type of particle. We checked whether the app's predicted value matched this range. For silt particles, this was the case for 100% of the samples. The app often overestimated sand content and only predicted it well in 56% of the cases, while clay content was often underestimated and matched the VSA result in only 33% of the samples.

Bulk Density

The average difference between predicted and measured values was 0.08 ton/m3, while the standard deviation of differences was 0.06 ton/m3. Although this doesn't seem to be high, considering the fact that bulk density values usually range from 1.0 to 1.5 ton/m3 in this pedoclimatic zone, the difference is quite substantial. Neither consistent underprediction nor overprediction was observed for this indicator.

Coarse Fragments

Compared to our VSA data, the differences with app results on coarse fragments (%) are substantial. The average difference was 10.25% with a standard deviation of 9.52%. These values are fairly high, questioning the accuracy of either the app or our VSA method. The scatter plot (Figure 7) shows there is no pattern in deviation between app and VSA: neither consistent underprediction nor overprediction was observed for this indicator. Since lab data was not available for this indicator, we can't draw a conclusion on the app's performance to predict coarse fragment content.

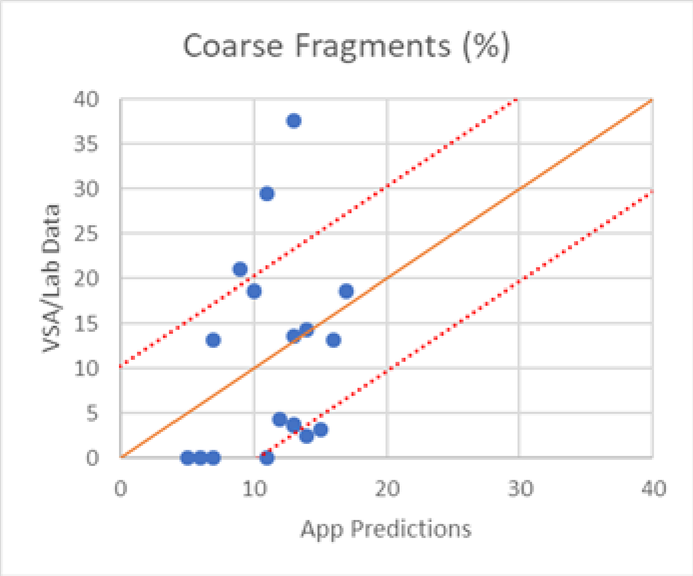

Figure 7: Comparison of the app's predicted values for coarse fragments vs. the measured values. Red lines indicate the average difference between app and vsa/lab.

Soil Organic Matter

The app appeared to be moderately capable of predicting soil organic matter content in our case study. The average deviation was 0.68% with a standard deviation of 0.13%. No evident over or under prediction was noted. However, the number of samples in this study was limited (n=8), which may affect the representativeness of the data.

Soil pH

Soil pH was predicted quite accurately, with an average difference of 0.51 and a standard deviation of 0.17. The sample size for this indicator was decent (n=25). However, as figure 8 shows, the app consistently underestimates the value for soil pH.

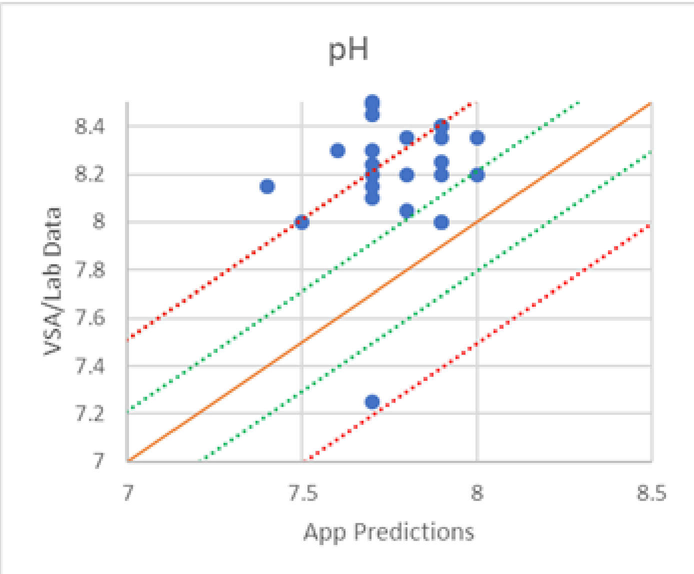

Figure 8: Comparison of the app's predicted values for pH vs. the measured values. Red lines indicate the average difference between app and vsa/lab. Green lines represent the average difference between VSA data and lab data, resulting from our VSA validation and together form an error bar.

Electrical Conductivity

Compared to our measurements for soil EC, the differences with the app were 0.2 dS/m on average, with a standard deviation of 0.12 dS/m. Figure 9 shows that the app consistently overestimates the electrical conductivity of the soil, compared to our measurements. While we measure rather consistent values for EC, the app predicts values in a much wider range.

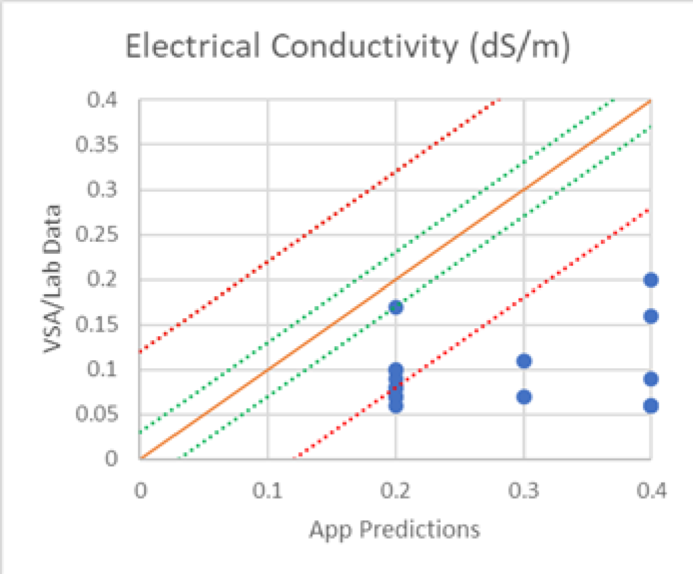

Figure 9: Comparison of the app's predicted values for electrical conductivity vs. the measured values. Red lines indicate the average difference between app and vsa/lab. Green lines represent the average difference between VSA data and lab data, resulting from our VSA validation and together form an error bar.

Soil Nutrients

Although the absolute differences for soil nutrients (P, N, K) between app predictions and lab data seemed low, the percentage difference is extremely high, as displayed in the table below (Table 2).

Table 2: Summary of the percentage and absolute differences for soil nutrients (P, K & N)

Nutrient	**n**	**Average Difference**	**SD Differences**	**Average |Difference|**	**Over or under estimation**
Available P	10	112%	59.18%	51.96 mg/kg	Systematic Under
Exchangeable K	4	91%	142.73%	0.16 meq/100g	n.a.
Total N	10	24%	364.72%	0.822 g/kg	n.a.

4.1.3 - App Accuracy: Soil Threats

To assess the app's capability of predicting soil threat levels, we used its own classification system (Annex B). For several locations, the app was not able to provide information for some threats, so the number of samples differ per threat. The results are displayed in table 7 in annex F. Figure 10 depicts how accurately the app predicts soil threat class, and whether threats are under- or over-predicted compared to our measurements and observations. These results are limited due to reliance on the app's classification scheme.

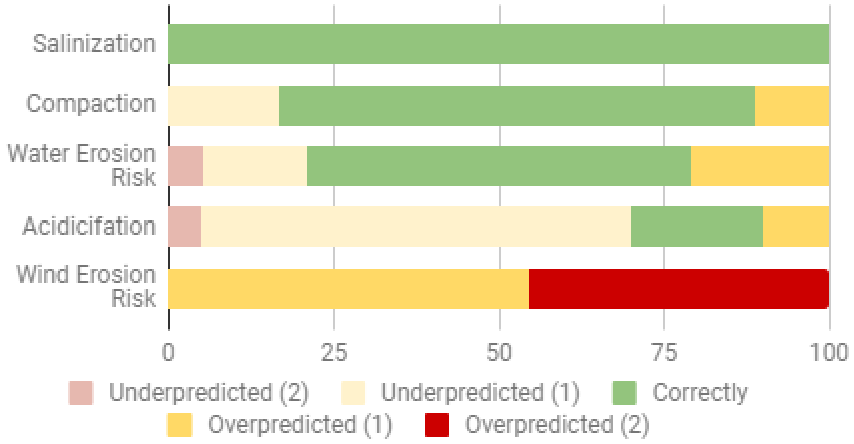

Figure 10: Classification of soil threats by app compared to VSA/lab observations

4.2 - Relevance

4.2.1 - Contextual assessment of summary and management advice

This was done using 3 different levels of elimination. A total of 18 app runs for different sites were assessed, these included different plots within the same farmer's field see Annex G.4 citrus, 4 vineyards, 1 Olive, 2 Kaki, 1 potato, 2 pomegranate,1 apricot,1 grassland and 2 peach plots. For each app run, 10 AMPs were recommended based on the apps matrix and input data. We, however, noted that 23 AMPs were consistently repeated, see figure 11.

11 out of the 23 AMPs were found to be relevant for the region. The 11 recommendations included eliminations of AMPs that were not relevant to the threats and parameters identified, the second elimination was based on physical suitability and the third elimination was based on the suitability of threats and parameters identified and the cropping systems. However, there are certain recommendations that were suitable but not priority, those were also eliminated at level 3 see figure 11. These recommendations were eliminated because of their redundancy. There were repetitions of AMPs within the same major AMP class. Notably within the nutrient major class composting, animal manures and slurry would constantly be recommended see figure 11.To highlight this, for example, in instances where the app recognized susceptibility to compaction as a threat with bulk densities greater than 1.5t/m3 , no till as an AMP was still suggested, even at sites where the soils were predominantly clay. Another example, was the suggestion of planting pits on already existing permanent orchards. Farmers 1 (CA001), 4 (AL 001-1), and 18 (MO002) received recommendations such as rotational grazing or area enclosure which were not relevant to the current management practices i.e. citrus, peach and vineyard respectively. Further elaboration of

this can be found on a summary of farmer characterisation in the Annex G and in the discussion.

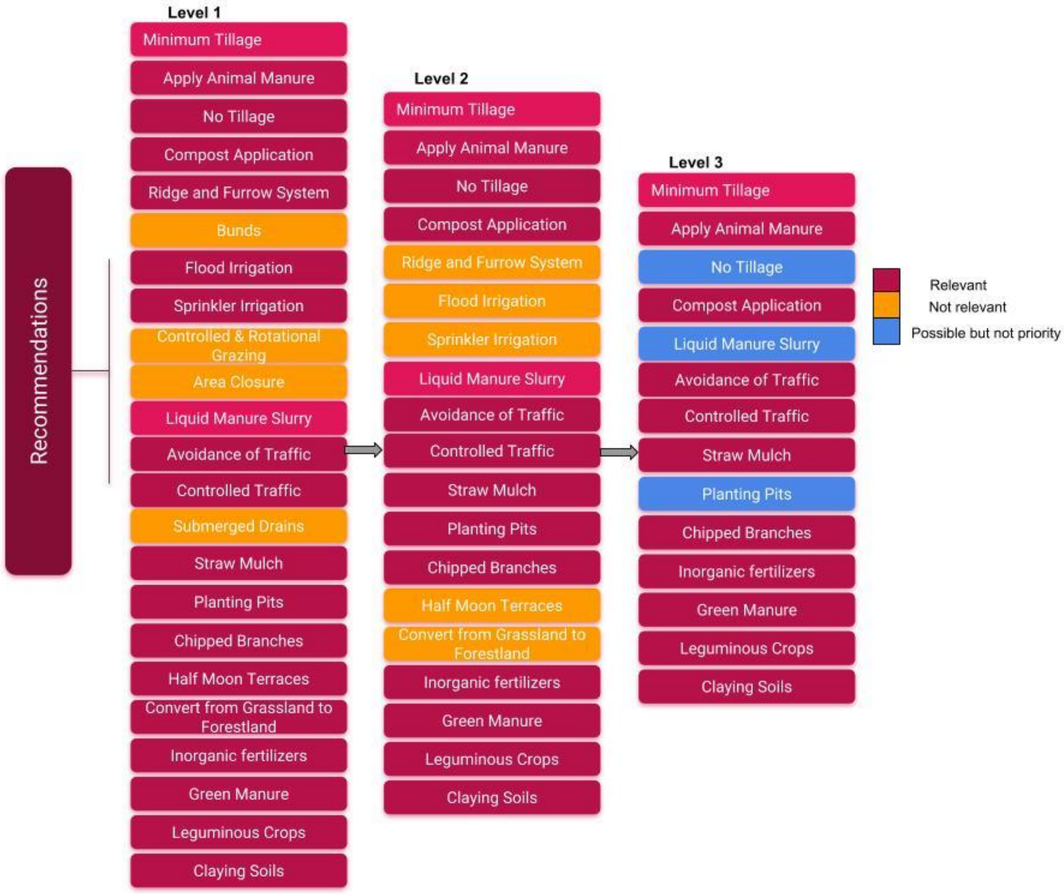

Figure 11: Relevance of proposed recommendations based on threat and parameters identified (level 1), physical suitability (level 2) and sqapp output, site status and our own expert opinion (level 3)

4.2.2 - Semi-structured Interviews

Twelve interviews were performed, of which 10 interviewees were male and 2 were female. Five subjects are full time farmers, one is an agricultural engineer that provides advice to farmers, two are part-time farmers, three are land owners involved in their farm management, and one is a full time farm manager.

Different soil indicators were used to describe soil quality by the farmers. Six of those indicators are explicitly mentioned in the app, while six others were not (figure 12). The most used indicator was soil texture, followed by organic matter content and calcareous material content. Although some indicators used require analysis to determine its value, farmers often rely on the general knowledge about the area. For instance, a farmer stated the soil had a high pH, without having the soil ever tested. Some farmers did test the soil, and could be more technical on their description. Most of the farmers used between two to four indicators to depict the soil, with texture being always present.

