Fostering soil management PRACtices and uptake and developing decision support TOols through LIVing labs in EU (PRAC2LIV)

Deliverable D5.2

PRAC2LIV Mock-Up Designs for Decision Support Tools for Soil Organic Matter, Nutrient Use Efficiency and Soil Moisture Retention

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ABSTRACT

The project PRAC2LIV focuses on Decision Support Tools (DSTs) for each of the topics soil organic matter, nutrient use efficiency and water retention, in support of fostering soil management in EJP Member States. The research includes DSTs from simple tools to the next generation level support systems. Both the scientific base of DSTs as well as their implementation and adoption at farm level are of interest. A stock-take has been performed via a questionnaire to national coordinators and the current use as well as future needs for such DSTs have been discussed in stakeholder groups. This report describes the designing process of DSTs. For this purpose, a set of predefined requirements is made after which mock-up designs for DSTs (mobile app) are made for each of the 3 themes, aiming at farmers. Conclusions are drawn for future development of mobile apps on the selected topics.

Disclaimer: this report presents mock-up designs for apps with the aim to discuss the steps that may be taken for their development and to give some inspiration as to their visual appearance. Before these can be actually constructed, further elaboration is required.

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EU	European Union
DST	Decision Support Tool
MOI	Soil Moisture Retention
NUE	Nutrient use Efficiency
SOM	Soil Organic matter
WP	Work Package

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1. Introduction

Decision support tools (DSTs) may be developed in many different ways, and thus their actual (digital) form and presentation of the DST may vary, e.g. mobile app, web portal, sensor/instrument, etc. Good DSTs will have algorithms that fit the purpose and deliver satisfying results. The latter is true not only in terms of reliability and accuracy, but also with respect to the desired function(s), e.g. monitoring, registration, advice, etc. In addition, for high adoption rates of DSTs by end-users, the interface and presentation of DSTs are considered to be very important. To illustrate this, this report presents and discusses the making of mock-ups designs for soil organic matter (SOM), nutrient use efficiency (NUE), and soil moisture retention (MOI).

A mock-up designs for a DST can be defined as a tool to visualize the current status of a virtual project (Riascos et al., 2015). Mock-up designs are useful for potential digital applications, as it visualises the concepts of the creators. By providing a visual presentation of the ideas, potential users and other stakeholders can see what the designers are working on. This helps in understanding the ideas of the creator, and opens up for discussions and including feedback.

Objectives

The objective of this report is to present both a structure and an example (mock-up) for the designing process of a mobile app for use at farm level, for the 3 selected topics.

The mock-up designs in this report are meant to give inspiration on what a DST should at least contain what the visualisation of the app might look like. Yet, they are not actually working apps and do not include scripts for the real application.

2. Methodology

Preliminary steps

The first preliminary step involves the writing of a short explanation of the desired DST and the major calculations involved (justification). This part requires knowledge on processes in the soil-plant agro-ecosystem and be done by the researcher involved.

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The second preliminary step is compelling a shortlist that specifies details of the desired DST which are used in the designing phase (Table 1). The shortlist may be seen as a starting point for the discussion between DST developer, envisaged end-users and researchers to fully comprehend the desired performance of the DST. The shortlist covers three aspects: aim of the DST, expected end-users, and required elements.

Table 1. Specification shortlist for the design of the mock-ups.

Specification Topics	Selection for PRAC2LIV Mock-Ups
Aim of the DST	
• Technical focus	Focus is on 3 stand-alone mobile apps for SOM, NUE, and MOI
• Purpose	Promote awareness, share knowledge, and give advice on soil management
Expected end-users	1st: Farmers and advisors; 2nd: policymakers
Required elements	
• Functionality	Advice
• Scale-level	Field and farm level
• Impact assessment	Indicate range of possible results of practices
• Reference values	Indicate target values (if available) and 'distance to target'
• Other features	Indicate economics
• Data-input	Make use of downloadable data as much as possible
• Display	Be user friendly
• Purchase costs	Be freely available

In PRAC2LIV, the focus is on 3 stand-alone mobile apps for SOM, NUE, and MOI, respectively that promote awareness, share knowledge, and give advice on soil management. Farmers and advisors were selected as primary group, more specifically the large group of farmers that are only moderately active in sustainable soil management. Innovators may need other types of DSTs, and farmers without basic knowledge on these topics may first need other support. In order to reach the selected target groups, DSTs are required that give advice on agricultural practices. If DSTs would be successful among the platoon of farmers in a region or Member State, then together a significant improvement in soil management (for SOM, NUE, MOI) may be achieved. This may be a reason for policymakers to develop an interest in such tools. Therefore, in this example, policymakers are

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considered a secondary group of end-users. The required elements are chosen from a practical point of view.

After the preliminary steps, a three-step process was used to draw the mock-up design. First, a flow-diagram was drawn including and connecting all proposed elements of the DST. In ICT-programming, often standard forms are used to indicate their purpose. For the mock-ups in PRAC2LIV use is made of some of these conventional forms and meanings (Figure 1).

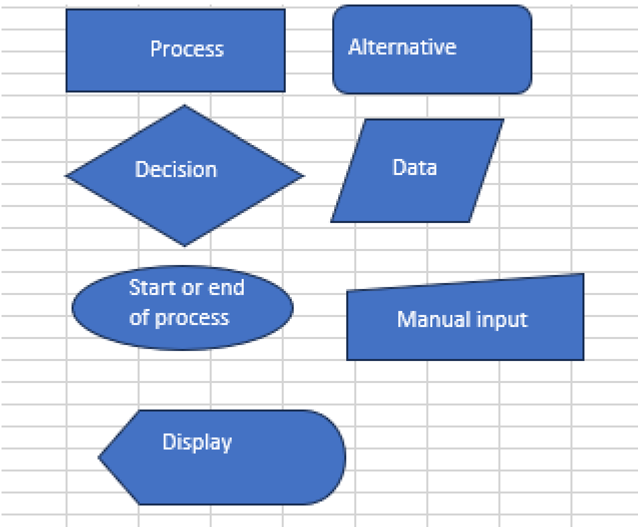

Figure 1. Forms and their meaning used in the flow diagrams of the PRAC2LIV mock-ups.

Secondly, the actual designs of the respective screens were made in MS Powerpoint. They are based on the design and format of a mock-up for agricultural biodiversity (Van Opstal & Van der Gugten, 2023), which is currently being elaborated into a real app by Earthwatch Europe and Wageningen University. Thirdly, to show how the screens would be aligned in the app on a mobile, the presentations were made into an interactive pdf.

3. Results Mock-Up Designs

The mock-up designs for the apps on nutrient use efficiency, soil organic matter, and moisture retention have in common that, focussing at field and/or farm level, they make use of similar data. This applies in particular to the first general screens of the apps. We assume that the 3 apps will make use of the same data in as much as possible, and ensured that, while creating an account to log on to the app, some general information is requested. The farm coordinates are most important, as it

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gives an indication on the soil type the farmer is working with. However, it should be noted that these designs are made with a specific regional situation in mind and by no means designed to be 'fit for all'.

3.1 Soil organic matter

3.1.1 Justification

An important aspect of a soil health is the organic matter content, which may perform several functions for soil quality and/or crop production, e.g. nutrient mineralisation and retention, water holding capacity, soil structure, and carbon sequestration. To get insights into their organic matter management, farmers can draw up an organic matter balance, i.e. the sum of input and output of organic matter and its impact on the soil organic matter content.

Drawing the organic matter balance has been practiced, on paper, by (mostly) arable farmers in several countries for decades. An app on laptop and/or mobile phone can offer several advantages , e.g. obtaining recommendations on-the-go, and/or evaluate the trend over time. To give an example, a mock-up app has been developed for calculating the soil organic matter balance at field and farm level. The entire iterative mock-up is presented in Annex 1.

3.1.2 Flow Diagram

The main flows in the diagram for the soil organic matter balance are the input and output flows of organic matter. The flow diagram in figure 2 shows that the method of calculating the OM balance is similar for both the farm level and field level. However, the calculation at farm level requires an extra step, i.e. the sum of the inputs and outputs.