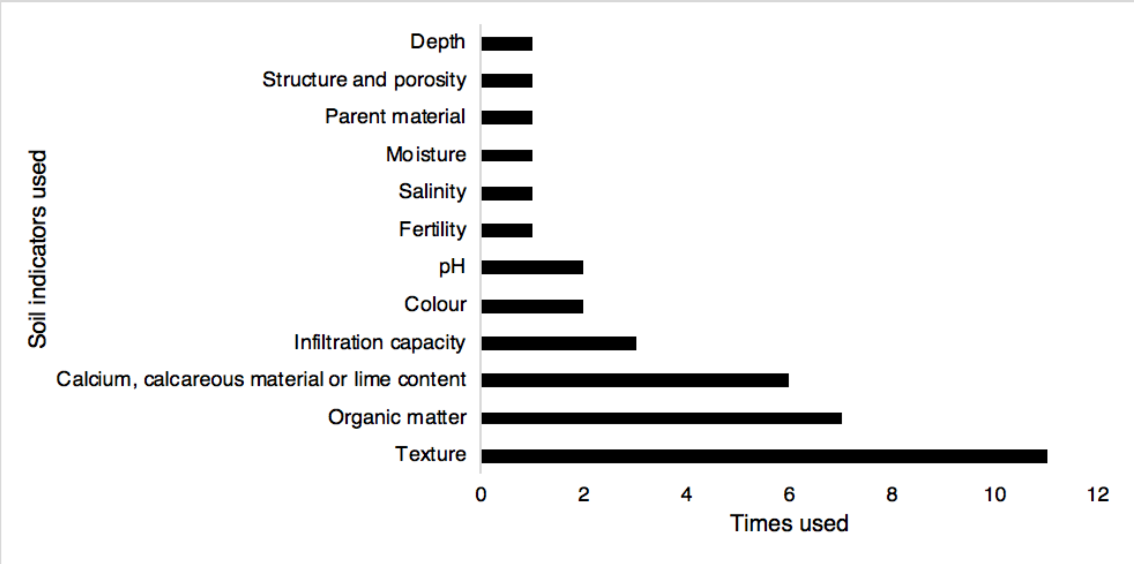

Figure 12: The number of times the soil properties were mentioned by the farmers (n=12) when describing soil quality

Many of the soil threats described by the farmers were in the app's considered list of soil threats. Only nutrient immobilization (due to high amount of calcium carbonate), soil-borne pests, deterioration of soil structure, and decrease in soil water availability are not considered by the app. Interestingly, some farmers did not identify any soil threat occurring in their fields (Figure 13).

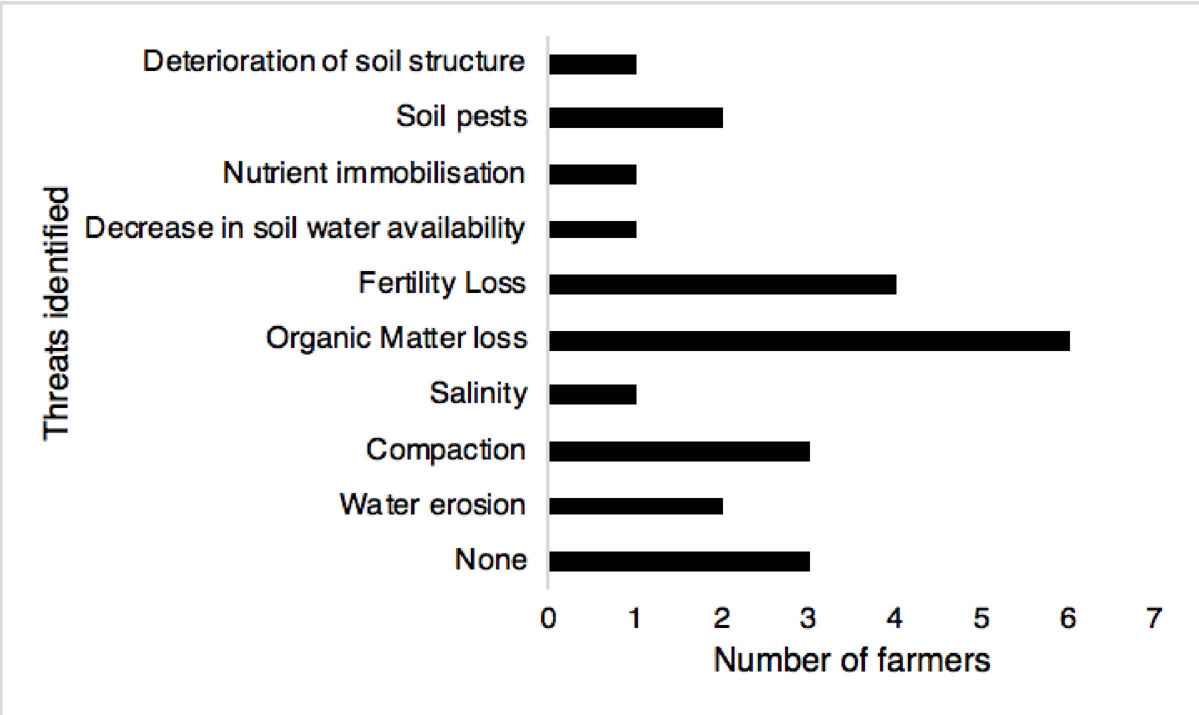

Figure 13: Number of farmers that identified different threats on their fields (n=12)

Most farmers agree on the predictions of soil physical and chemical properties. Some of those farmers, however, mainly accept the values as plausible. None of the farmers agreed on predictions for biological properties of their soil, due to a lack of knowledge on biological soil quality indicators (Table 3). Farmers tended to accept the values given for parameters that they were less familiar with, as long as the parameter depicted the qualitative category in which their classified their soil. For instances, specific values for EC couldn't be agreed, but if the values indicated a salinity level in which they could reflect on their soils, then the parameter was accepted. Some parameters were more often sources of disagreement than others. For instance, organic matter was very often stated lower than the predicted by the app, while pH was almost always matching farmers perception.

Table 3: Percentage of farmers that agree with different soil properties proposed by the app

	Agrees or accepts the values	Partially agrees	Disagrees	Unable to evaluate
Physical properties	64%	27%	9%	
Chemical properties	64%	36%		
Biological properties				100%

When presented with the soil threats predicted by the app, many farmers did not recognise water erosion happening in their fields. Additionally, soil compaction, and pH, presented the highest degree of mismatch (Table 4). Certain threats predicted by the app, for instance pH extremes, matched in value with the farmer expectations, however, farmers did not perceive it as a threat to soil quality or to crop productivity. None of the farmers could judge whether soil biodiversity loss was an occurring phenomenon in their fields, and none of the app runs produced data to detect it as a threat.

Table 4: Percentage mismatch between the app's predicted soil threats and the farmers' perception (the methodology followed to obtain the following values is explained in Section 3.2)

Soil threat	% mismatch
Soil erosion by water	45.5%
Soil erosion by wind	0%
Soil compaction	63.6%
Soil salinisation	18.2%
Soil OM decline	0%
Nutrients	23.3%
Extremes of pH	54.5%
Contamination	0%
Biodiversity loss	0%

The recommendations were presented and discussed with the farmers. From that discussion, we could state that 51% of the recommendations given were proposing AMPs already in practice (Table 5). On average only 4% of the recommendations were considered as plausible future AMPs by the farmers. There were no obvious trends of individual farmers being exclusively negative on the practices proposed, or farmers predisposed to adopt more recommendations. Most of the farmers categorised the recommended practices following the values expressed on Table 5, describing the majority of the practices as already in use, or not to be considered, and in a much lesser extent to be considered.

Table 5: Percentage of recommendations that were already in practice or were/were not considered by the farmers

General qualification of recommendations	% of recommendations
To be considered	4%
Already in practice	51%
Not to be considered	45%

The underlying reasons explaining why certain practices were not considered are exposed in Figure 14. It can be seen that 47% of the not considered recommendations were discarded due to the practice of an alternative measure. For instance, farmers applying manure did not consider application of compost when recommended to do so. Although one may not consider them as equivalent practices, farmers felt that they covered the same functions, and were inclined to the practice that required less financial input or that was more easily achievable (due to the high availability to manure, for instance).

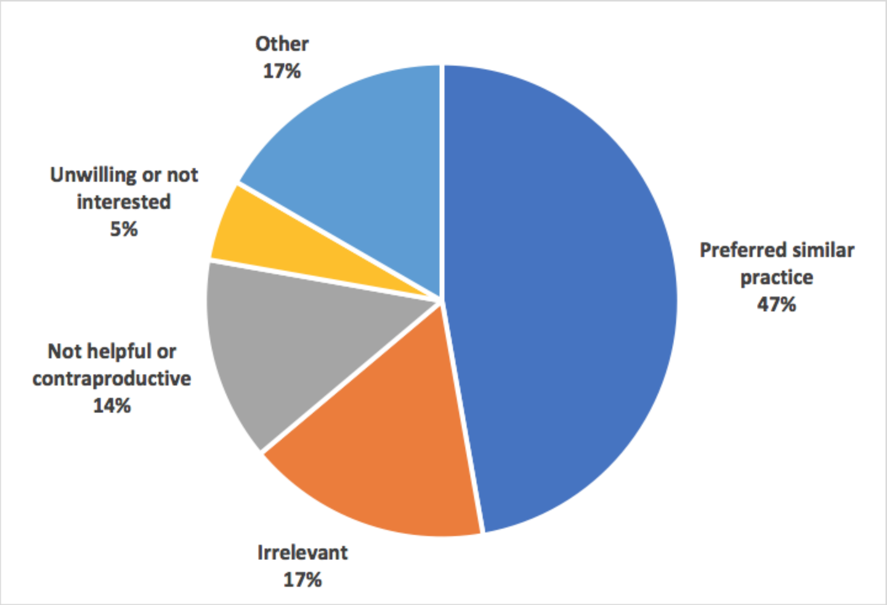

Figure 14: Reasons behind not considering the AMPs recommended.

4.3 - Functionality

The questionnaires that were conducted consisted of questions related to the possession and use of mobile phones, a 1-5 scoring system to indicate their familiarity with terms used in the app and open-ended questions with suggestions for improvements. A total of 19 responses were received.

The questionnaire showed that every respondent has a phone and has cellular reception at their field. However, 18 out of 19 respondents had connection to the internet on their field and only 11 out of 19 respondents uses apps often. The results of the suitability of the app as a medium are summarised in the table below (Table 6).

Table 6: Results survey analysis on suitability of app as medium

Uses a phone	100%
Uses apps	58%
Has network connection at field	100%
Has internet connection at field	94%

The table below (Table 7) shows the familiarity of the respondents to the terminology used in different parts of the app. The table shows the averaged scoring of different types of terminology. Terms related to soil properties score lowest on average while the respondents were pretty familiar to the soil threats and AMPs discussed in the questionnaire. The results of the terminology are summarised in the table below (Table 7). Tables with the average scoring of every individual term is included in annex D.

Table 7: Familiarity of farmers with different types of terminology on a score from 1 - 5

Topic	Averaged score
Familiarity with terminology soil properties	3.7
Familiarity with terminology soil threats	4.5
Familiarity with terminology AMPs	4.5

5 - Discussion

5.1 - Accuracy

In order to assess the app's capabilities to predict soil parameters and soil threats, we performed an accuracy analysis. We compared data acquired from our visual soil assessment (VSA) with app data provided for the same location. If lab data was available, we also compared these to the data provided by the app. Besides the quantitative analysis on soil property accuracy, we performed a more qualitative analysis on the classification of soil threats by the app.

This way, the VSA played an important role in our research. Although our field measurement were done in a systematic way, the VSA put some limitations on the study. Firstly, the method was validated using lab data that was acquired from farmers, cooperatives, and UMH. Unfortunately, these sets were quite limited, preventing us from confirming the validity of our method for some indicators. On top of that, comparing VSA results with lab data showed that our method was unsuitable to measure certain indicators. Although the methods are straight-forward, drawing conclusions from data that is not validated is not scientifically justified. In the end, this reduced the number of app soil properties that could be considered in our accuracy analysis.

Data on field slopes are generally interpolated and processed from altitude maps. As mentioned before, maps are processed to a resolution of 250m. As terrace widths are often smaller than 250 meters, the process can neglect this highly local topography and predict a larger slope than there is in reality.

While working with the app we noticed that the location that the app automatically provides does not always match reality. It sometimes uses a previous location or a complete random location. Since this results in outputs unrelated to the end-user's field, the issue should be fixed. Also, we suggest to make an extra function in the location tab that allows you to choose a location or navigate the map by entering coordinates or an address.

While running the app, some of the soil properties and soil threats never had any data, for example the amount of wind erosion per year. Also, some data layers seem to be inconsistent. For example, the app regularly provided no (rainfall data) or highly inaccurate data (altitude).

For some soil parameters, we were unable to assess the app's accuracy, since we lacked lab data to validate our VSA. This goes for bulk density, coarse fragments and soil texture. For other parameters, the app performed well (soil organic carbon) or reasonable (pH, EC).

SQAPP uses the *Global Soil Dataset for Earth System Modelling* for the prediction of nutrient levels (Exchangeable potassium, Olsen phosphorus and Total nitrogen). There big differences between lab data and app data for nutrient. WIth most of the nutrients missing the threat level by two classes in the classification system used by SQAPP (Fleskens et al., 2017). Also electric conductivity (EC) data was retrieved from this source. These values were generally slightly overestimated. Soil pH data was retrieved from *Soilgrids* - from our analysis, these values were consistently underestimated.

The app uses rainfall data to select suitable AMPs. From our comparison with a third party source, we conclude that there is a substantial deviation between these sources, often of a magnitude that would result in different classification. Although we can't assess the accuracy of this source, we want to stress the importance of reliable rainfall data for the app to be able to estimate soil erosion by water and provide suitable AMPs.

With only three classes (low, moderate, high), the precision of threat results is not too rigorously tested - there could be considerable variation of results even if they fall within the same threat class (EC is not particularly accurate, but results always fell within the "low" threat class for salinization.

The app classifies soil parameters to identify soil threats using global threshold values (Figure 1, annex B). However, this classification system is not crop specific, since crop type is not incorporated in the app, which limits the value of its judgement. For example, the app uses the electrical conductivity of the soil to classify salinization threat. Since crops type is not specified, the *low risk* class ranges from 0 to 2 dS/m, while almonds, not an unfamiliar crop in this area, begin suffering from salinization at EC values higher than 1.13.

Compaction, water erosion and acidification were fairly accurately predicted by the app, compared to our measurements. The pH, however, was consistently underpredicted by the app. The fact that for most samples the pH ranged around the class threshold of 8.0 led to a relatively high number of misclassifications. Our VSA appeared to be unsuitable for assessing the accuracy of water erosion vulnerability. This soil threat will be left out of the rest of the discussion. For wind erosion risk, however, the app predicted a high risk, or provided no data at all. Our conclusion often didn't match with the app's results, which might have been due to difficulty in determining wind erosion with our VSA.

The biggest limitation to our study was the amount of resources available. Both time and lab facilities were lacking. This limited the amount of parameters we could analyse, the amount of measurements we could take and the methods we could use. If more resources were available a more thorough study could have been conducted and more app parameters could have been analysed. For future research we would recommend facilitating a laboratory so that the missing parameters can be analysed.

5.2 - Relevance

5.2.1 - Contextual assessment of summary and management advice

We tried to judge the app run as if we were the farmers. As such, we did not change any of the parameters after performance of the VSA to assess whether there would be a difference in the recommendations provided. We recognize that if we had input soil data that farmers had available or data from our VSA, we would have yielded more relevant information.

However, out of 23 identified recommendations from the 18 app runs, only 11 AMPs were found to be most relevant to the study area. These sites may be farmer's fields or plots within farmer's fields depending on the size of the field. Site 4 (AL 001-1) & 5 (AL 001-2) are plots within the same farmers' field. Whilst the app identified the same threats and parameters needing attention. The app provided similar recommendations but in different order of priority. This was similar for farmer 8 (CA 003-1) & 9 (CA 003-2).For sites 17 (MO001) and 18 (MO002), the app identified the exact same threats and parameters needing attention but provided different recommendations. The only difference between site 17 & 18 was soil cover.The app recommended sprinkler and flood irrigation for sites 8 & 9 when they both had drip irrigation already in place. For site 17 the app suggested claying soils when the threat that needed attention was susceptibility to compaction. Soils with finer particles like soils with higher clay content are more susceptible to compaction (Batey, 2009). See Annex G.

The app supplies 10 AMPs irrespective of the site. For example, there may only be 5 AMPs that are suitable enough to combat a certain soil threat. The app will still fill the recommendations list to 10 AMPs, thus including 5 less suitable AMPs. End-users may not recognise the overexploitation of recommended AMPs in the case where the soil quality is "good" or threats are low.

To highlight how characterisation of the different AMPs into their various classes, may be problematic and distinctively off. Our observations, for example, showed that in farmers 1(CA001), 4 (AL 001-1), and 18 (MO002) (annex G) ,received recommendations such as rotational grazing or area enclosure which were not relevant to the current management practices i.e. citrus, peach and vineyard respectively. If the farmer was in any way practicing silvo-pastoralism this would be sensible. However, the farmer does not and unfortunately has no way of inputting this information on the app. Within the water management major AMP class for example, ridge and furrow and soil bunds were recommended irrespective of the input being permanent cropland and in this studies context case fruit tree orchards.

The app does not have provision for the end-user to input their current management practise or current land use outside the boundaries of the app i.e. permanent crop, arable etc. This results in recommendations that may not necessarily be applicable for example, recommendations of straw mulch when chipped branches would be a more suitable recommendation due to availability of material.

Farmers should also not be recommended to convert their land to forest or otherwise abandon their livelihood. Whilst this makes sense for the app's logic especially when the soil threats identified are in relation to soil structure and nutrient class, these sorts of sweeping conversions (and other similar recommendations) may be useful within a research or policy context but as soon as such a recommendation is presented to a farmer it may suggest that the app is not designed with their best interest in mind.

5.2.2 - Semi-structured Interviews

From the interviews it was evident that the farming community in the area is not a homogeneous group, not in opinions, understanding of soil quality, farming practices, nor uses of technology. This complicates, and perhaps precludes the formulation of a unified or reduced ‘farmer opinion’ on the app. Even farmers with similar management practices and crop types expressed themselves differently when faced with the management advice of the app. Nevertheless, some of the issues and themes encountered occurred frequently enough to warrant discussion.

Farmers describe soil quality using few indicators and are often more reliant on the evaluation of the crop productivity to depict their soils. This may indicate that the dominant concept of soil quality is what some describe as soil productivity (Bünemann et al., 2018). Although the app reports a wide range of indicators to describe soil properties, some farmers mentioned a few indicators not considered by the app. An interesting and recurring one is the presence of calcium carbonate, which plays a big role in nutrient availability for the plants. Some of the indicators, though, were not fully understood yet by farmers. Biological soil quality indicators, for example, are still largely unknown. The discussion is, then, does an indicator become irrelevant due to that lack of understanding? One approach to deal with this discussion is to show such indicators only for expert or advanced users. However, another approach may consider that although the indicator is not fully understood, it still provides a benchmark of certain aspect of soil quality that the farmer can use to reflect, monitor and compare. Hiding the least known indicators may not be necessarily better for the end user, however, it must be noted that more extensive and detailed explanatory information on such indicators will be needed. By linking these indicators to threats and management advice, the app can add meaning and relevance to an indicator that wasn’t previously identified as a priority.

Most of the interviewed farmers did not analyse the soils, which can be interpreted in two ways. On one hand, it is an optimal gap where the app could provide the lacking information, but on the other hand, it may also indicate that farmers are not very dependable on soil information to select their management practices. Further research in this aspect is needed, since it is crucial to understand whether farmers are willing to engage with the information that the app provides.

Farmers’ perceptions of soil threats are particularly diverse. Some farmers may not identify any threats while others in the same pedoclimatic zone and cropping system do. Contrasting definitions of soil threat between the app and the farmers were also noted. For instance, high values of pH were often referred as a threat by the app, while many farmers did not feel it as an issue of concern to their soils. That could have implications for the adoption of the recommendations based on that threat. Providing information on the mechanisms by which these threats can impact the soil and crop productivity could bring these positions closer to one another. Interestingly, water erosion is often underestimated by farmers, which tend to disagree with the outputs predicted by the app. The disagreement is an interesting observation, since it reflects how the information is received by the farmer, and how it is processed. When faced with contradicting information to their perceptions, farmers may either examine their assumptions or discredit the information given. The drivers that may incline towards one or the other option largely depend on how fundamental their knowledge is, or how trustworthy the input from the new source is.

The recommendations provided by the app proved to show a bit of redundancy with the practices already in place. That is a factor which may dramatically decrease the relevance of such recommendations. The fact that only 4% of the recommendations are to be considered as plausible AMPs casts doubts on the efficiency of the application as a transformative tool towards the adoption of sustainable land management practices. In that sense, being able to refine the recommendations by allowing the input of practices already in place may help to reduce such overlapping.

Some of the recommendations were considered a bit general, and not local and context specific enough, in that sense, the app could be more adaptive to context-sensitive interpretations of quality by allowing enterprising end-users to specify additional field characteristics such as crop type and current AMPs.

5.3 - Functionality

Based on our own experiences with using the app and the questionnaires filled in by the farmers, there are some points for improvements that need to be discussed. Even though the amount of useful respondents to the questionnaire was limited, some useful information emerged from the questionnaire.
Using the app for the first time proved to be very difficult. There is only a very brief tutorial available that can only be watched once. After this the user is supposed to find out by him or herself what kind of information can or needs to be filled in and what kind of information is provided by the app. Especially, the cumulative probability density functions of the soil properties are difficult to understand without any guidance.

Some of the field characteristics that are allowed to be changed by the user are difficult, if not impossible, to know. Especially the landscape position is almost impossible to be determined in the field, e.g. the difference between flat plains and smooth plains is very small.

Based on the questionnaires we can state that the terminology in the soil threats and recommendations sections are clear. However, many of the soil properties terms remain unclear to the user. Especially, cation exchange capacity, course fragments volume and phosphorus using the Olsen method were not well understood. In the open-ended questions farmers did mention phosphorus as an important nutrient, however the method used to derive phosphorus was not familiar to them. The questionnaire also showed that the medium type used does have some practical implications for the respondents as about half of them does not use apps that often. However, we have to note that the sampling size was very small and might not be representable for the entire Albaida region. Furthermore, 7 questionnaires were returned with a score of 5 for the familiarity of all the terms. We doubt that this is reality and the presented scores might be overestimated due to this.

The app allows the user to save and store a location with its relating input and output information. This is a useful feature, however when opening this location and changing the input coordinates the field characteristics do not automatically update. This results in a mismatch between actual field characteristics and field characteristics of a different location.

In determining the apps potential end-users, it is worth debating on the static nature of the app. How often would a potential end-user have to use the app? For example, apps that provide information on market prices, climate information, are dynamic. Whilst on the other hand, after using SQAPP for a single site, it may take time before the app is used again. As such it might make more sense to an extension officer or an advisory service provider or a farmers' cooperative as middle men within the value chain. This is because these agents are mobile and as such need insight on the various farmers they work with.

6 - Recommendations for improvement

Our study culminates in the following 11 core recommendations for improvement of the iSQAPER Soil Quality App:

Accuracy:

A1. Insert the the option to let users search and specify location using direct address and coordinate entry

A2. Reconsider source and evaluate accuracy of datasets for:
- 'Soil pH'
- Nutrient Availability
  - 'Exchangeable Potassium'
  - 'Phosphorus using the Olsen method'
  - 'Total Nitrogen'
- 'Electrical Conductivity'
- 'Wind erosion vulnerability (classified)'

A3. Work to fill gaps in datasets for:
- 'Rainfall data'
- 'Altitude'
- 'Soil Wind Erosion in Agricultural Soil'
- 'Wind erosion vulnerability (classified)

Relevance:

R1. Allow for entry of optional field characteristics including crop type and AMPs

R2. Allow user to specify 'user type' during profile creation (Farmer vs Researcher) and curate recommendations accordingly

R3. App should not give 10 AMPs arbitrarily, instead listing all that exceed a score threshold

R4. Require that 'land cover' be manually entered rather than auto filling 'arable' or 'other'

Functionality:

F1. Include a detailed/guided tutorial that can be reviewed by the user at any time

F2. Soil properties terminology has to be clarified and links to more information could be provided

F3. 'Landscape position' should be auto filled (locked to latitude and longitude) and not allowed to be changed manually

F4. Re-specifying coordinates for a saved location should automatically update field characteristics to match (altitude, precipitation, landscape position, and slope)

7 - Conclusions and Outlook

In our study we sought understanding on how SQAPP performed on three levels: accuracy, relevance, and functionality. We were encouraged by our results and the response of farmers in the region that this can be an impactful tool in moving towards sustainable soil use and continued productivity in the region.

The app aims to provide a “holistic assessment of soil quality” and inform users about agricultural management practices available to them to improve their soil. It was designed with the intention of guiding users to not only access this data but to understand where they stand by providing comparative contextual information and how they can overcome threats and limitations to the quality of their soil.

Farmers already access agricultural information by a variety of means and this should be taken into consideration in the design and roll-out of the app. The app is seemingly designed to rest in the palms of farmers themselves but it is crucial to understand that the product will exist in a complex web of stakeholders and interests. Farmer cooperatives, agricultural advisory services/extension services, and consultants could potentially serve as end-users. To reiterate this, the language and terminology used by the app greatly influences the potential end-user and as such a review on the language is worth considering. This was well expressed by farmer interview 3. See Annex H. The potential for more varied end-users could be useful for investigation in future studies.

Although this study is limited to the greater Albaida region, several conclusions can be drawn for applicability in other regions of the world. For example, from the farmer interviews it is distinct that while the app’s main objective may be in the holistic assessment of soil quality, farmers were interested in recommendations that related soil quality in terms of soil nutrition and how this related to overall productivity. Interpretations of the SQAPP to local languages may greatly improve the user-friendliness of the app. A review of the AMPs to the specific local context as we observed would greatly increase the validity and relevance of the app.

In terms of accuracy, we can conclude that SQAPP has some trouble accurately predicting soil parameters. Some parameters were fairly accurately predicted (like SOC, slope, rainfall, soil erosion by water), while for others, estimations were highly inaccurate or no data was provided at all (wind erosion, nutrient availability). For the prediction of some other parameters, the app showed potential, but is not accurate yet (pH, EC). Since erroneously predicted data may lead to a wrong classification of soil properties or threats and thus to unsuitable management advice; if possible higher accuracy should be pursued.

Following the philosophy of the greater iSQAPER project, our study embraced a multi-actor approach whereby stakeholder feedback was central to assessing indicator performance and management recommendations reported in the app. It is clear that to change the way people relate to their soil and promote sustainable productivity, data must not simply be made available, but conveyed in such a way that it is convincing and actionable. This highlights a need for the scientific community to step aside from traditional, technocentric research in order to better grasp the environment in which soil information is diffused and adopted. Only then can knowledge transfer be expected to also bring about transformation. The Soil Quality App, with its obvious potential, should aim for no less.

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Appendices

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Annex A - Team Details

Description team members

Team TEMPR consists of members with specific and relevant knowledge on issues related to soil degradation and how this translates to land management. Each member has specific interests that will be fundamental in contributing to the study of SQAPP.

Name	*Mail address*	*Specialisation*
Pim van den Berg	pim.vandenberg@wur.nl	Land degradation

Pim van den Berg studied in the Netherlands and is currently pursuing a specialization in sustainable land management. He has specific experience on researching dam sedimentation in Australia and the consequences of this to threats on land management. He also has interest in modelling post-fire erosion and the consequent effects on soil water repellence. He hopes to be able to provide insight on land management on spheres that are a consequence of human behaviour to the degradation of land.

Cleveland Rex Steward cleveland.steward@wur.nl Engineering, Project Manager

Cleveland Rex Steward studied Civil Engineering in California and has considerable experience in managing projects within the state of California. He also pursuing a specialization in sustainable land management at Wageningen University in the Netherlands. His main interest are in formulating decision-making tools on issues related to land management with an outlook at the watershed level. He hopes to be able to find interlinking issues on land management within different scales of governance and their influence on policy.

Martí Vidal Morant marti.vidalmorant@wur.nl Agronomy

Martí Vidal Morant studied in Spain and agronomy in Wales. He is also currently pursuing a specialization in sustainable land management in the Netherlands. His main interests are in looking at soil pollution and remediation with specific focus on soil microplastics. He has specific experience on soil nutrient analyses and environmental impact assessment with a focus on chemical soil properties. He hopes to contribute to research on plant-nutrient availability and soil pollution.

Emily Ongus emily.ongus@wur.nl Agronomy, Project Manager

Emily Ongus has a background in agronomy from Kenya. She is also currently also pursuing a specialization in sustainable land management in the Netherlands. She has specific experience on rural advisory services for small-holder farming systems and in managing projects on sustainable agricultural systems. Her main interest are in integrated approaches to land management that foster agronomical solutions to land degradation. Specifically, on soil nutrient analyses; soil and water conservation. She hopes to continually contribute to fostering solutions that bridge the gap between research and knowledge dissemination at multiple scales within various agricultural value chains.

Thijs van der Zaan thijs.vanderzaan@wur.nl Erosion control investments

Thijs van der Zaan is also pursuing a specialization in sustainable land management. He studied in the Netherlands and has specific experience on socio-economic analysis of soil conservation investments. He main interests are centred on participatory approaches to soil and water conservation investments. He hopes to contribute to research on various scales of soil and water conservation investments but with specific emphasize on approaches to adoption of these measures. He has a global outlook to local solutions.