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EJP SOIL
European Joint Programme

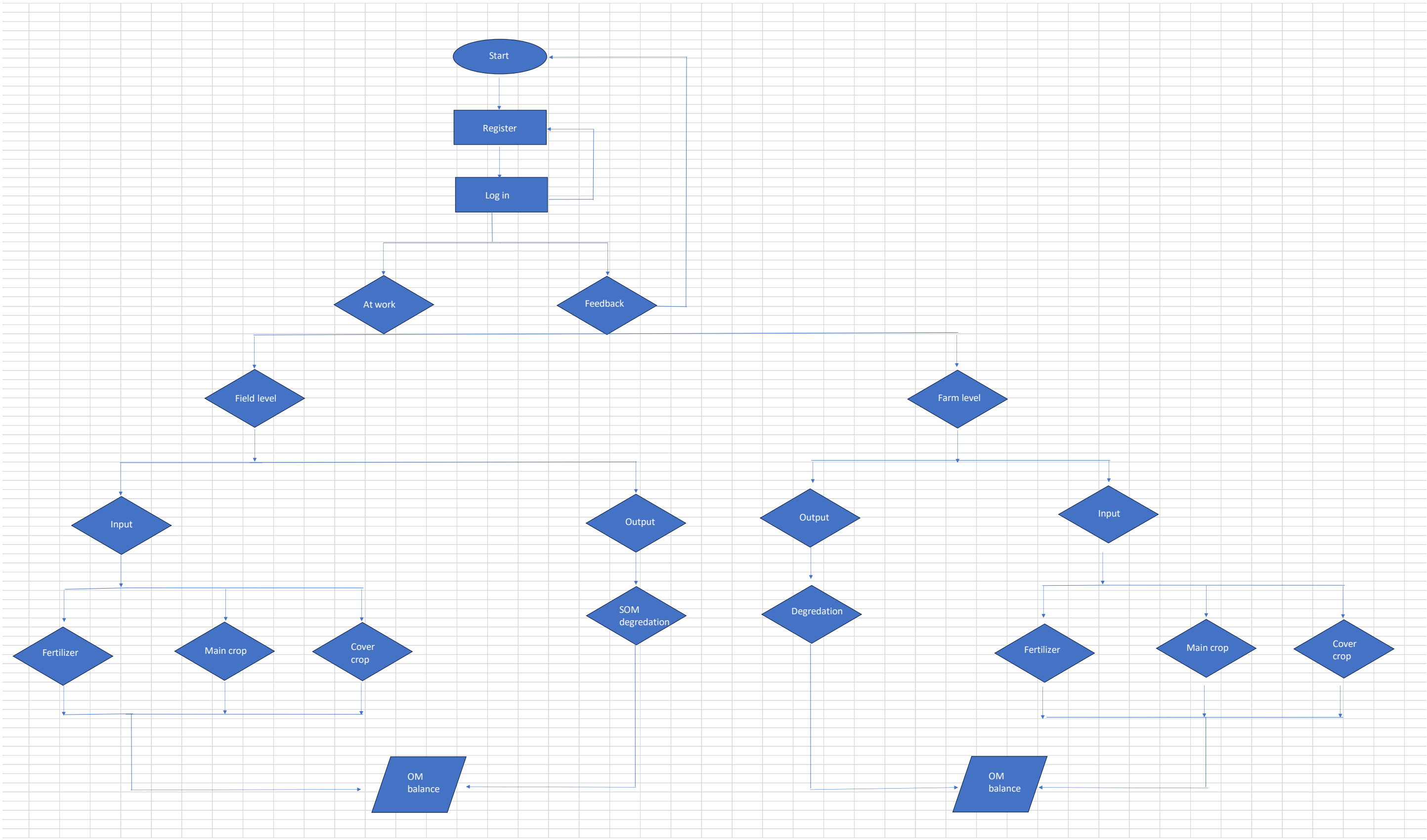

Figure 2. Flowchart for the Soil Organic Matter balance.

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3.1.3 Mock-Up Design

Starting screens

The first few screens of the app give farmers the possibility to create an account and specify their farm type, including the farm coordinates as described in 4.4.1. After the starting screens, a farmer can decide whether he wants to create an organic matter balance on field or farm level.

Field level

The field level calculation consists of the screens, which are the input, output, and the actual balance. In the input screen, a farmer can indicate what organic matter inputs are applied on the field. This can be different kind of fertilizers, such as manure or compost. Another source of organic matter are the possible crop residues. Finally, the growth of a cover crop can be indicated. This is presented in Figure .

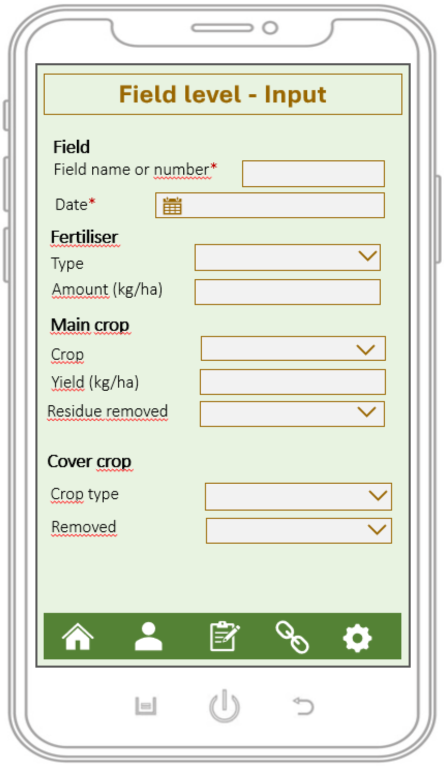

Figure 3. Different carbon input sources on field level.

The output level allows the calculation of the organic matter degradation. A default rate can be chosen based on the soil type, but another rate can be indicated when a farmer has more insight in this. This is presented in Annex 1.

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The final screen subtracts the output from the input, thus calculating the organic matter balance on field level as presented in Annex 1.

Farm level

The organic matter balance on farm level is calculated in a similar way, but combines the activities on all the fields. Therefore, it is possible to include many inputs on the first screen. By clicking on input A, the user gets the screen as presented in Figure . Here an input type, can be chosen. Depending on the input type, different crop or fertilizer types can be chosen and their corresponding quality. This indicates the organic matter input. This can be done for all the inputs on the farm.

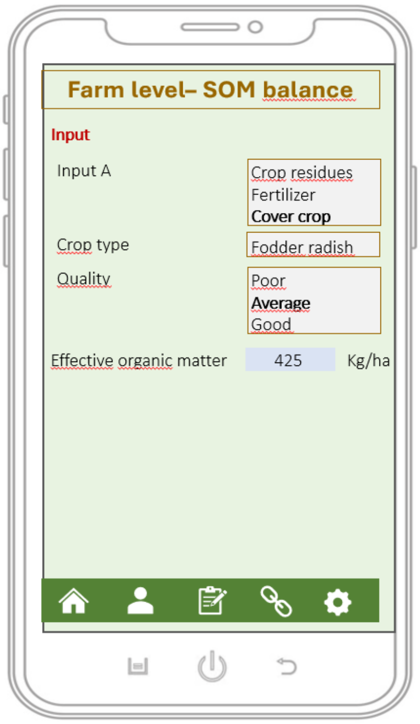

Figure 4. Soil organic matter input on farm level.

On the first screen, a default or chosen degradation rate can be indicated. Eventually, this results in the organic balance on farm level as presented in Annex1, along with the entire mock-up design.

All input is calculated as the effective organic matter input, which is the organic matter that is still present in a soil one year after application.

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At present, in some countries more elaborate DST for soil organic matter are available of being developed. These tool may be based on dynamic SOC-models such as the ROTHC model, and/or include other ecosystem services, e.g the Cool Farm Tool (Cool Farm Tool, https://coolfarm.org/).

3.2 Nutrient Use Efficiency

3.2.1 Justification

In recognition of the fact that, of all plant nutrients, nitrogen (N) is considered the most important, this paragraph addresses N Limiting nitrogen emissions is a major public debate in Western Europe. Many farmers must make change to their N fertilization scheme. This may require more than simply lowering the rate. Recently, a European wide network has been started to create an inventory of crop nutritional decision tools to summarise current knowledge & best practices (EU-project NutriCheck (https://nutri-checknet.eu/). Nitrogen use efficiency is crucial for sustainable agriculture as it helps maximize crop productivity while minimizing environmental impact. Efficient nitrogen use ensures that plants receive adequate nutrients for optimal growth, reducing the need for excessive fertilizer application and mitigating nutrient runoff and pollution. Besides, it increases the efficiency of the farmer and therefore results in a better financial result. A useful feature is the Nitrogen Use Efficiency (NUE) of a crop. Worldwide different definitions of NUE exist. A most used definition of NUE is 'the ability of a system to convert nitrogen input into output' (Fagaria, Baligar, 2005). An increase in efficiency for nitrogen in otherwise similar conditions indicates lower environmental losses and more efficient use of resources.

To calculate NUE, we assume the following formula:

$$NUE = \frac{Nitrogen\ removed\ from\ field\ by\ crop\ product\ (kg/ha)}{N\ fertilizer\ applied\ (kg/ha)} \text{ x } 100\%$$

The mock-up app is designed to calculate the NUE from the amount of product harvested (yield) and a fertilisation plan or actual fertilisation. Nitrogen efficiency can be calculated both without and with the nitrogen stock change in the soil. For more insight, the calculated NUE can be shown in a graph plotting the potential yield against an increasing nitrogen input. With sliders, the yield can then be

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increased or decreased, as well as the amount of nitrogen applied. The NUE can then be recalculated and the position of the calculated point in the graph changes.

3.2.2 Flow Diagram

The flow diagram in figure 5 for the mock-up app for N gives a step by step overview of the decisions a user could make when using the app. The flow diagram shows that for this example, the decision was made to make a mock-up of the planning of nitrogen at field level. After filling in the required information such as crop yield and nitrogen application, the nitrogen use efficiency is calculated. A loop has been implemented after displaying the nitrogen use efficiency graph, making it possible to benchmark the achieved nitrogen use efficiency with an average nitrogen use efficiency for the crop and soil type in the specific area.

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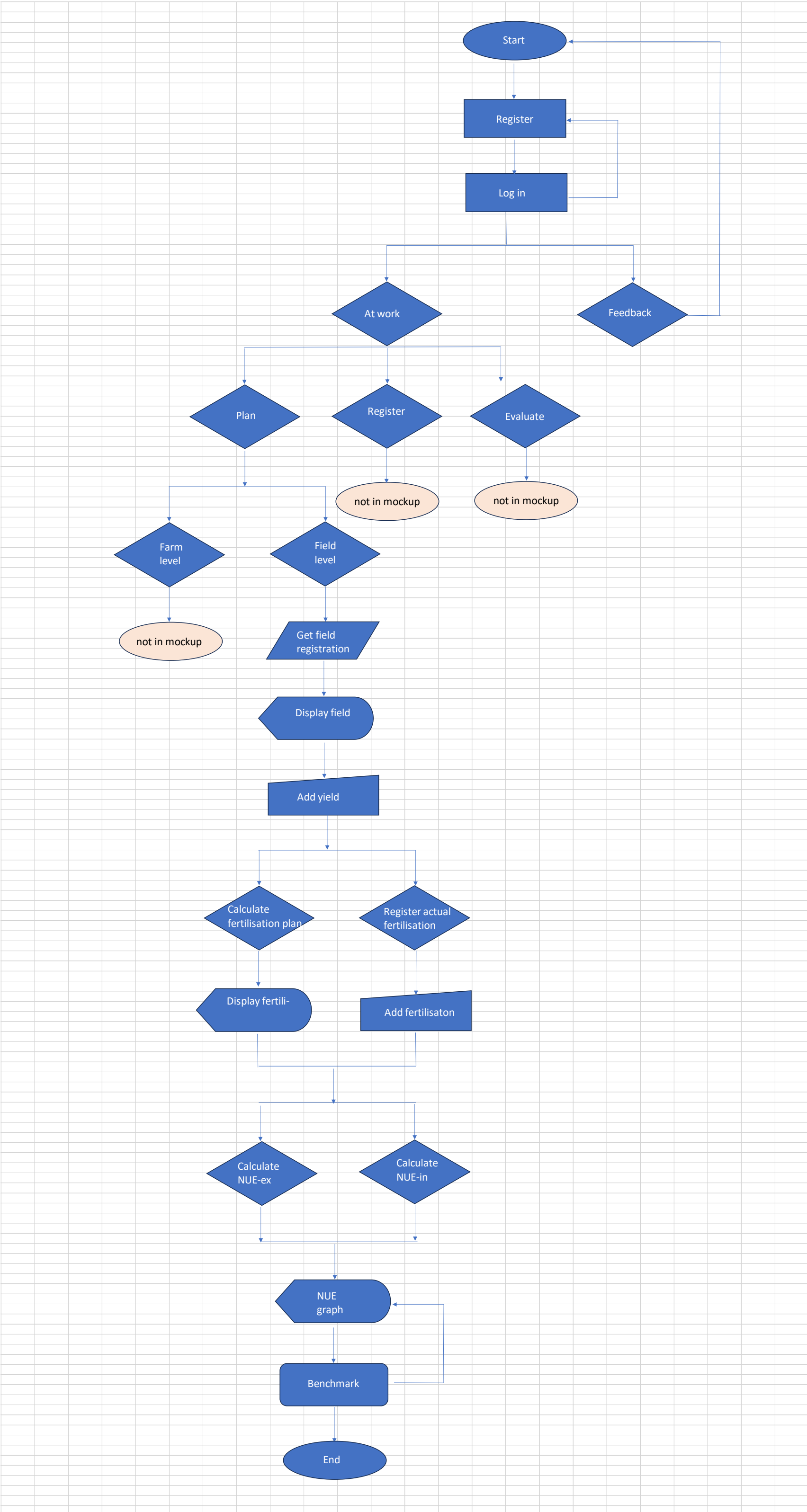

Figure 5. Flowchart Nitrogen Use Efficiency.

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3.3.3 Mock-Up Design NUE

Starting screen

The first few screens of the app give farmers the possibility to create an account and specify their farm characteristics as described paragraph 3.1. After the starting screens, a user has the options to change his profile, give feedback or go to my farm. In the my farm screen a user can decide whether he wants to plan, to register of to evaluate. This can either be done on farm or field level. The screens are presented in Figure 6.

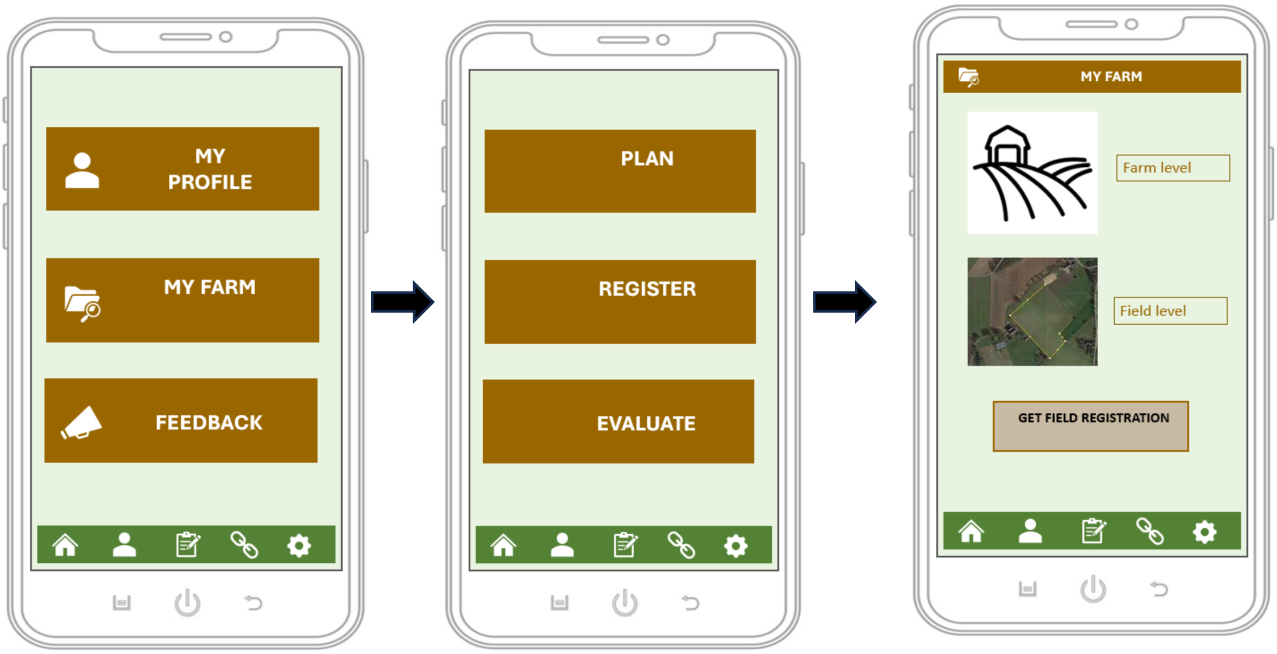

Figure 6. Different screens with options to plan, register or evaluate the NUE on farm or field level.