Annex B - SQAPP Details

Description of SQAPP:

1. Area Selection and Global Data Grids

In the first step, the user is asked to select the area that will be analysed using an interactive map. The app anticipates field characteristics for the selected location using database information including *altitude, precipitation, landscape position, slope* and *land cover.* The user has the freedom to modify the values for these variables if needed.

2. Soil Properties

From global ISRIC datasets, the app provides a list of soil properties and their estimated values for the selected plot. Values in these database layers are calculated using machine learning and interpolation between measured points (Hengl et al., 2017). The following properties are included in the app:

- Depth to Bedrock
- Bulk Density
- Cation Exchange Capacity
- Course Fragment (volume)
- Phosphorous using the Olsen method
- Exchangeable potassium
- Soil microbial abundance
- Soil macrofauna groups
- Soil Organic Carbon
- Soil pH
- Plant-available water storage capacity
- Silt content
- Sand content
- Clay content
- Total Nitrogen in Soil
- Electric conductivity

The values for these properties are inherently estimations based on aggregated observations and calculations and may therefore be inaccurate on plot level. The app allows users to modify these estimations, for example in case the user has access to more accurate data on the quality of the soil. When users have access to more accurate data, they will be able to upload it to the SQAPP database to improve the quality of the remaining app output and global data sets. However, this function is not available yet in the current version of the app. The app also compares soil property values at the target location to characteristic values for soils under the same land-use and in the same pedo-climatic zone, using a percentile graph. These charts show where the provided value lands on a cumulative probability density function of the given indicator, thus providing users with an idea of how their soil properties to compare to soils under similar conditions. The pedoclimatic zones are drawn by overlaying the Peel's climate zones (Peel et al., 2007) and the soil classes predicted by SoilGrids (Hengl et al.,2017).

3. Soil Threats

Based on the soil property data that was provided and modified in the previous step, the app shows the user which soil threats are relevant for the selected location. The app distinguishes these soil threats:

- Wind erosion
- Water erosion
- Compaction
- Salinization
- SOM Decline
- Biodiversity Loss
- Soil Contamination
- Acidification
- Nutrient depletion

As with the soil properties, the app shows the state of every soil threat and how vulnerable the selected plot is to these soil threats compared to other soils in the same pedo-climatic zone and with the same land-use. The figure below shows the thresholds of every soil threat.

SOIL THREAT and indicator		**THRESHOLDS**			
Soil erosion by water					
Soil loss (t/ha/year)		0-2	2-10	>10	
Vulnerability (class)		low	medium	high	
Soil erosion by wind					
Soil loss (t/ha/year)		0-0.5	0.5-3	>3	
Vulnerability (class)		low	medium	high	
Soil compaction					
Natural susceptibility		low	medium	high	
Soil salinisation					
Electrical conductivity (dS/m)		0-2	2-4	>4	
Soil organic matter decline					
Soil organic carbon content (%)		0-1	1-2	>2	
Soil nutrient depletion					
Exchangeable K (cmol/kg)		0-0.2	0.2-0.3	>0.3	
Available P (Olsen method) (mg/kg)		0-20	20-40	>40	
Total N (g/kg)		0-1	1-2	>2	
Soil acidification					
Soil pH	<5.5	5.5-6.5	6.5-7.5	7.5-8	>8
Soil contamination					
Arsenic (mg/kg)		0-37.5	37.5-50	>50	
Cadmium (mg/kg)		0-2.25	2.25-3	>3	
Chromium (mg/kg)		0-300	300-400	>400	
Copper (mg/kg)	pH <5.5	0-60	60-80	>80	
	pH 5.5-6.0	0-75	75-100	>100	
	pH 6.0-7.0	0-101.3	101.3-135	>135	
	ph >7.0	0-135	135-200	>200	
Lead (mg/kg)		0-225	225-300	>300	
Mercury (mg/kg)		0-0.75	0.75-1	>1	
Nickel (mg/kg)	pH <5.5	0-37.5	37.5-50	>50	
	pH 5.5-6.0	0-45	45-60	>60	
	pH 6.0-7.0	0-56.25	56.25-75	>75	
	ph >7.0	0-82.5	82.5-110	>110	
Zinc (mg/kg)		0-150	150-200	>200	
Soil biodiversity					
Soil biodiversity index		low	medium	high	

Figure 1: Soil threat and indicator thresholds

4. Management Advice

Based on data determined in the previous steps, the app gives a summary of the potential for soil property improvement. It shows which soil parameters and threats need attention so the user can decide which should have priority. Next, the app provides recommendations for measures or “agricultural management practices” (AMPs), to realize these potential improvements. Although the users can modify some input, global data plays a dominant role in formulating these soil management recommendations. The app selects from around 80 AMPs derived from a generalisation of some databases, including WOCAT based on suitability of soil properties and field characteristics. At first suitable options are identified based on the local characteristics e.g. slope, land use and precipitation. The suitable AMPs are then ranked and presented in order of priority, according to prevalence of threats they are known to address (Fleskens et al., 2017). The app provides a brief description of the AMP and a cost indication on a scale from low to high. The app gives a total of 10 AMPs.

Annex C - Strategic Field Visits

Methodology*:*

App runs:

Data provided by the app was directly contrasted with data collected by the project team or, in some cases, other dependable scientific sources. For each farm visited, app inputs were assembled for a representative field site (altitude, annual precipitation, landscape position, slope, and land cover). The app was run for this coordinate. First, field characteristics predicted by the app were recorded and the app was run with these initial inputs. Results for soil properties, soil threats, and recommendations were recorded. Second, field characteristics assembled by the project team were used to run the app. Results for soil properties, threats, and management advice have again be recorded for this second run. This process was repeated if a single farm is large enough and field characteristics vary significantly across the area. In this case fields of a single farm were handled individually.

Field assessments:

In order to characterize soil properties, we used a Visual Soil Assessment tool (VSA) as described by ISQAPER (Alaoui & Schwilch, 2016) to assess soil quality. To ensure the applicability of the assessment method in our study area, it should be validated using dependable local data. To do so, 6 sets of lab data were acquired from UMH, farmers and cooperatives, which we used to compare to our VSA results. In this way, we ensured that the data we collected during the rest of the project is applicable within the study area. .

Sampling Design

The measurements sought and methodologies employed in our field assessments are outlined in the table below. Some properties will be evaluated using techniques outside the scope of a VSA: grain size analysis was conducted using a VSA technique, bulk density calculated from penetrometer readings, pH tested with a kit, and electric conductivity tested with a kit as well.

In order to get representative data, the simple random soil sampling method was used. At least two replicates of each measurable parameter were collected per sampling site. This may vary depending on the size and heterogeneity of the farm. Soil samples were collected from (0- 40) cm in depth in arable crop fields. This may increase in farmers’ fields with tree crops in order to get measurable data within the rooting zone.

Table 1: Soil properties included in the app and methods we will use to measure them.

Soil property	Measureable	Tool	Lab data
Physical properties			
Depth to bedrock (cm)	✓ (up to 50cm)	VSA (Shovel)	✓
Bulk density (kg/m3)	✓	Penetrometer	✓
Clay (%)	✓	VSA	✓
Silt (%)	✓	VSA	✓
Sand (%)	✓	VSA	✓
Course fragments (%)	✓	VSA	✓
Water storage capacity (mm)	✗		✗
Chemical properties			
Soil organic carbon (%)	✗		✓
Soil pH	✓	pH/EC meter	✓
Cation ex. capacity (cmolc/kg)	✗		?
Electrical conductivity (dS/m)	✓	pH/EC meter	✓
Exchangable K (cmol/kg)	✗		✓
Available P (mg/kg)	✗		✓
Total N (g/kg)	✗		✓
Biological properties			
Soil microbial abundance	✗		✗
Soil macrofauna group	✗		✗

Soil Threats

During our field visits, a number of methods were employed to identify soil threats. Some threats were directly measured and recorded whereas others were assigned a score. As our means and materials were limited, there were several threats, included in the app, that couldn't be evaluated. Aside from the *Soil Erosion* threat, our methods were derived from the ISQAPER Visual Soil Assessment guidelines (Alaoui & Schwilch, 2016).

For threats that were able to be directly quantified using the same units as the app, measured values were compared directly to the probability distribution function and exact values provided by the app. For each curve, as with soil properties, ranges are delineated to classify the results as either low, moderate, or high risk. Thus, we assessed the deviation between measured and SQAPP values and where these points fell within these classifications. For threats which couldn't be directly quantified, we used our own scoring method to determine whether risk posed is low, moderate, or high, and compared our classification to that of the app. A breakdown of these threat assessment methods is provided below:

Table 2: Soil threats included in the app and methods we will use to measure them.

Threat/ Indicator	✓ Recorded / → Scored	App Output (unit)
Acidification		
pH (-)	✓ Recorded	pH (-)
Erosion		
Stocking Method	→ Scorecard	Rate (ton/ha/yr) Risk (L/M/H)
Compaction		
Penetrometer Management VSA	→ Scorecard	Risk (L/M/H)
Salinization		
EC (dS/m)	✓ Recorded	dS/m
Biodiversity Decline		
Lab Data	→ Scorecard*	Index (L/M/H)
SOM Decline		
Lab Data (%)	✓ Recorded*	%
Nutrient Decline		
Lab Data	✓ Recorded*	Available P Total N Exchangable K
Contamination		
Lab Data	✓ Recorded*	Highest Heavy Metal Concentration

* *Method of recording/classification depends on format of lab data*

- **Soil Erosion**
  Based on Stocking's (2013) handbook, we distinguished erosion by wind and water as different processes. Based on the indicators, observations and field characteristics, we judged both wind and water erosion on a qualitative, ordinal scale. Stocking's method uses indicators like *rills, gullies, root exposure, rooting depth, armour layer, pedestals* and more. Since the time aspect of erosion is very hard to assess, we only considered soil erosion on a qualitative level, based on these indicators. To identify these indicators, we used scorecards.

  Wind erosion was assessed on a ordinal scale, on which 0 represents good conditions, 1 moderate conditions and 2 indicates a poor condition. With this method we could only assess the susceptibility to wind erosion and not the actual amount of sediments being transported by wind. The classification was based on a method described by the University of Hertforshire (2011).

- **Compaction**
  To check the actual level of compaction in the field, used the penetrometer and a

combination of two empirical formulas. The penetrometer gives a *penetration resistance (kPa)*. We have to note that the compaction is depending on more than just penetration resistance, depth, bulk density and clay content. The parameter we did not take into account was soil water content. The main reason for leaving the soil water content out of our scope is that it can vary strongly based on the weather and seasonality. Together with the *depth* of the penetration, the bulk density was estimated using the following formula (Hernanz et al., 2000):

$BD = 0.913\ PR^{0.096} \times d^{-0.061}$

in which
BD = Bulk Density (Mg m-3)
PR = Penetration Resistance (kPa)
d = Depth (cm)

With this bulk density value, we determined the *apparent compactness* of the soil, which is used as an indicator for compaction by SQAPP. To do so, we used the following formula (Jones, 2003):

$PD = BD + 0.009C$

in which PD (t m-3) is the *apparent compactness* and BD and C respectively represent bulk density (t m-3) and clay content (% wt).

These formulas combined gave us the follow formula to determine the *apparent compactness*:

$PD = 0.913\ PR^{0.096} \times d^{-0.061} + 0.009C$

- **Salinization**
  State: Electro-conductivity (dS m-1) using an EC-meter.
  Classification: The ISQAPER project provides a list of threshold values for many crops that can be used to for classification of the threat. A printed version of this table was used during field work to assess the validity of the app's classification system, compared with our measured data (Barão & Basch, 2017).

- **Soil Organic Matter Decline**
  Left out of our scope due to insufficient means and materials. Can only be assessed if the farmer has more elaborate soil quality data.

- **Biodiversity Loss**
  Left out of our scope due to insufficient means and materials. Can only be assessed if the farmer has more elaborate soil quality data.

- **Soil Contamination**
  Left out of our scope due to insufficient means and materials. Can only be assessed if the farmer has more elaborate soil quality data.

- **Acidification**
  State: pH
  Classification: The app checks the current pH level and classifies it. We measured the pH in the field at a depth of 10cm and 40 cm by using a pH meter. We took the average of the two measured values and compared this to the app's output.

- **Nutrient Depletion**
  State: Essential nutrients for plant growth: N, P, K. could only be assessed if the farmer had more elaborate soil quality data. A lot of nutrient data was supplied by a farmer cooperative and the essential nutrients were compared to the app's output.

Annex D - Questionnaire Results

Table 3: Questionnaire Results - Soil Properties

Soil properties	Score
Depth to Bedrock	4.3
Bulk Density	3.6
Cation Exchange Capacity	3.1
Course Fragment (volume)	3.1
Phosphorous using the Olsen method	3.6
Exchangeable potassium	3.6
Soil microbial abundance	3.8
Soil macrofauna groups	3.7
Soil Organic Carbon	3.8
Soil pH	4.4
Plant-available water storage capacity	4.3
Silt content	3.4
Sand content	3.7
Clay content	3.8
Total Nitrogen in Soil	4.2
Electric conductivity	3.4

Table 4: Questionnaire Results - Soil Threats

Soil threats	Score
Soil Erosion By Wind	4.6
Soil Erosion By Water	4.7
Compaction	4.3
Salinization	4.5
Soil Organic Matter Decline	4.4
Soil Biodiversity Loss	4.3
Soil Contamination	4.6
Acidification	4.2
Nutrient Depletion	4.7

Table 5: Questionnaire Results - Soil Management Recommendations

Recommendations	Score
Minimum Tillage	4.7
Strip Cropping	4.3
No Tillage	4.6
Using Deep-Rooting Crops	4.2
Liquid Manure/Slurry	4.2
Apply Animal Manures	4.9
Use Inorganic Fertilizers	4.4
Crop Rotation	5
Compost Application	4.7
Conversion to Grassland	3.6

Annex E - VSA Validation Discussion

- **Texture Class**

Determination of the soil texture class is dependent on three soil parameters: *clay content, silt content* and *sand content.* Comparing our VSA results with available lab data (n=3) shows that *silt content* and *sand content* can be estimated well with our method as lab data values match our predicted soil texture class in all three cases. For *clay content,* however, the results match only once. Therefore, the ability of our VSA to assess this parameter is up for debate. As all three parameters were derived using the same test, *silt* and *sand content* results should be viewed with some scepticism.

- **Coarse Fragments**

None of the acquired lab datasets contained data regarding coarse fragments present in soils. Therefore, the validity of measurements for this parameter remains uncertain. Although the method is simple and reproducible, the limited number of samples taken within each VSA could limit the accuracy of the measurements.

- **pH**

The acidity of the soil was measured using a portable pH meter. Comparison of VSA versus lab data shows that the results there is some deviation between the measured values and the lab data, as illustrated in the graph below. However, this deviation is small and our VSA was not constantly over or underestimating the pH. Therefore, we can deliberately use our VSA data for soil pH to assess the app's accuracy.