Planning fertilisation

For the use of this app, the following steps are envisaged:

- Step 1: The planning tool can be plugged in at both farm and plot level. Plot level is worked out in this mock up. The data for the plot in question can be downloaded from the internet or entered into the tool. The result appears in a subsequent screen.
- Step 2: The fertilisation plan for the plot can be downloaded from the internet or entered into the tool. The result appears in a subsequent screen.
- Step 3: NUE can be calculated.
- Step 4: In the visual display of the result, sliders can be used to adjust the result and recalculate the NUE.

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The sliders are presented in Figure 7. It shows that for each field the NUE can be calculated. The NUE is recalculated when the N-input and yield are adjusted. This allows for an estimation of what the yield needs to be at certain N-input levels in order to achieve certain goals. Besides, the graph shows whether the N-input and the current yield level are close to an optimum, or whether increasing the nitrogen input would substantially increase the crop yield. The entire mock-up is presented in Annex 2.

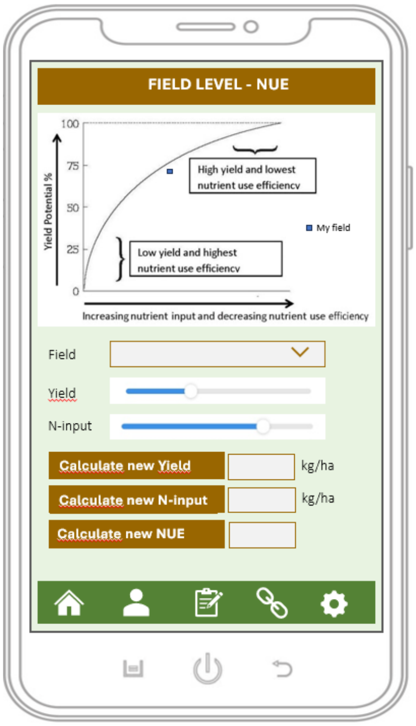

Figure 7. Sliders to recalculate the NUE at different yield levels and N-input levels, and the possibility to benchmark the realised nitrogen use efficiency with other farmers.

3.3. Soil Moisture Retention

3.3.1 Justification

Water availability is crucial for the plants' development, playing a key role in processes such as nutrient uptake, photosynthesis and respiration. In periods of drought, water availability can be the most limiting factors in crop development. With the effects of climate change becoming more evident, it is to be expected that water stress experienced by crops will increase. Therefore, it is crucial for farmers to know how their fields can hold water and how much water is required for an optimal crop development.

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The mock-up design is presented that performs the calculations for the Water Holding Capacity at field level with Dutch farming systems in mind. The calculations are made by creating a pF-curve. The pF-curve is a graph that describes how water is retained in the soil at different levels of suction pressure and herewith gives an indication of the water availability to plants and the soil's drainage characteristics. An example of a pF-curve is presented in figure 8.

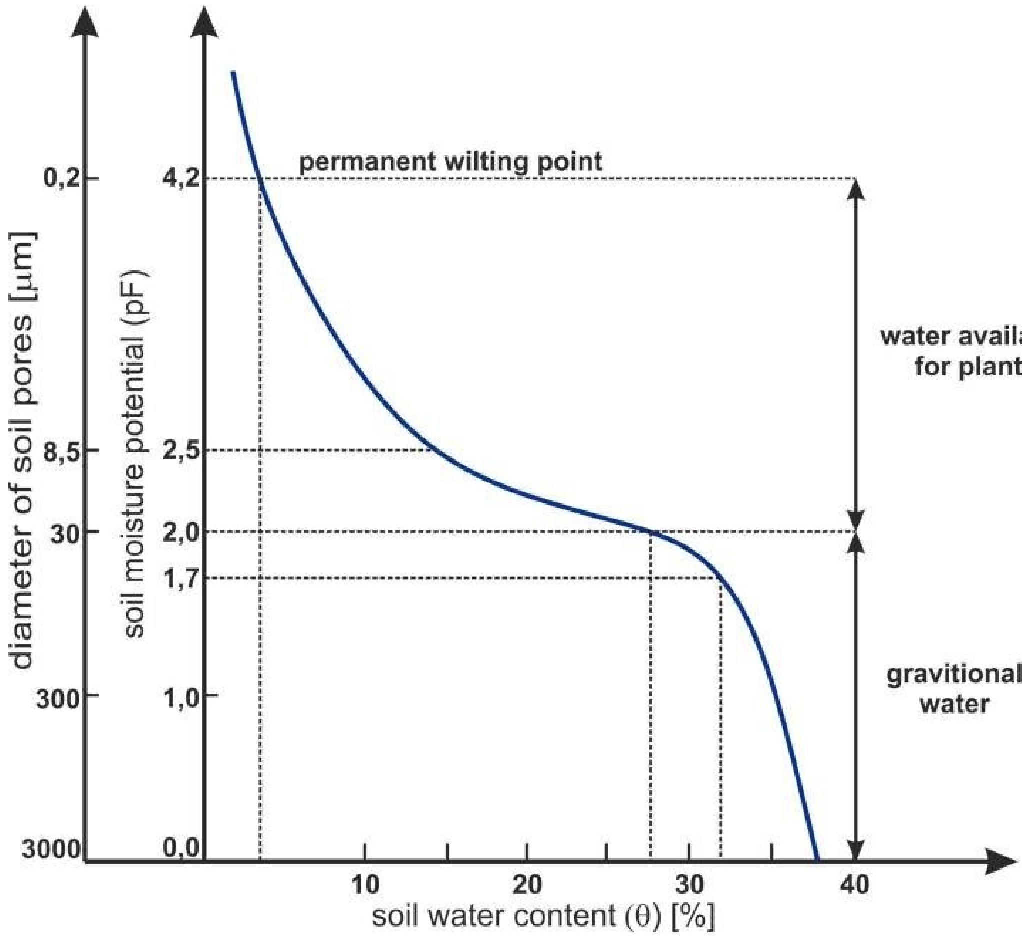

Figure 8. Example of a pF-curve (Baziak et al., 2019).

At a pF-curve, the suction level of 4.2 indicates the wilting point. At this point, the soil holds on to the water too tightly making it impossible for a plant to absorb water from the soil. At a value of 2.0, the field capacity is reached. This is the point after a soil has lost all of its free draining water that leaches out a soil because of gravity. The ideal water content corresponds with a pF-value of 2.5. At this point, sufficient water is available for crop roots but the soil is not saturated.

To give an indication on when to irrigate based on the water availability and the soil characteristics, a mock-up has been designed. The entire mock-up can be found in Annex 3.

3.3.2 Flow Diagram

The corresponding flow diagram for the mock-up app for Moisture Retention is presented in figure 9. It shows that the eventual pF-curve is based on the soil samples and sensor information, of which the information can be inserted either by filling them in manually or downloading them from another source. This information is eventually used to calculate the advised gift based on the pF-curve.