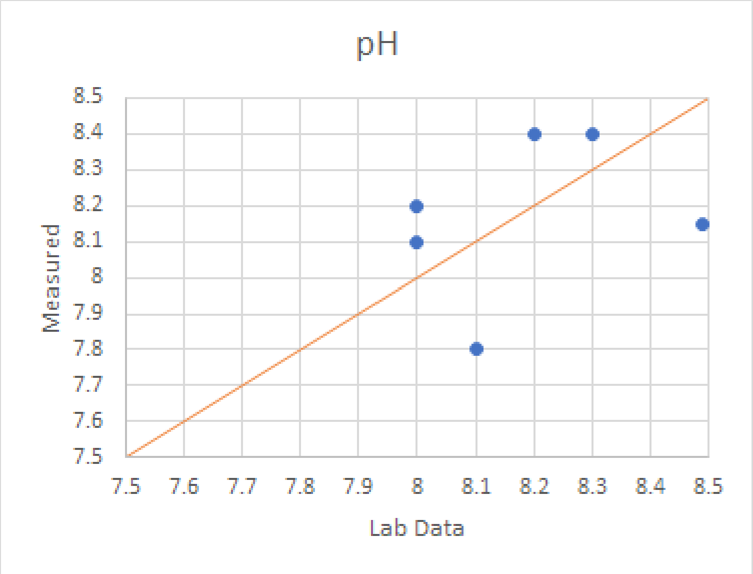

Figure 2: pH values from lab analysis and VSA (n=6)

- **Electrical Conductivity**

For measuring the soil's electrical conductivity, a portable digimeter was used. Differences between VSA results and lab data were substantial, but clearly in the same order of magnitude, as the graph shows.

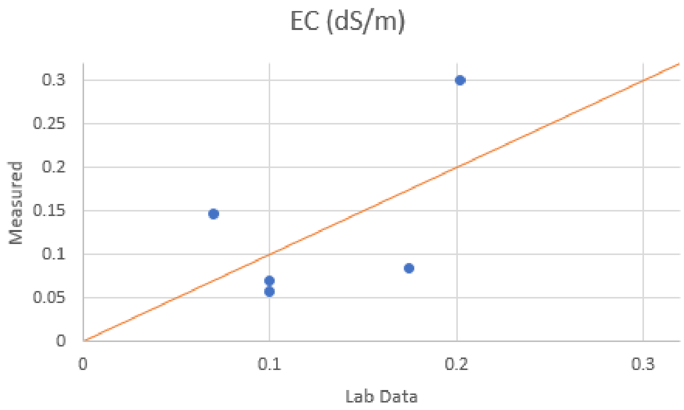

Figure 3: EC values from lab analysis and VSA (n=5)

- **Bulk Density & Compaction**

The lab and VSA datasets from UMH we acquired did not include any data for bulk density or compaction, which makes it impossible to validate our VSA method. This shortcoming needs to be considered while using measurement results to draw conclusions on the performance of the app

Annex F - Results App Accuracy Assessment

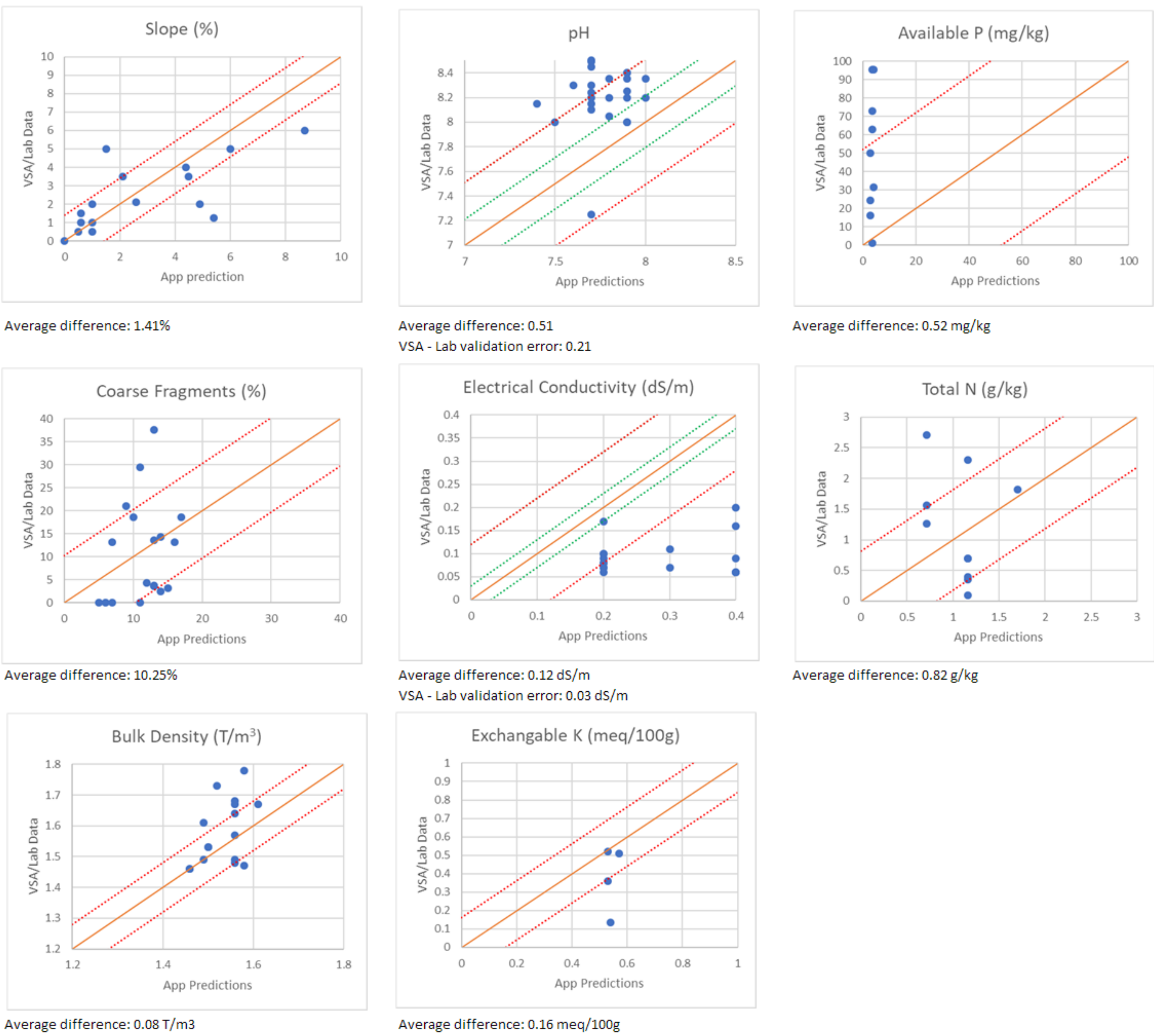

Figure 4: *Visual representation of VSA results and app predictions. Red lines indicate the average difference between app and vsa/lab. Green lines represent the average difference between VSA data and lab data, resulting from our VSA validation and together form an error bar.*

Table 6: Sites used in the study. Red squares indicate sites used for validation of VSA.

Farm ID	CA 001	**CA 002**	EL 001	**AL 001-1**	AL 001-2	CLF 001	CLF 002	CA 003-1	CA 003-2
Date	15-6	15-6	14-6	18-6	18-6	19-6	19-6	20-6	20-6
Coordinates	39.051 / -0.522	39.087 / -0.509	38.165 / -0.713	38.840 / -0.511	38.841 / -0.511	38.774 / -0.833	38.776 / -0.834	39.066 / -0.533	39.066 / -0.534
Farm ID	CA 004-1	LL 001-1	LL 002-1	CA 005-1	L-CA 006	**EL 002**	BI002	BI001	
Date	20-6	20-6	20-6	20-6	21-6	22-6	25-06	25-06	
Coordinates	39.086 / -0.511	39.275 / -0.529	39.279 / -0.548	39.068 / -0.465	39.086 / -0.513	38.194 / -0.737	38.627 / -0.781	38.657 / -0.788	
Farm ID	MO001 / L-UMH-001	MO002	**VI 001**	L-UMH-2	L-UMH-3	L-UMH-4	**L-UMH-13**	L-UMH-14	
Date	26-6	26-6	26-06						
Coordinates	38.823 / -0.808	38.822 / -0.807	38.563 / -0.972	38.82999 / -0.81606	38.39858 / -1.38761	38.41942 / -1.36237	38.04619 / -0.8793	38.0463 / -0.87963	

Table 7: Results threat classification comparison

		Classification App - VSA/Lab				
	n	-2	-1	0	+1	+2
Salinization	18	0	0	18	0	0
Compaction	18	0	3	13	2	0
Water Erosion Risk	19	1	3	11	4	0
Acidicifation	20	1	13	4	2	0
Wind Erosion Risk	11	0	0	0	6	5

Annex G - AMPs Relevance Analysis

	Farmer	Site	Characteristics	Threat needing attention	Parameters needing attention	Recommendations
1	CA001	Citrus	Permanent + cover Drip Irrigation	Plant available water storage capacity, bulk density, Phosphorus	Susceptibility to compaction	Minimum Tillage, Apply Animal Manure, No-Tillage, Compost Application, Planting Pits, Flood Irrigation, Sprinkler Irrigation, Controlled and Rotational Grazing, Area Closure, Liquid Manure or Slurry
2	CA002	Kaki	Permanent + No Cover Drip Irrigation	Bulk density, plant available water storage capacity, soil carbon.	Susceptibility to compaction, Phosphorous	Minimum Tillage, No-Tillage, Apply Animal Manure, Compost Application, Ridge-furrow system, Flood Irrigation, Sprinkler Irrigation, Liquid Manure or Slurry, Avoidance of Traffic, Controlled Traffic.

3	EL 001	Pomegran ate	Permanent + No cover Flood Irrigation	Soil pH, Potassium	Phosphorous Nitrogen	Apply Animal Manures, Compost Application, Minimum Tillage, No-Tillage, Liquid Manure or Slurry, Avoidance of Traffic, Controlled Traffic, Drains, Straw mulch, Ridge furrow systems
4	AL 001-1	Peach	Permanent + Cover Drip Irrigation	Phosphorous ,	Water erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to Compaction, Phosphorous	Apply Animal Manure Minimum Tillage Compost Application No tillage Avoidance of Traffic Chipped Branches Controlled traffic Flood Irrigation Sprinkler Irrigation Controlled and Rotational Grazing

5	AL 001-2	Apricots	Permanent + Cover Drip Irrigation	Phosphorous	Water erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to Compaction, Phosphorous	Applying Animal Manures Compost Application Minimum tillage No tillage Liquid manures Avoid traffic Controlled traffic Chipped branches Planting pits Flood irrigation
6	CLF 001	Vineyard	Permanent + No Cover Rainfed	Bulk Density	Water erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to Compaction, Phosphorous	Minimum tillage No tillage Apply animal manures Compost application Straw mulch Ridge furrow systems Flood irrigation Sprinkler irrigation Liquid manure slurry Avoidance of traffic

7	CLF 002	Vineyard	Permanent + No Cover Rainfed	Soil pH	Water erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to Compaction, Phosphorous	Compost Application Liquid manure or slurry Apply Animal Manures Chipped Branches Straw Mulch Ridge-Furrow System Flood Irrigation Sprinkler Irrigation Minimum Tillage No-Tillage
8	CA 003-1	Kaki	Permanent + No Cover Drip Irrigation	Nitrogen	Susceptibility to compaction, Phosphorous, Nitrogen	Apply animal manure Compost application Minimum tillage No-tillage Avoid traffic Controlled traffic Chipped branches Strawed mulch Ridge furrow systems Avoidance of traffic

9	CA 003-2	Young Orange Trees	Permanent + No Cover Drip Irrigation	Nitrogen	Susceptibility to compaction, Phosphorous, Nitrogen	Compost application Minimum tillage No-tillage Apply animal manures Controlled traffic Chipped branches Straw mulch Ridge-furrow systems Flood irrigation Sprinkler irrigation
10	CA 004-1	Navel Oranges	Permanent + Cover Drip Irrigation	Soil Organic Carbon	Susceptibility to compaction, Phosphorous	Apply Animal Manure Minimum Tillage No-Tillage Compost Application Flood Irrigation Sprinkler Irrigation Controlled and Rotational Grazing Area Closure Liquid Manure or Slurry Avoidance of Traffic

11	LL 001-1	Oranges	Permanent + No Cover Drip Irrigation	Soil Organic Carbon	Water Erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to compaction, Phosphorous	Minimum tillage No-tillage Apply animal manures Compost application Planting pits Straw mulch Ridge-furrow systems Flood irrigation Sprinkler irrigation Avoidance of traffic
12	LL 002-1	Peach/Apricot	Permanent + No Cover Flood Irrigation	Nitrogen	Water Erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to compaction, Phosphorous	Compost application Minimum tillage No-tillage Apply animal manures Chipped branches Bunds Planting pits Straw mulch Half-moon terraces Ridge furrow systems

13	CA 005-1	Pomegranate	Permanent + No Cover Drip Irrigation	Plant Available Water Storage	Susceptibility to compaction, Phosphorous	Apply animal manures Compost application Minimum tillage No-tillage Avoidance of traffic Controlled traffic Chipped branches Straw mulch Ridge furrow system Flood irrigation
14	EL 002	Grassland	Rotational Grazing Rain Fed	Nitrogen	Susceptibility to compaction, Potassium, Phosphorous, Nitrogen	Conversion from grassland to forest Apply animal manures Compost application Submerged drains Area closure Sprinkler irrigation Liquid manure or slurry Avoidance of traffic Controlled and rotational grazing Drains

15	BI002	Olive	Permanent Crop + No Cover Rainfed	Exchangeable Potassium	Water Erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to Compaction, Phosphorous, Nitrogen	Compost app Liquid manure/slurry Animal Manures Inorganic fertilizers Green manure Leguminous crops Bunds Planting pits chipped branches ridge-furrow systems
16	BI001	Potato	Arable + No Cover	Bulk Density	Water Erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to Compaction, Phosphorous	Retain crop residues Claying Soils Conservation Agriculture Deep rooting crops Apply animal manures Min tillage Conversion to grassland No-tillage Compost application Crop rotation

17	MO001	Vineyard	Permanent + No Cover Drip Irrigation	Plant Available Water Storage.	Water Erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to Compaction, Phosphorous	Apply animal manure Compost application Minimum tillage No tillage Avoidance of traffic Liquid manure or slurry Controlled traffic Chipped branches Planting pits Straw mulch
18	MO002	Vineyard	Permanent + Cover Drip Irrigation	Plant Available Water Storage	Water Erosion Vulnerability, Wind Erosion Vulnerability, Susceptibility to Compaction, Phosphorous	Minimum tillage Apply animal manure No tillage Compost application Flood irrigation Sprinkler irrigation Controlled and rotational grazing Area closure Liquid manure or slurry Avoidance of traffic

Remarks

1. Site 4 (AL 001-1) & 5 (AL 001-2) are plots within the same farmers' field. Whilst the app identified the same threats and parameters needing attention. The app provided similar recommendations but in different order of priority. This was similar for farmer 8 (CA 003-1) & 9 (CA 003-2).
2. For sites 17 (MO001) and 18 (MO002), the app identified the exact same threats and parameters needing attention but provided different recommendations. The only difference between site 17 & 18 was soil cover.
3. The app recommended sprinkler and flood irrigation for sites 8 & 9 when they both had drip irrigation already in place.
4. For site 17 the app suggested claying soils when the threat that needed attention was susceptibility to compaction. Soils with finer particles like soils with higher clay content are more susceptible to compaction (Batey, 2009).

Annex H - Interviews

Interview 1
ID: EL001

Farmer details

Name: Fernando Anton Vidal
Address: lat 38,165 long -0,713
Contact: nandoanton@gmail.com; +34 678732902
Gender: M *Age: +- 40* *Years at location:* 8

Farm characteristics

Crop type(s): Pommegranate (also grows melons, and alfalfa, and a plot of fallow land that were not observed in the visit) Irrigation: flood irrigation		
Farm type: Conventional, managed as ecologic (but not certified) *Farm size:* 2ha pomegranate 0.5ha melons		
Ownership/Labour: Owner, own labour.		
Annual Precip *+- 350 l*	*Slope* *Very low*	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- The soil is not analysed
- The farmer uses colour as a soil quality indicator, linking a darker colour with higher soil quality.
- The soil "smoothness" and "how it absorbs water" are also important indicators that he uses. He links those indicators to soil salinity.
- He describes his soil as loamy clay, with high salinity and with high content of calcium.
- He considers his soil to be of a general good quality, however the salinity and the clay limits the type of crops he can grow. Well suited for pomegranates or melons, but unsuited for tomatoes, for instance.
- He sees his soils are naturally low in organic matter.

Soil threats

- He identifies salinity as the bigger threat to his soils (this is due to the multiple times used irrigation water, that has been drained from fields upstream).
- He does not observe organic matter decline, due to the organic fertilisers he adds.
- He does not identify erosion occurring in his field, neither by wind or water.
- No general problems of nutrient decline, as long as he applies fertilisation yearly.
- According to the farmer compaction may occur if salinity is not managed properly.

Management practices

- The area is designated as a SPA (special protection area) for wild birds, embedded in the framework of natura 2000. This limits the management options and the nutrients he can apply.
- To manage high salinity content he needs to “wash” the soil in winter, when more water is available, with a much more lower value of salinity.
- He applies manure and liquid humus yearly in the plot.
- The amount of manure (goat and sheep) he applies is based on the expertise given by the agricultural technician, following the limitations marked by the SPA.
- Usually, he left the pomegranate as a grazing area starting at the end of autumn for the goat and sheep of another farmer (retired this year). He identified this practice useful to control weeds and to enhance soil fertility.
- He works with the rotovator twice a year, and ploughs at half a meter deep (at least) once a year. He finds this practice necessary to break the layers formed by the salts of irrigation water, that he argues could damage the roots and hamper infiltration.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Agrees on the values given. Unable to specify specific values but texture class is correct.
Chemical	Agrees with the properties given, but unable to understand the specific values or certain indicators (CEC), Does not consider his soil is poor in nitrogen, especially when its irrigated with multiple times used water. **The lack of data of salinity is a drawback since the app is not able to identify his considered main threat.**
Biological	Does not know about biological indicators used by the app.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), *orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).*

Threat	App	Agreement/comments	Farme
Soil erosion by water		Not happening	
Soil erosion by wind	ND	Not happening	
Soil compaction	ND	Compaction due to salinity is a problem that needs heavy tillage once every two years.	
Soil salinisation	ND	Salinity is the biggest threat for him	
Soil OM decline		He applies organic manure and amendments, he is satisfied with the organic matter in his plot.	
K		Does not agree with the low nitrogen value. Its soil is not particularly infertile, with the organic amendments he adds is more than enough to satisfy the pomegranates requirements.	
P			
N			
Acidification		Agrees on a high soil pH. He is not concerned though about the impacts that may have.	
Contamination		Unaware	
Biodiversity	ND	Does not know	

From the recommendations given:

- Apply animal manures -- He already does
- Compost application -- He considers unnecessary due to the liquid humus and the manure applied
- Avoidance or controlled traffic: keeps traffic of machinery to the indispensable works.
- Minimum tillage and no-tillage -- He considers the recommendation infeasible due to the need to break the compact layers formed by salts.
- Liquid manure or slurry -- (applies liquid humus)

General position on the recommendations:

The farmer believes that the recommendations are too broad and general, some of them are redundant with the practices already established, which are unavoidable once you get to know your own land. He feels that the app is not very well adapted to the local situation, as it misses the salinity problem, which is his biggest threat, and, therefore, does not generate recommendations to tackle it.

App functionality and opinions

- He finds that the app could be better suited to future investors in the land to get more information on the soil before they acquire it.

Interview 2
Farm ID: CA001
Farmer details

Name: Jesús Higon
Address:--
Contact: 0034 653638290
Gender: male Age: 53 Years at location: All his life

Farm characteristics

Crop type(s): *Orange*		*Irrigation: Automated drip*
Farm type: *Conventional*		*Farm size: 0.5 ha (5 fanecaes)*
Ownership/Labour: Not owner, works lands of people from Valencia.		
Annual Precip Very variable, from 300 up to 500	*Slope* Medium, compensated by the terraces	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- He describes his soil as a well draining reddish soil, he has a term called "gravó", which may refer to a high content of gravel. Thus, with not a very high content of clay. Nevertheless, he denies his soil being sandy, as the other soils found in the fluvial area.
- Calcaric soil with low organic matter
- He does not monitor soil quality with laboratory analysis.
- The possible deficiencies in nutrients are read through the performance of the plant and colour of the leaves.

Soil threats

- Does not recognise soil erosion occurring in the field, neither by water or by wind. The terraced system prevents soil from being washed away.
- Compaction occurs, but maintains that the soil is able to infiltrate a good "enough" amount of water.
- The amount of organic matter is low, but that not seems to affect the performance of the crop.
- The fertility of the soil is not bad, however, support of NPK is needed.

Management practices

- Fertilisation is applied with the irrigation system.

- Drip automated irrigation system.
- Pre-emergency and post-emergency herbicides are applied regularly.
- Pruning residues are crushed and left in the soil
- Once every two years he breaks the soil with tillers.
- Additions chelates to increase availability of iron in the soil. According to the cooperative recommendations.
- Adds different ratios of NPK according to the advice provided by the cooperative technicians.
- Yearly pulverisation of the plant with fungicides and insecticides to prevent diseases.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Does not make many comments on the results, agrees that could be assertive values, he would be unable to give values for the indicators. Agrees on the texture.
Chemical	Accept the rank of the values given, would be unable to give specific values for the chemical properties, but recognises low organic matter, high pH, low salinity. Ignores specific values for nutrient content, **although states that iron and micronutrients** (specially Zn and Mn**) are essential for proper citrus management, which is not provided by the app** and can be deficient in some seasons.
Biological	Does not know about biological properties

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).

Threat	App	Agreement/comments	Farme
Soil erosion by water		Does not recognise water erosion happening in the field, due to the structured terraces in which it is cultivated. He argues, though, that in very extreme events, some soil can be lost at the terraces edges.	
Soil erosion by wind	ND	Not happening	
Soil compaction		Soil can become compact.	

Soil salinisation		Not happening		
Soil OM decline		Agrees. Soil naturally poor in OM.		
K		In terms of nutrients he agrees that the soil can be poor in some (without specifying), due to the sequestration of the nutrient by the calcareous material.		
P				
N				
Acidification		Agrees, seems not an issue to monitor.		
Contamination		Not aware of		
Biodiversity	ND	Does not know		

Recommendations

- Compost application: Not considered, inorganic fertiliser easily applied through the irrigation system and acquired through the cooperative.
- Minimum tillage: Only tills once every two years without turning the soil
- Animal manures: Not considered, inorganic fertiliser easily applied through the irrigation system and acquired through the cooperative.
- No-tillage: Only tills once every two years without turning the soil
- Avoidance of traffic: Low traffic already in place, the traffic present for pulverisation and chipping prunnings can not be minimised.
- Controlled traffic: Low traffic already in place, the traffic present for pulverisation and chipping prunnings can not be minimised.
- Chipped branches. Prunnings already smashed and left in the soil.
- Planting pits: Unconsidered practice, does not seem to be interested.
- Flood irrigation: Definitely not an option, transformed to drip irrigation
- Sprinkler irrigation: Definitely not an option, transformed to drip irrigation

App functionality and opinions

- He recognises that soil is becoming a more important subject on farming, up until the moment, the only parameter to look at was the plant health status.
- The information he requires from the soil is mainly related to nutrient, for which he gets technical advice from the experts in the cooperative, that produce a fertiliser plan for him.
- He believes that the app could be much more useful for technicians, agronomic experts or land managers, in order to produce advise for the farmers, rather than being the farmer itself the one to obtain and interpret that information.

Interview 3
Farm ID:
Farmer details

Name: Cecília
Address:--
Contact:--
Gender: *F* *Age:* *48* *Years at location:* 20 years

Farm characteristics

Crop type(s): Persimmons	*Irrigation:* Drip irrigation	
Farm type: Conventional	*Farm size:* 1ha	
Ownership/Labour: Agricultural advisor, does not own the land visited.		
Annual Precip 450l	*Slope* 1%	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- Sandy clay soil
- Very low amount of organic matter
- High calcium carbonate content

Soil threats

- Erosion by water does not occur in that flat lands.
- No wind erosion
- Compaction is superficial, due to the dry soil and the formation of crust. The sandy soil is not easily compacted.
- No salinity.
- Extremely low value of organic matter decreasing due to the increased use of inorganic fertilisers instead of manure.
- High soil pH that may reduce the availability of iron.
- Nutrients are highly immobilised, more organic matter would help increasing their availability.

Management practices

- She stated that farmer applies fertiliser through the irrigation systems, besides that, there is no more input.
- Chipped branches are crushed and left in the soil.

- Soil is tilled with a rotovator once every two years.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Agrees
Chemical	Disagrees in organic matter content, that must bue lower. Total nutrients could be higher, but not available.
Biological	Unaware of the values for biological indicators.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).

Threat	App	Agreement/comments	Farme
Soil erosion by water		Not happening.	
Soil erosion by wind	ND	Not happening	
Soil compaction		Soil can become compact only superficially.	
Soil salinisation		Not happening	
Soil OM decline		Agrees. Soil naturally poor in OM (even lower value than the one presented by app)	
K		Nutrients present but not available due to the immobilisation of the nutrient by the calcareous material.	
P			
N			
Acidification		Agrees.	
Contamination		Not happening	
Biodiversity	ND	Does not know	

The interviewee is not the owner of the land, therefore, she is unable to decide whether a recommendation will be applied by the farmer or not, nevertheless, the following recommendations were discussed, taking into account her expert opinion;

- Apply animal manures: This is definitely what she recommends to farmers.

Increasing the organic matter can also increase the amount of available nutrients, due to the interacting charges between nutrients, carbonates, and organic matter surfaces.

- Compost application: Similar to the first recommendation, but manures are cheaper and far more available.
- Minimum tillage and no-tillage: In citrus and persimmons plantations, there is not too much ploughing and tilling of the land.
- Avoidance and controlled traffic: Machinery is indispensable to the agricultural system of the area, however, the traffic is not excessive, since the land is hardly tilled.
- Chipped branches: A very common practice, almost ubiquitous in the area.
- Straw mulch: Same opinion as the application of compost.

App functionality and opinions

- Farmers hardly rely on soil data, and they are not completely able to understand it.
- Farming practices are deeply rooted in farmers beliefs. A modification of the practices would imply a much harder to achieve change of behaviour and mindset.
- Technicians, however, do understand and translate soil data to farmers. In that sense, the app could be of much more use for them.

Interview 4
Farm ID: AL001 & AL002
Farmer details

Name: Damaso
Address:--
Contact:--
Gender: M Age: 65 Years at location:

Farm characteristics

Crop type(s): Peach, saturn peach, persimmons Irrigation: Drip irrigation		
Farm type: Biodynamic Farm size: 14ha		
Ownership/Labour: Owner (but does not work the land)		
Annual Precip *250/300 l*	*Slope* Sloped land managed with terraces	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- He defines the soil as alkaline clayish soils, *"it is not a strong soil but good for fruit growing".*
- Good for maintaining cool temperatures, not a very dry soil.
- Naturally poor in organic matter

Soil threats

- Does not identify water erosion or wind erosion occurring in his fields.
- Neither compaction or salinity are recognised as occurring threats when the farmer was asked.
- Regular amendments with organic matter are necessary in order to maintain it at adequate levels, since it is a soil naturally prone to loose it.
- The fertility of the soil is low, and according to the farmer it requires more input than other soils in nearby areas.
- No problems of extremes of ph, nor pollution

Management practices

- Organic liquid fertiliser (biodynamic), decomposed nettles and algae, applied through the drip irrigation system.
- Manure application once a year
- Rotavator maximum at 20-25cm
- Drip irrigation system to increase productivity and to support the plants under dry

periods. Has a whole system of water self-supply.
- The rests of the prunnings from the trees are crushed and buried in the soil, adds extra organic matter.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Unable to agree in the specific values. Agrees on the general qualitative meaning of the values, however, feels that texture should be more clayish.
Chemical	Agrees with the properties given, but unable to understand the specific values or certain indicators (CEC).
Biological	Does not know about the biological indicators used by the app.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).

Threat	App	Farmer agreement/comments	Farme
Soil erosion by water		Not happening	
Soil erosion by wind	ND	Not happening	
Soil compaction		Not happening	
Soil salinisation		Not happening	
Soil OM decline		He agrees on the low values of OM and he needs to add constant amendments to keep them at adequate levels.	
K		He has an infertile soil, so he needs external input of nutrients in the field.	
P			
N			
Acidification		Soils may have high pH, but not at all extremes or concerning.	
Contamination		Unaware	

Biodiversity	ND	Does not know	

From the recommendations given, the following were discussed with the farmer;

- Minimum tillage and no-tillage: The farmer uses only the rotavator once a year in a very superficial way, very unlikely to change this practice that he already considers it minimal but necessary.
- Apply animal manures: He already applies cow manure.
- Apply compost: He applies biodynamic liquid compost.
- Planting pits: Understands the meaning of the practice and its function, agrees it is a nice practice. [Seems uninterested though in implementing it or on how much use would it be in his situation].
- Flood irrigation: Unnecessary since he is pleased with the efficiency and automation of the drip irrigation system.