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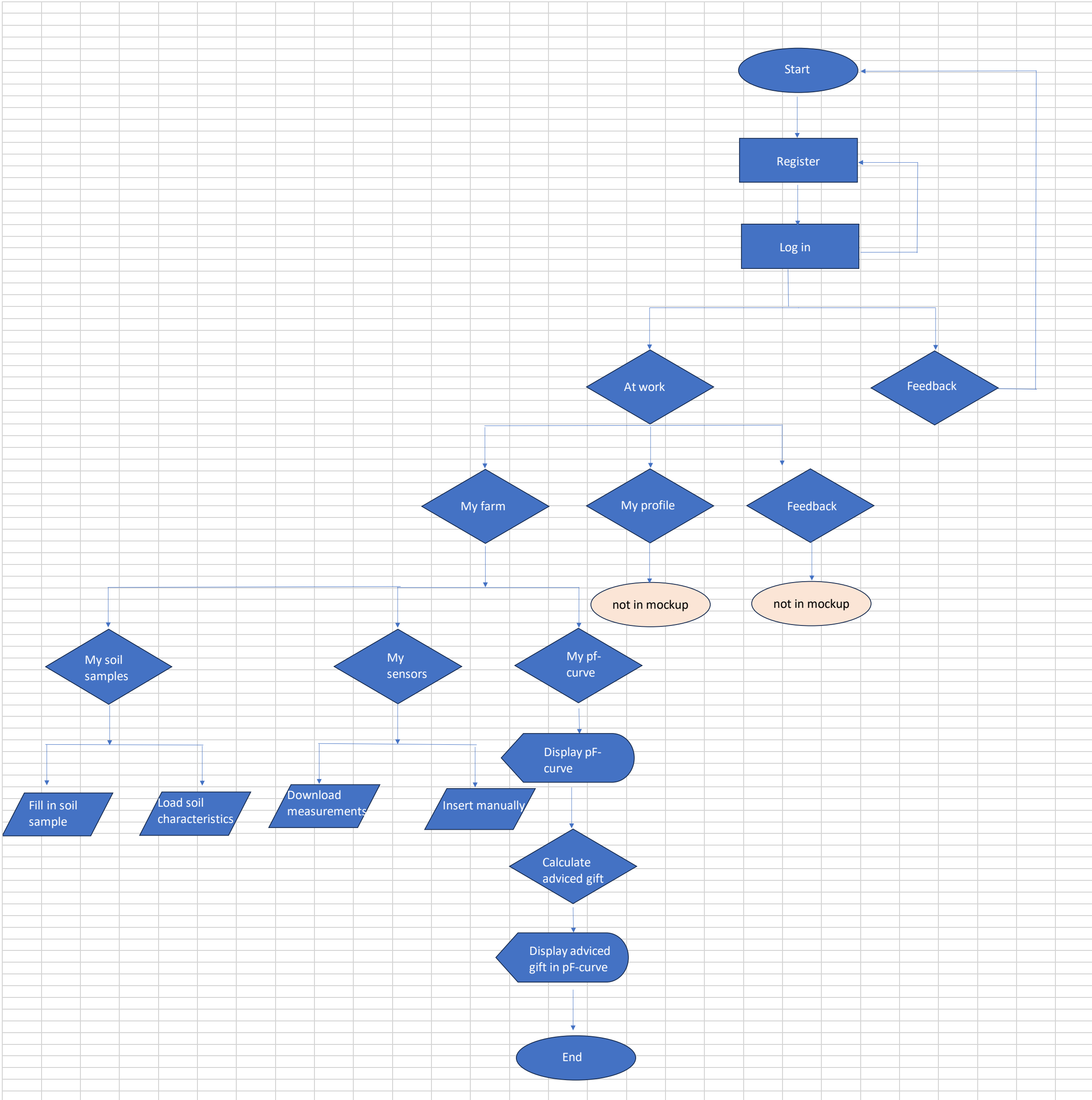

Figure 9. Flowchart Water Holding Capacity.

3.3.3 Mock-Up Design

Starting screen

The first few screens of the app give farmers the possibility to create an account and specify their farm type, including the farm coordinates as described in 4.4.1. After the starting screens, a user can decide whether he wants to manage his soil samples, his sensors or his pF-curve.

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My soil samples

To generate a pF-curve, it is required to know the soil type of the farm. This information can be implemented in two ways, either by importing a soil sample or deriving the soil characteristics from general soil maps. It is preferred to import a soil sample, as this gives a more accurate indication of the soil characteristics.

A soil sample can be implemented per field. To estimate the pF-curve, the clay, silt and sand content is required. If available, the Ca-CEC, Mg-CEC and K, Na, H, al, Fe-CEC can give additional information. This information can be won from a soil sample and can be implemented in the app in a screen as presented in Annex 3.

If such a soil sample is not available, the soil characteristics can be derived from a map, such as https://bodemdata.nl/basiskaarten (example for The Netherlands). The app moves to the location or coordinates provided, and a farmer can select the field of interest as presented in Annex 3.

My sensors

in the screen My sensors a farmer can either manually upload or download the results of a sensor in the fields. This eventually results in a graph as presented in Annex 3. It is possible to place different sensors in a field, as fields can be heterogeneous and sensors might be inconsistent.

My pF-curve

Based on the soil type a pF-curve is generated, indicating the wilting point, field capacity and filling point. This is presented in Figure 10. The measured water volume is based on the measurements of the sensor. After filling in the rooting depth, an advised water gift can be calculated with the following equation (with rooting depth expressed in mm):

$$advised\ gift = (field\ capacity - \ measured\ volume) * rooting\ depth$$

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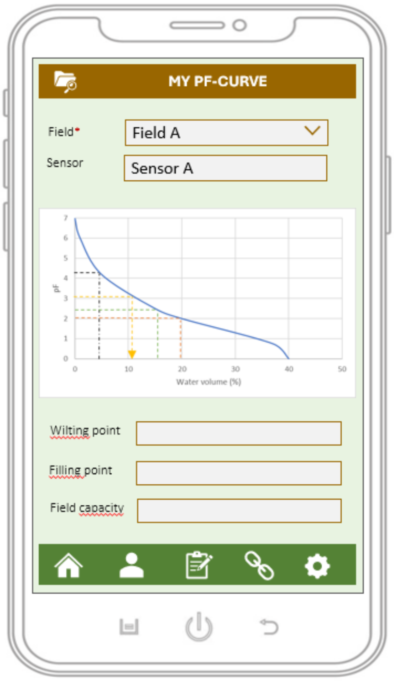

Figure 10. Final pF-Curve, including the irrigation advice.

4. Conclusions

The development of mock-up designs for DSTs serves as a practical demonstration of how future tools can be both scientifically sound and user-friendly. These prototypes show that it is possible to create tools that are not only effective in optimizing soil management practices but also adaptable to the diverse conditions and challenges faced by farmers across Europe. Additionally, the novel pictorial visualization methods proved to be valuable for discussing and exchanging information around DST's and soil health. At a higher level, the visualization method was found useful for generating new directions for programmes, such as EJP Soil including important topics that could be (re)evaluated. Together, mock-up designs and pictorial visualization methods offer a fruitful approach for engaging end-users and stakeholders in development of DSTs and aligning research efforts.

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5. Recommendations

This work details the development of mock-up designs for DSTs focused on improving nutrient use efficiency, soil organic matter management, and moisture retention. These mock-ups serve as illustrative examples to guide the conceptualization and design of future DSTs by visualizing potential functionalities and interfaces.

The mock-ups were designed as stand-alone mobile applications, each targeting specific aspects of soil management. For instance, the nutrient use efficiency (NUE) app helps farmers optimize nitrogen usage by calculating NUE based on inputs like crop yield and fertilization plans. The soil organic matter (SOM) app aids in managing organic matter inputs and outputs at both field and farm levels, while the moisture retention app addresses water management, offering irrigation recommendations based on real-time soil moisture data.

These mock-up designs emphasize the importance of user-friendly interfaces, real-time data integration, and adaptability to different farming conditions. They aim to inspire the development of DSTs that are both scientifically robust and practically applicable, supporting sustainable soil management across diverse agricultural contexts.