App opinions

- *"Nowadays the figure of the farmer is being lost, the owner now are not dependable only on the land to feed their families, it becomes a business oriented model, specialised workers carry out the decision taken by the managers, which are the responsible to get information on their fields and act upon it. In that context, the application may result useful to give extra information to make right decisions"*
- Regardless of the opinion expressed on the interest of such information becoming available, the farmer states that he is not likely to use the app, as he obtains soil information from advisors and the technicalities of it are interpreted by them.

Interview 5
Farmer ID: CLF001
Farmer details

Name: Maria José Velázquez
Address:
Contact: *mj.velazquez@bodegaslosfrailes.com*
Gender: *F* *Age:* *40-45* *Years at location: Family holding (more or less involved during her life)*

Farm characteristics

Crop type(s): *Vineyard*		*Irrigation: Rain fed*
Farm type: *Organic*		*Farm size:* *130ha*
Ownership/Labour: *Co-owner*		
Annual Precip	*Slope*	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- Has a complete geological survey carried out in 2016
- She describes the soil as formed by sedimentary carbonate rock (dolostone) with a high content of magnesium carbonate.
- Her soils are heterogeneous in the profile, some with a higher content of clay and calcium than others. Generally, soils with high clay content.
- Naturally poor soils in organic matter.

Soil threats

- One of the main threats regarding the productivity is water availability and nutrients, since the high content of calcium carbonates blocks the nutrients present in the soil.
- Soil erosion by water is observed in some events, that is controlled by the built terraces.
- No problems of pollution are identified, and extremes of pH are not mentioned, since that seems not to have huge impacts on the productivity.
- Soil organic matter is a worrying issue that needs to be managed with external input. The decline in organic matter lowers the availability of nutrients and

deteriorates soil structure, which, eventually, diminishes water availability for the plant.

Management practices

- A big quantity of compost is applied in the vineyards.
- Terraces are built and maintained to prevent erosion.
- Green cover is sown in the soil between the vines to decrease evaporation from the soil and to add an extra input of organic matter when the crop is buried.
- Prunnings are crushed and left in the soil.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Disagrees on the value given for clay content (should be higher). Would like to see how the percentage of coarse fragments may relate to overall soil quality. The plant-available water storage capacity at 30cm is not reflecting what happens at the root zone of the vine, she doubts on the utility for her of that indicator.
Chemical	Expresses interest on the values given, and seems to agree on them all. She is interested on how this values compares to her soil analysis, which, as much as she can recall seem to be both in the same line. **The active lime content is a very important indicator for her that is not given, as it determines the degree of sequestration of nutrients by the soil.**
Biological	Was not aware of biological soil indicators to express soil quality. She expresses interest on this indicators, however she misses if the values given are good, to be expected or bad.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).

Threat	App	Farmer agreement/comments	Farme
Soil erosion by water		Due to intensive rainfall, erosion events occur, therefore, measures to prevent soil loss are necessary.	
Soil erosion by wind	ND	Not happening.	
Soil compaction		Feels that compaction is an occurring threat, due to the percentage of clay content, and machinery traffic should be kept as a minimum.	

Soil salinisation		Not an issue.	
Soil OM decline		Soils are naturally poor in organic matter and big amounts of compost inputs are required.	
K		Due to the active limestone, many nutrients may not be available for the plant, therefore, it is important to add the compost, as it brings nutrition and it improves the availability.	
P			
N			
pH		pH are high, however, the implications of the value are not relevant for the production.	
Contamination		Not aware of.	
Biodiversity	ND	Unable to tell.	

About the recommendations given, the following were discussed:

- Apply animal manures: The preferred option is to apply compost [improvement of CEC]
- Compost application: Already in practice.
- Minimum tillage: Already in practice. In fact, no tillage or ploughing of the land is applied besides the burying of the green cover.
- Avoidance of traffic and controlled traffic: Already in practice, machinery traffic on the wine vintage and input applications are considered unavoidable.
- Chipped branches: Already in practice.
- Straw mulch: Deeply interested on the measure, she asks the implications and the benefits of it and how it can be applied.
- Ridge-furrow systems: Considers it unfeasible in vineyards.
- Flood irrigation: Water is not available in the area.

App opinions

- Great source of information that could be used as a supplementary source besides soil analysis.
- Different cultivars should be an input of the app, since the recommendations given may not be useful for all.
- The management system could also be an input, if one is practicing rainfed agriculture, transformation to irrigation may not be feasible where water is not available.

Interview 6
Farm ID: CA003
Farmer details

Name: Eliseo Martí Conca
Address:--
Contact:
Gender: M Age: 55 Years at location: All his life

Farm characteristics

Crop type(s): Oranges and persimmons		*Irrigation: Drip irrigation*
Farm type: Conventional		*Farm size: 13ha*
Ownership/Labour: Labours and manages the land for a big land owner		
Annual Precip	*Slope*	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- No soil analysis are being carried, however, leaf samples from the orchards are analysed sporadically to see any nutrient deficiencies.
- Loamy clay soil
- Highly calcareous soil
- Overall good soil quality for oranges and persimmons, the land is more or less fertile due to the confluences of the two rivers in the region.

Soil threats

- Water erosion is not identified by the farmer, the small terraces protect against any soil loss. However, the recently orchard planted field has been worked in such a way to avoid soil erosion in a u-shaped form.
- Wind erosion does not happen.
- Compaction happens in the field, however, it is desired by the farmer, since it enables the easy transit of machinery through the fields.

Management practices

- Fertirrigation applied through the common irrigation system.
- Additionally, liquid manure is applied twice a year (very good to improve the oxygenation of the soil).

- Soil sprayed with glyphosate two or three times a year
- Prunings crushed and left in the ground
- Trees sprayed yearly with pre emergency fungicides and pesticides
- Tillage of the soil once every two years ("puncturing the soil")

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Agrees on the qualitative meaning of the values given except on the clay content, that argues should be higher.
Chemical	Agrees on the low values for organic matter and high values of soil pH. However, does not know how to interpret the other results. He is not aware of an estimate nutrient content of the soil.
Biological	Does not know about biological indicators used by the app.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it), blue (a happening phenomena but not identified as a threat by the farmer).

Threat	App	Agreement/comments	Farme
Soil erosion by water		Not happening	
Soil erosion by wind	ND	Not happening	
Soil compaction		Happens but desirable.	
Soil salinisation		Does not happen	
Soil OM decline		Aware of the fact, that is the reason behind the application of liquid manures besides the inorganic fertilisers.	
K		Unaware of the values for nutrients in the soil. However, he does not feel that the soil is particularly infertile. It lacks, however, some micronutrients, such as iron zinc and manganese, that are often applied when deficiencies are detected in the tree.	
P			
N			
Acidification		Aware of the high pH, but in his management	

		practices that is not a hampering fact for productivity.	
Contamination		Unaware	
Biodiversity	ND	Does not know	

From the recommendations given, the following were discussed:

- Apply animal manures: Already in practice.
- Compost application: Argues that compost will not have the same benefit as liquid animal manure, with it, the plant has a much higher input of available nutrients.
- Minimum and no tillage: Tillage is only done once every two years.
- Avoidance of traffic and controlled traffic: Traffic is necessary to carry out pulverization works, harvesting, fertilising and pruning (crushing the prunings). Unlikely to reduce it more, (compaction is desirable for better machinery traffic).
- Chipped branches: Already in practice.

App functionality and opinions

- Availability of soil information is important, however, his management is limited to the main tasks given by the technician. The technician, argues, would benefit more from this information, as he does the fertilisation plans.

Interview 7
Farm ID: CA004
Farmer details

Name: Esteve Puertos			
Address:			
Contact:			
Gender: *M*	*Age:* *55*	*Years at location: All his life*	

Farm characteristics

Crop type(s): Oranges (navelina)		*Irrigation:* Drip irrigation
Farm type: conventional		*Farm size:* 1.2ha (plot)
Ownership/Labour: *Labous land for different owners*		
Annual Precip	*Slope*	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- Overall good soil quality for orange production
- Does not analyse the soil.
- Lime content is medium-low compared to other plots in the region
- Sandy loam soil

Soil threats

- Erosion by water is minimum in the plot (flat land)
- No erosion by wind
- Compaction does happen but does not suppose a threat
- No salinity
- Organic matter has declined during the years, He argues that in 40 years it may have gone down from 2% to 0.5% nowadays due to the little input of organic fertilisers.
- No extremes of pH
- No soil pollution

Management practices

- Does not till the land, he considers it an unnecessary practice
- Fertilisation added through the irrigation system. Fertilisers are added in equal proportions for all the members of the scheme.
- Two or three sprays of glyphosate in the soil to control weeds.
- Pulverisation of pre emergency pesticides

- No extra addition of fertiliser besides the inorganic inputs applied by the irrigation scheme.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Without giving specific values, he agrees on the texture class given, but is unaware of the bulk density, coarse fragments or plant-available water storage capacity.
Chemical	Considers the organic matter to be lower than the given value. He esteems it to be 0.5% or even lower. Agrees on the possibility of having a high pH and low salinity. Does not have an opinion on the other properties given.
Biological	Does not have knowledge on biological soil indicators.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it), blue (an occuring phenomena but not identified as a threat by the farmer).

Threat	App	Agreement/comments	Farme
Soil erosion by water		Not happening	
Soil erosion by wind	ND	Not happening	
Soil compaction		Compaction of the soil occurs, but it is not a problem for the orange production.	
Soil salinisation		Not happening.	
Soil OM decline		Soil organic matter is indeed very low, even lower than that predicted by the app. [It is not clear, however, what is the importance of having a high OM content in the soil by the farmer, although concerned by it, no amendments or practices to improve the indicator are being considered by him].	
K		The farmer does not contradict directly the values of nutrients in the soil, he is not aware of what the nutrient contents might be. However, he argues that with the communal	
P			

N		fertirrigation system, is usually input enough.	
Soil pH		Agrees on a high value of pH but not aware of any negative consequences.	
Contamination		Not aware of	
Biodiversity	ND	Does not know	

From the recommendations given by the app, the following were discussed;

- Apply animal manures: This is a measure that should be done, according to the farmer, as it improves organic matter and nutrients in the soil. [However, the farmer does not contemplate applying the measure, when asked, he states that it would increase the production costs, which he has to keep at a minimum, specially when working lands that are not their own].
- Minimum tillage and no-tillage: He does not till the land.
- Compost application: [same discussion and answer as the first recommendation]
- Avoidance of traffic and controlled traffic: Traffic is kept to the minimum, since the land is not ploughed.
- Chipped branches: Already in practice.
- Flood irrigation and sprinkler irrigation: Uses drip irrigation.
- [Controlled and rotational grazing: mentioned but not discussed, considered not relevant in this context].

App functionality and opinions

- All the information provided is good, nevertheless, the information provided by an analysis may be more relevant for a particular site. [Referring in this case, to leaf analysis of the plant].
- Unlikely to use the app, as the technicalities of soils are hardly interpretable. His farming practices are also, not dependant on soil information.

Interview 8
Farmer ID: LL001-2
Farmer details

Name: Jose Vicente Flordelis
Address:--
Contact:--
Gender: M *Age:* 53 *Years at location:* Family land (all his life more or less involved)

Farm characteristics

Crop type(s): Oranges, peaches and apricots *Irrigation:* Drip automated irrigation (except the apricot field which is flood-irrigated, transformation to drip expected in the upcoming years).		
Farm type: *Conventional* *Farm size:*		
Ownership/Labour: Own land (other sources of income as well)		
<u>Annual Precip</u>	*<u>Slope</u>*	*<u>Land cover class</u>* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- Does not analyse the soil
- Sandy loam soil
- Not a very rich soil in OM, however improvements have been made during the years.
- The soil is light and free draining, with a very good structure and nice porosity.
- The soil was before very sandy, due to management practices and soil import, the texture has also improved.

Soil threats

- Water erosion does not occur even though the plot is in sloping land. That is due to the reverse-sloped bench terraces, designed in such a way that water is slowed down and eventually drains in the stream (temporary stream, normally dry). Eventually, after a very strong event, some of the terraces may break and soil may be lost.
- Wind erosion is not a problem in the area
- The soil is not compacted, and compaction is not a risk.
- Soil is rich in nutrients, however most of them are sequestered by the high amount of calcareous material.

Management practices

- Growth of a recognised and protected variety of orange called “clemençol”.
- Input of organic matter in the form of fulvic and humic acids (already decomposed OM)
- Input of Iron chelates to improve availability of iron.
- Herbicide application 2-3 times a year.
- No till, only in recently planted fields.
- Prunnings are crushed and left in the soil.
- Pulverization of pre and post plaguicides
- Inorganic fertilisers also applied (slow release formulations)
- Additionally an organic product based on decomposed leafs (Chamae®) is also applied. The objective of such organic amendments is to increase the organic matter in the soil in order to increase the availability of nutrients of the plant [by ameliorating the CEC].

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Agrees on the values given by the app.
Chemical	Agrees on the values given, but is unsure about the exact number of organic matter, could be higher in places were humic and fulvic acids have been added for some years already, and lower in the areas where not.
Biological	Does not comment on biological indicators.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).

Threat	App	Agreement/comments	Farme
Soil erosion by water		Not happening	
Soil erosion by wind	ND	Not happening	
Soil compaction		Does not occur. Sandy soil.	
Soil salinisation		No problems.	
Soil OM decline		Agrees, soil is poor in organic matter. Continuous management and amendments may have improved the value given by the app.	
K		Nutrients are sequestered by the lime present in the soil. Signs of ferric chlorosis can be observed if chelates are not applied. Misses an indication of the presence of active limestone	
P			

N		and some micronutrients.	
Extremes of pH		High values of pH may diminish the availability of some nutrients. Additionning of OM is necessary to compensate.	
Contamination		No problems of pollution in the area.	
Biodiversity	ND	No comments.	

From the recommendations given, the following were discussed;

- Apply animal manures: Inputs of decomposed OM is preferred by the farmer.
- Minimum tillage and no tillage: Already in practice
- Compost application: Already in practice
- Avoidance of traffic and controlled traffic: Machinery traffic is done only at harvest and applying compost.
- Chipped branches: Already in practice.