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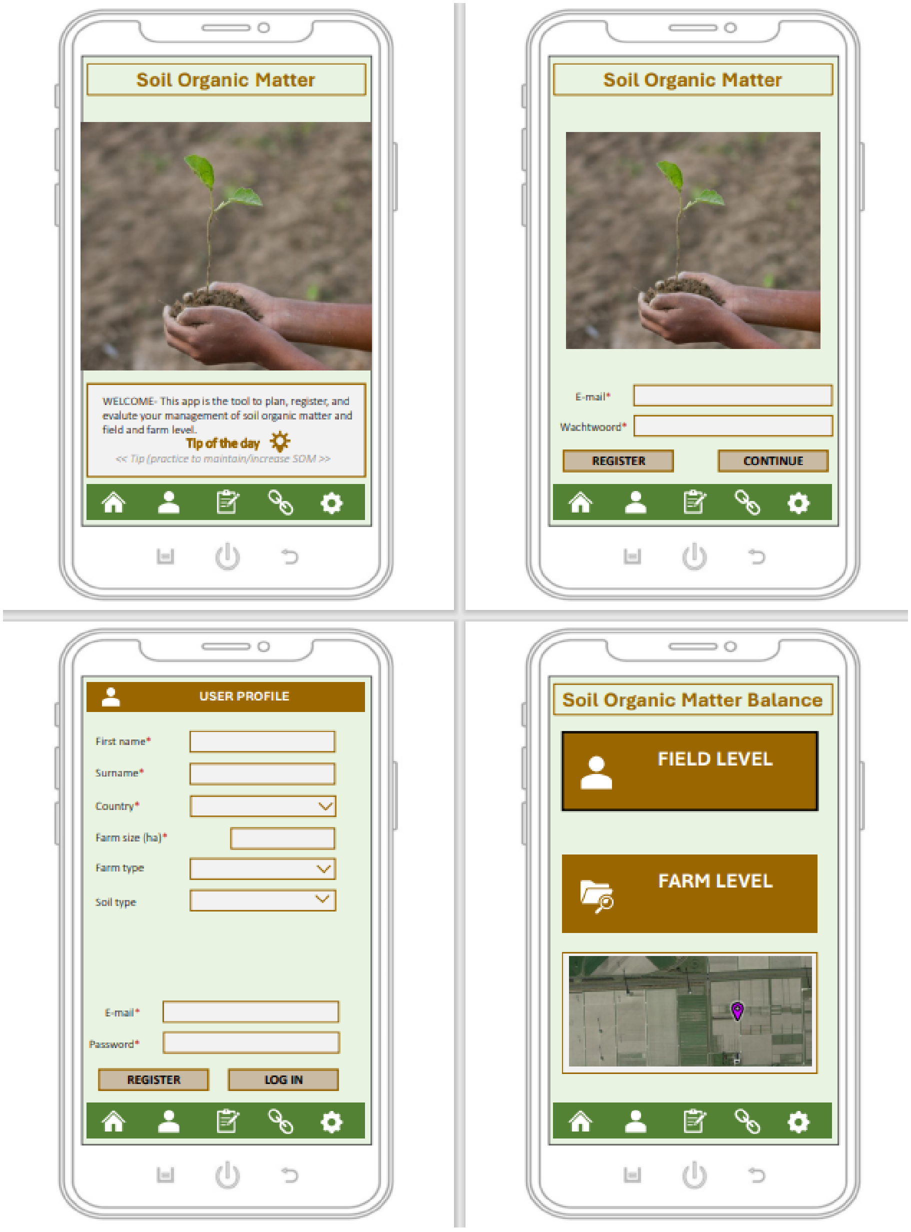
Annex 1. Mock-up design Soil Organic Matter Balance



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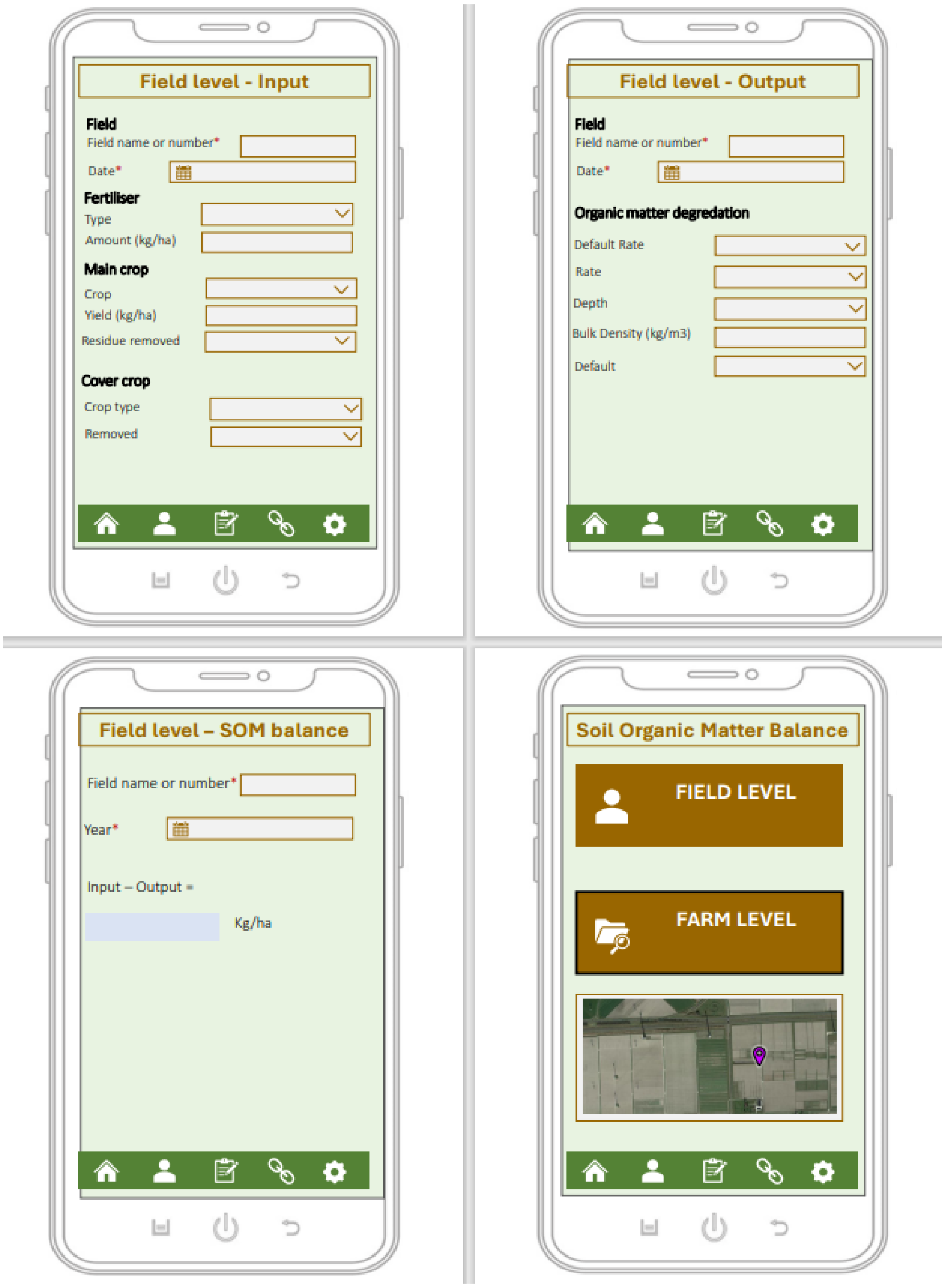

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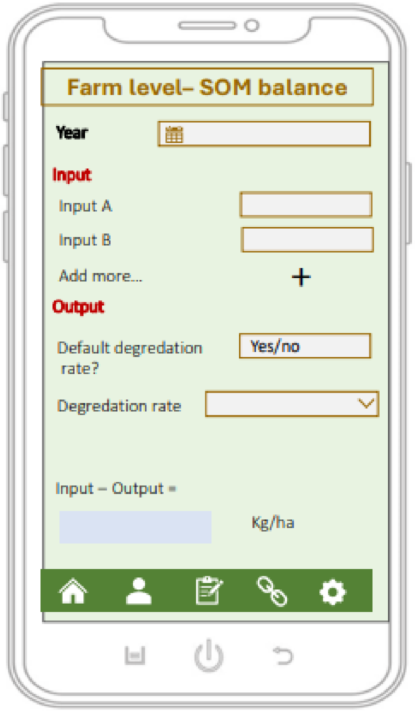