Interview 9
Farm ID: CA005
Farmer details

Name: Javier		
Address:--		
Contact:--		
Gender: M	*Age:* 71	*Years at location:* 20

Farm characteristics

Crop type(s): Pomegranates		*Irrigation:* Automated drip irrigation
Farm type: Conventional		*Farm size:* 3ha
Ownership/Labour: Owner, hires labour when needed.		
Annual Precip	*Slope* Valley	*Land cover class* Arable / grazing / permanent no cover / permanent covered / vegetables / other

Soil properties

- Does not analyse the soil.
- Very deep soil. He could corroborate the fact when he dug a profound trench in the soil for the installation of some pipelines.
- Sandy loam soil.

Soil threats

- He does see some effects of soil erosion by water, especially in the parts of the field where different drainage pathways come together. Some works needed to be performed to improve the contention walls of the field.
- Erosion by wind is not observed, neither compaction, fertility loss, pollution, salinity or extremes of pH.
- The farmer experiences problems with soil fauna, especially moles.
- Low presence of organic matter is low and manure is applied to compensate.

Management practices

- Heavy landworks have been made to improve and transform the land. The plots have been flattened following the contour lines and drainage pathways have been shaped to direct water towards the ephemeral stream.
- Very superficial tillage with the rotovator is applied (not to damage the root system).

- Restrictive fertilisation inputs are applied, pomegranate performs better when the plant suffers some nutrient and water stress at flowering stages. Inorganic fertilisers and manure are the preferred inputs.
- Regular pulverisation of pesticides (to prevent fungal infections and aphids).
- Minimal pruning to maximise number of fruits per plant.. However, extra structural support for the plant is required to stand the fruit weight. Very productive system, up to 27kg per tree.
- Crushed prunnings left in soil.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Agrees on all the given values.
Chemical	He states that the OM could be lower than that predicted. Does not know the specific values of nutrients or EC, so he is unable to comment. The fertility of the soil is adequate enough not to concern him.
Biological	Does not know about biological properties

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).

Threat	App	Agreement/comments	Farme
Soil erosion by water		Not any more, had to be managed with heavy landworks.	
Soil erosion by wind	ND	Not happening	
Soil compaction		Not happening	
Soil salinisation		Not happening	
Soil OM decline		Agrees. Soil naturally poor in OM.	
K		Unable to comment, since he is not aware of the specific values of soil fertility. However, not a concerning issue. Pomegranate is not a highly demanding crop, and with the input applied seems to be far more than enough to provide vigorous growth and good yield.	
P			
N			
Extremes of pH		Not a problem.	
Contamination		Not aware of	

Biodiversity	ND	Does not know	

From the recommendations given, the following were discussed;

- Compost application: The application of compost is not considered, thinks is more beneficial to apply manure (lower cost and higher nutrient content).
- Minimum tillage and no-tillage: Very superficial till made, improves infiltration and weed control.
- Apply animal manures: Already practiced.
- Controlled traffic: Kept to minimum, additionally, compaction is not an issue.

App functionality and opinions

- *New farmers need more and more information provided of this kind to make decisions on best management practices.*
- *My farm is highly automated and I often rely on the use of apps to manage the irrigation schedule. Most likely, the use of apps to manage soils is to become more relevant.*
- [The farmer speaks, however, on the benefits of using soil apps referring to third persons, as if others where to benefit but not himself]

Interview 10
Farm ID: EL002
Farmer details

Name: Paco
Address:--
Contact:--
Gender: M *Age: +-40* *Years at location: 15*

Farm characteristics

Crop type(s): Grazing land (transformed from artichokes 3 years ago) *Irrigation:* Flood irrigation		
Farm type: Organic		*Farm size: 3ha*
Ownership/Labour: Owner, own labour.		
Annual Precip *NA*	*Slope* Flat	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- Loamy clay soil texture
- Very basic pH
- Extremely high content in lime
- Soil deposited from the eroded calcareous mountainous range besides the elche plain.

Soil threats

- Extremely low water erosion, due to the mosaic type of landscape, with natural barriers to erosion, also a very flat land.
- Very low wind erosion, vegetation stripes around the plots screens the wind from taking the soil.
- No compaction problems
- Low organic matter but he does not see a decrease or a loss of it. With his management, he incorporates it to the soil.
- Basic pH but not a threat to the soil or pastures.
- There is no soil pollution, however, irrigation water may bring a lot of nitrates.
- He is a strong believer that pastures increase soil biodiversity. Therefore, there is no risk of decreasing soil fauna.

Management practices

- Field originally dedicated to horticulture (mostly artichokes). Three years ago he

converted it to pastures.
- He combines his own lands to grow fodder, with a urban silvopastoral system, grazing his flock of goats in council owned terrains. He advocates for the use of livestock as weed and vegetation control instead of herbicides.
- The stocking rate is 14 heads per hectare.
- He flood irrigates the fields as a support in dry periods.
- Traditional varieties of grassland, combined with deep rooting species and nitrogen fixers.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Agrees on the properties, however, he states that texture is heterogeneous in the field, and there are places where more clay is found than that predicted by the app.
Chemical	Agrees. He states that OM in the top layer could be higher due to his management.
Biological	Unable to comment specific values for biological indicators, but he is confident that diversity must be high compared to other places in the area.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).

Threat	App	Agreement/comments	Farme
Soil erosion by water		Minimal, flat land with natural barriers to heavy water flow.	
Soil erosion by wind	ND	Not happening	
Soil compaction		Not happening	
Soil salinisation	ND	Salinisation is very high in the area, halophytes are part of the natural vegetation. However, the varieties he plant are dealing well with it, irrigation.	
Soil OM decline		Soil organic matter is low but after the management he states that higher values could be measured.	
K	ND	He does not recognise a loss in fertility, and	

P	ND	with the livestock manure inputs the grasses respond well.	
N			
Extremes of pH		Indeed, very basic pH, however he doubts on how much a threat this could be.	
Contamination		Not aware of	
Biodiversity	ND	Good overall soil biodiversity.	

From the recommendations given, the following were discussed,

- Conversion from grassland to forest: Current land use is sustainable for the present environmental conditions.
- Apply animal manures: Already in practice.
- Compost application: Expensive, unless he collects and compost the manure of his flock, for the time being he applies the manure directly into the soil.
- Submerged drains: Doesn't seem relevant nor feasible.

App functionality and opinions

- He would use information provided from the app carefully, contrasting with the local knowledge he gathers from its fields.
- He stresses the importance of bridging the gap between science and society, however doubts that an app could be the optimal medium for it. Instead he proposes the figure of individuals acting as extension services. *"I have convinced far more people in the bar about a sustainable practice than any organised formative session"*.

Interview 12
Farmer ID: MO001
Farmer details

Name: Oscar
Address:
Contact:
Gender: M *Age:* +-40 *Years at location:* 4

Farm characteristics

Crop type(s): Vineyards		*Irrigation:* Drip irrigation
Farm type: Organic		*Farm size:* 110ha
Ownership/Labour: Farm manager		
Annual Precip 500l but 300 days of sun	*Slope* NA	*Land cover class* *Arable / grazing / permanent no cover* *permanent covered / vegetables / other*

Soil properties

- Do not analyse soil samples
- Two different soil types can be found. In the sloping land close to the mountain, the soil is sandy, while in the valley bottom is Clay loam.
- Not specially nutrient rich.
- Very low organic matter (he thinks the value could be around 0.5% or a bit higher due to management).

Soil threats

- Erosion by water can occur, especially after intense rainfall events.
- No erosion by wind occurs, the permanently covered soil and the vegetation present (vineyards) prevent that from happening.
- Compaction always occur.
- No salinity, nor fertility loss, pollution or biodiversity loss.
- Very low organic matter content.

Management practices

- Green cover between vine rows (still experimenting on which varieties are most suited, a row left bare with natural vegetation growing, and the other row with

legumes).
- Planted green cover is mowed and left in the soil. Adventitious plants between the rows are mowed and buried (to avoid water competition).
- Manure applied and buried in autumn (in waning moon, enhances humification).
- Tillage every 3 or 4 years (very superficial)
- Biological pest control, and use of allowed organic products.
- Prunings left in soil.

Response to App Results

Soil properties given by the app	Farmer comments
Physical	Agrees on the given values.
Chemical	Thinks that pH could probably higher, and that the values of organic matter are surely above reality. **Lime content would be a nice addition.**
Biological	Very interested on biological soil quality indicators but is unable to interpret the values.

Note: app results colour given by the output, farmer colour code; green (not an issue or in good quality), orange (a concerning issue but does not hamper production due to its control through management), red (a highly concerning issue that sometimes can affect production), white (the farmer is not aware of the threat or does not know about it).

Threat	App	Agreement/comments	Farmer
Soil erosion by water		It does occur, and maintenance of the terraces is needed. The rainwater harvesting deposits get often filled with sediment.	
Soil erosion by wind	ND	Not happening.	
Soil compaction		Compaction does occur, and heavy machinery plays a big role (harvest machine very heavy but required).	
Soil salinisation		No problems.	
Soil OM decline		Soil is low in organic matter, much more than the value given by the app. Continuous amendments are required to improve it. To obtain better OM content would be very useful for a higher water retention in the soil.	

K		A very high content of lime, so nutrient sequestration is common, this can reflect on very low values for available nutrients.	
P			
N			
Extremes of pH		High values of pH may diminish the availability of some nutrients.	
Contamination		No problems of pollution.	
Biodiversity	ND	Very interested to know how is the farm performing in terms of biological soil indicators.	

From the recommendations given, the following were discussed,

- Minimum tillage and no-tillage: Tillage is kept superficial and minimum once every 3 or 4 years. Except the burying of the green covers made with a rotovator.
- Apply animal manures: Already in practice
- Compost application: Prefers the application of manure, has more available nutrients and higher presence of microorganisms.
- Flood irrigation and sprinkler irrigation: Not relevant in drip irrigation systems.
- Avoidance of traffic: Indeed, traffic is an issue that enhances compaction, is kept to the minimum.
- Chipped branches: Already in practice.
- Straw mulching: Has been tested, however it is hard to work the land afterwards and does not hamper weed growth.

App functionality and opinions

- He believes that the app can be really useful in order to see variations in different lands on soil quality.

Annex I - Questionnaire

SQAPP Survey

We are a group of students from Wageningen University researching the potential for a mobile phone app to provide farmers with soil data. We want to make sure the application uses the correct terms that are also relevant to farmers. Thank you for taking the time to help us with out study!

Background Information			
Name:			
Age:		Gender:	
Place of Residence			

How many years have you been farming? _____
I am a *fulltime* / *part-time* farmer (circle)
Do you have any other sources of income / occupations? If yes, which one(s)? …… ………………………………………………………………………………………………………...
Farm Size:
Main Crops: …… ………………………………………………………………………………………………………... …… ………………………………………………………………………………………………………...

Cell phone use and Practicality	
Do you have a phone?	No / Yes
Do you use apps on your phone?	No / Sometimes / Yes
Do you have cellular reception at your farm?	No / Sometimes / Yes
Can you connect to internet with your phone on your farm?	No / Sometimes / Yes

App Terminology					
For the following soil quality indicators, please indicate to what extent you are familiar with it. *1 - I've never heard of this indicator* *2 - I've heard of this indicator, but I don't know what it means* *3 - I've heard about this indicator, and I vaguely know what it means* *4 - I know what this indicator means, but I don't know how it relates to land management* *5 - I know what this indicators means and how it relates to land management*					
Depth to Bedrock	1	2	3	4	5
Bulk Density	1	2	3	4	5
Cation Exchange Capacity	1	2	3	4	5
Course Fragment (volume)	1	2	3	4	5
Phosphorous using the Olsen method	1	2	3	4	5
Exchangeable potassium	1	2	3	4	5
Soil microbial abundance	1	2	3	4	5
Soil macrofauna groups	1	2	3	4	5
Soil Organic Carbon	1	2	3	4	5
Soil pH	1	2	3	4	5
Plant-available water storage capacity	1	2	3	4	5
Silt content	1	2	3	4	5
Sand content	1	2	3	4	5
Clay content	1	2	3	4	5
Total Nitrogen in Soil	1	2	3	4	5
Electric conductivity	1	2	3	4	5

Terminology - Soil Threats *For the following soil threats, please indicate to what extent you are familiar with it.* *1 - I've never heard of this soil threat* *2 - I've heard of this soil threat, but I don't know what it means* *3 - I've heard about this soil threat, I vaguely know what it means* *4 - I know what this soil threat means, but I don't know how it relates to land management* *5 - I know what this soil threat means and how it relates to land management*					
Soil Erosion By Wind	1	2	3	4	5
Soil Erosion By Water	1	2	3	4	5
Compaction	1	2	3	4	5
Salinization	1	2	3	4	5
Soil Organic Matter Decline	1	2	3	4	5
Soil Biodiversity Loss	1	2	3	4	5
Soil Contamination	1	2	3	4	5
Acidification	1	2	3	4	5
Nutrient Depletion	1	2	3	4	5

Are there threats or indicators missing from these lists? (what threat or indicator is not on this list which is relevant to you…?)

____
___
_____
____
____
____
____
____
____

Terminology - Management Practices *For the following management practice, please indicate to what extent you are familiar with it.* *1 - I've never heard of this management practice* *2 - I've heard of this management practice, but I don't know what it means* *3 - I've heard about this management practice, I vaguely know what it means* *4 - I know what this management practice, but I don't know how to do it myself* *5 - I know what this management practice means and know how to do it myself*					
Minimum Tillage	1	2	3	4	5
Strip Cropping	1	2	3	4	5
No Tillage	1	2	3	4	5
Using Deep-Rooting Crops	1	2	3	4	5
Liquid Manure/Slurry	1	2	3	4	5
Apply Animal Manures	1	2	3	4	5
Use Inorganic Fertilizers	1	2	3	4	5
Crop Rotation	1	2	3	4	5
Compost Application	1	2	3	4	5
Conversion to Grassland	1	2	3	4	5

Minimum Tillage					
Minimum tillage is a soil conservation system with a goal of minimum soil manipulation necessary for a successful crop production. It is a tillage method that does not turn the soil over. It is alternative to intensive tillage, which changes the soil structure using ploughs.					
Does this description help clarify the measure?	No - 1	2	3	4	5 - Yes

Composting					
Composting is decomposing organic matter for recycling as a fertilizer and soil amendment. Compost is a key ingredient in organic farming.					
Does this description help clarify the measure?	No - 1	2	3	4	5 - Yes

Deep Rooted Crops					
Growing deep rooted crops can break up compacted soils and improve soil quality. Deep rooted crops can be perennial plants like alfalfa or annual plants like forage radish. As part of a crop rotation, deep rooted crops also enable a more balanced soil fertility management.					
Does this description help clarify the measure?	No - 1	2	3	4	5 - Yes

What suggestions do you have for improving the clarity of these suggestions?

____
____
____
____
____

Do you know where to find more information about these management practices?

____
____
____
____
____