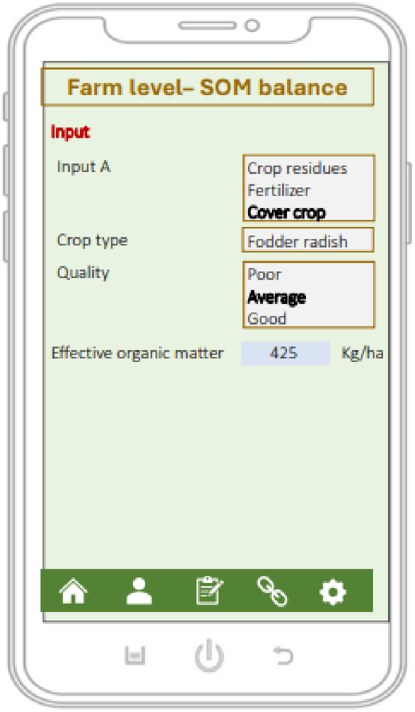

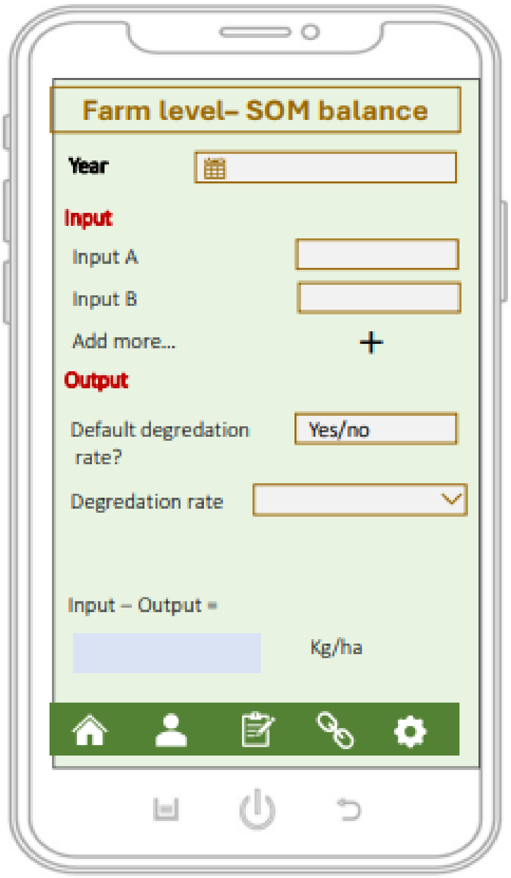

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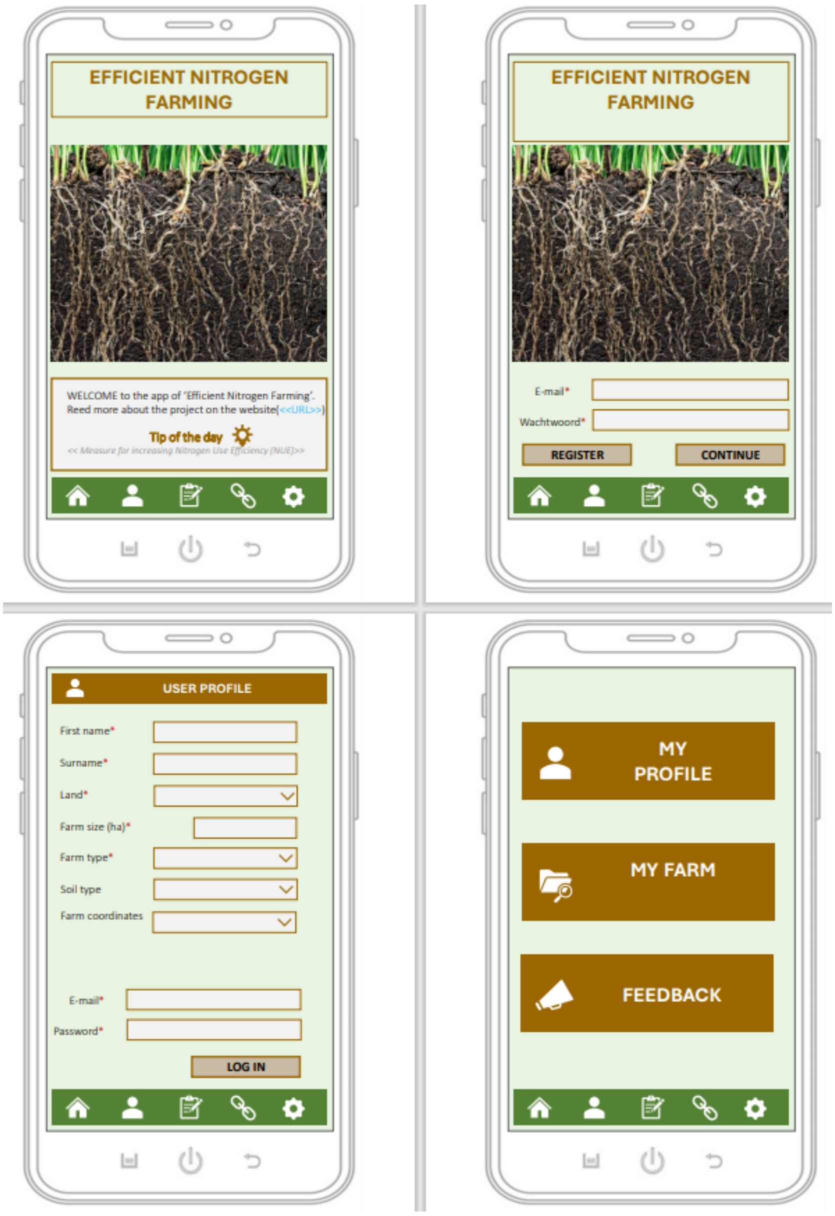
Annex 2: Mock-up design Nitrogen Use Efficiency



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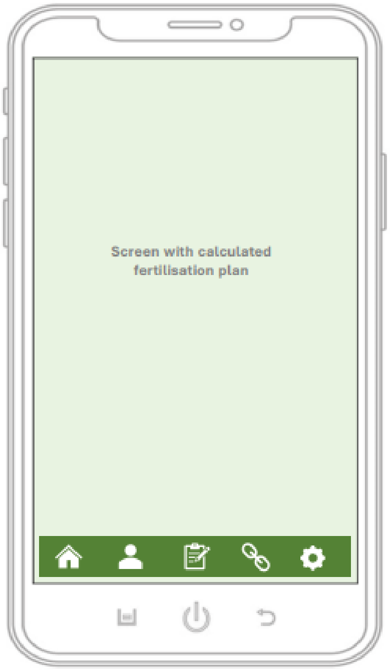

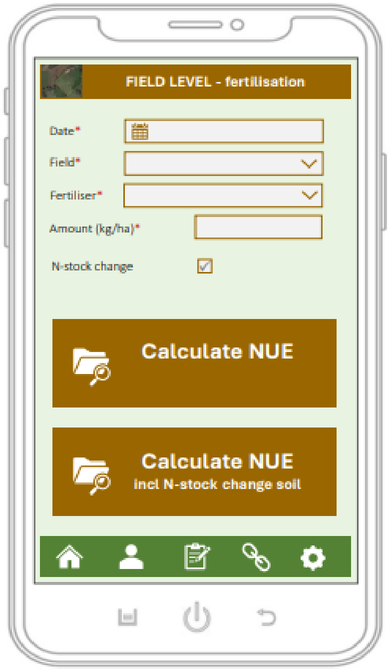

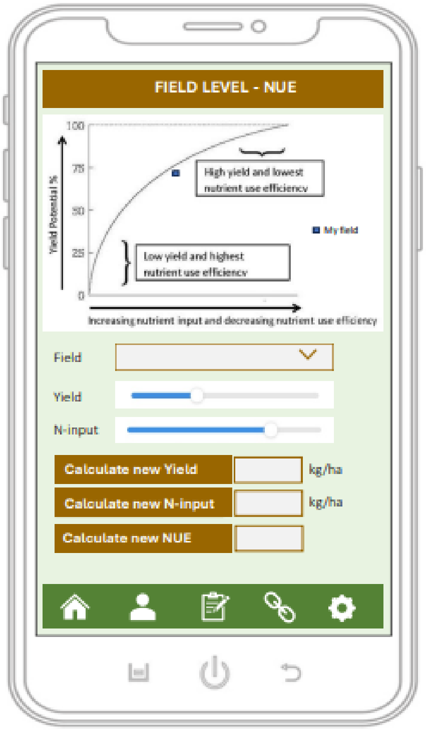

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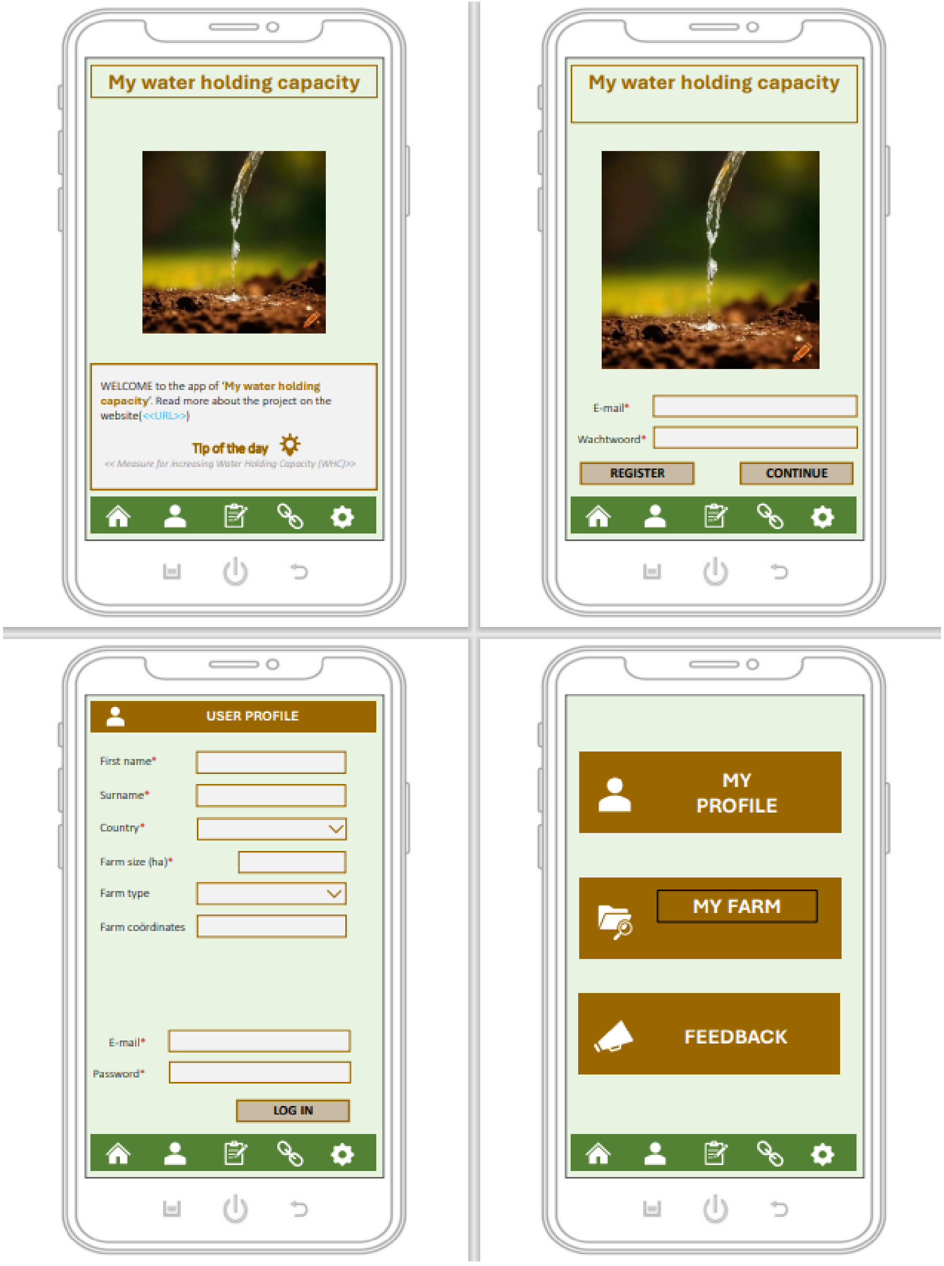
Annex 3: Mock-up design Water Holding Capacity



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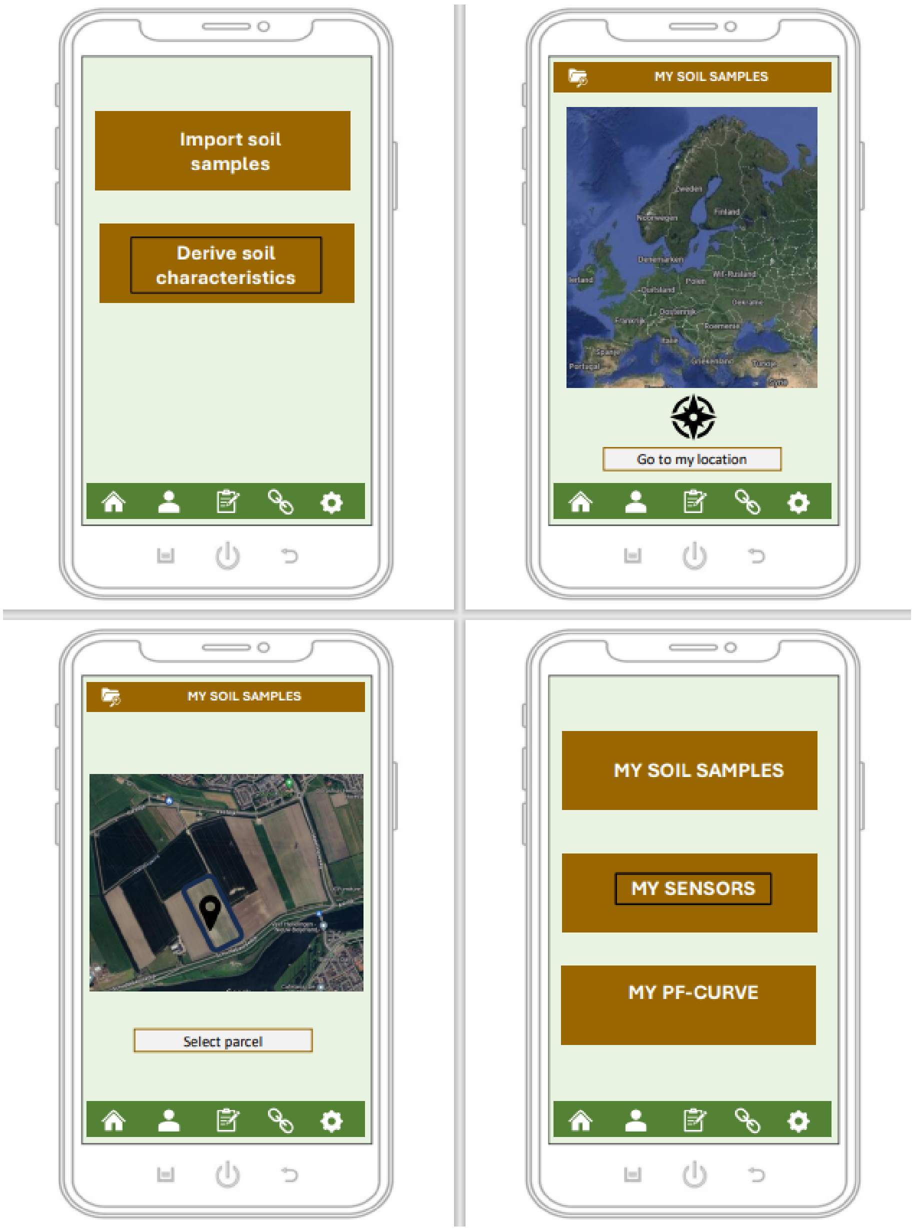

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