Map-based visualization for communication about potential and ongoing regenerative agriculture practices

Name: Jakub Stachurski (s2753529)
Supervisor: Erik Faber
Critical observer: Kasia Zalewska-Kurek
Date: July 7, 2025
Graduation Project Thesis
Program: Creative Technology, Bsc
Faculty: EEMCS
University of Twente

Abstract

The issue of emissions and pollution in agriculture has been picked up by multiple organization. Some of the organizations believe that Regenerative Agriculture(RA) could alleviate some of the issues. Regenerative agriculture is a somewhat open term, but in wide strokes it is a holistic approach that aims for a healthier soil and ecosystem on and around farms. This thesis tried to create a solution to display progress of RA initiative in a flexible and farmer-oriented way. This has been accomplished through researching what the farmers need to know and integrating it into a web-based map visualization. The visualization has flexible way of categorizing farmers into organization-specific categories also called milestones, this addresses the open definition of regenerative agriculture. While the research created a working prototype, the user experience of such an approach needs to be investigated and improved further. The results of the 4-person test, that collected observations and feedback, also show this. Aside from usability issues, it also highlighted the need for documenting and explaining the interactions and the need for a more long-term test. Nevertheless, the core concept shows promise as after getting through the prototype the first time, the users seem to be positive on the continuous use of the prototype.

Acknowledgement

I would like to thank the people that made this project possible. The first of which are the supervisors Dr. Kasia Zalewska-Kurek and Dr. Ir. Erik Faber, which I would like to thank for the constant support and guidance in the project. I would also like to thank Foodvalley for the opportunity to work on this project, and more specifically Ileen Wilke and Karin Slobbe-Visser for overseeing the project. I also want to thank Madeleine Leertrouwer for the cooperation and sharing of insights between our two projects.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Giving a green touch to agriculture

Emissions related to agriculture amounted to 10.8% of total emissions in the EU in 2022 [3]. This does not even touch on the other damage that agriculture and food production does to the environment. Other forms of impact like the introduction of pesticides [4] and excessive nitrogen compounds [5] in the ground and groundwater are also a major problem for the industry. To reach climate goals and ultimately keep our planet livable for the generations to come, a lot of environmental impact, including things mentioned above, need to be reduced. There are many measures in place for other industries, including agriculture. The measures for agriculture in particular are hampered by many factors, like monetary and labor cost [6, 7], inadequate education among farmers [8, 9, 10] and socioeconomic factors [11] among others.

One way to reduce the environmental impact of agriculture is regenerative farming. Regenerative farming, also called regenerative agriculture, is a set of changes done to the process of growing crops and/or ranching animals to make that process more sustainable. [12]

This is where Foodvalley comes into the picture. Foodvalley is an organization that wants to make food production in general follow more sustainable practices. Such practices reduce the negative impact on the environment and society and introduce balance. [13] Aside from talking to farmers about adopting regenerative agriculture, Foodvalley communicates with all companies in the chain from field to store shelf.

One of Foodvalley's initiatives is the Regenerative Innovation Portfolio (RIP) [14] Which gets a group of regional stakeholders involved in food production together into a landscape. This landscape is put in place, so the stakeholders can adopt more sustainable practices together. Since things like reducing pesticides has to be coordinated between different farmers for best results. Foodvalley already established such a landscape in Spain. [15] The role of Foodvalley in the RIP is that of an agenda setter, and they are responsible for networking with the potential RIP stakeholders.

1.2 Many facts, many stakeholders, one landscape

Because this initiative is quite new, innovative but also complex due to the amount of stakeholders. This makes the stakeholders reluctant to just participate right out of the gate. Therefore, there is a dire need for a place, tool or platform, where results, insights and potential hurdles around adopting regenerative agriculture can be shared. This tool is not only needed to show the stakeholders the benefits of participating, but also to bring the stakeholders together and lower the complexity that stems from having many stakeholders and thus voices. Having such a tool would help Foodvalley in creating new landscapes and making current landscapes even more sustainable by keeping prospective and current stakeholders well-informed.

The goal of this Graduation Project is to design such a tool. The project focussed on showing effects of sustainable practices on farms, but does not exclude the other kinds of stakeholders like processing plants, warehouses, and stores. The main focus was creating a map-based visualization to show insights about regenerative agriculture to stakeholders in the innovative and cutting edge initiative of RIP. Creating this map based-tool could involve visualizing data on each plot of land owned by stakeholders, most notably farmers, and neighboring plots. This has been dropped later in favor of just noting down the farm locations. Since, as mentioned before, some sustainable measures work best if everyone around also participates. This makes the challenge quite unique, since it pushes the boundaries

of what has been done to make food more sustainable. With the field of regenerative agriculture still developing, this task involved a lot of research.

1.3 Research questions

The goal of this project is to design the map tool for Foodvalley in an informed and scientific way. Therefore, the project had set out to answer research questions in order to see how a proper implementation has to include and how it should perform.

The main question this paper seeks to answer is:

RQ How to design a map-based tool that visualizes data related to adopting sustainable practices in an informative way?

To answer this question, this paper tried to solve the following sub-questions:

SQ 1 What drives an agricultural stakeholder to adopt regenerative agriculture practices?

SQ 2 What kind of information is beneficial to share between farmers?

SQ 3 What kind of agriculture-related data can be found publically?

SQ 4 How can the project safely visualize or make use of data that is not meant to be public?

SQ 5 How can the important data pertaining to sustainable agriculture adoption be visualized on a map?

SQ 6 How can a map application give the farmers clear steps to adopt a more regenerative approach?

The first two questions were answered through literature research, where those questions were asked directly. Afterward, the next two questions were answered by searching through the internet for sources of public data while also assessing how much data can be sourced from stakeholders. The last two questions were answered by looking at examples and taking lessons from them.

2 Background research

In order to answer the majority of sub-questions, the paper starts with three kinds of background research. The first is literature research, which answered the first two sub-questions.

The second type of research looked in public databases of data that is freely available. This mostly solved the question of what data can be used without problems. (SQ 3)

The final type of research is researching similar solutions, and looking at their strengths and shortcomings. This answered (SQ 5 and SQ 4), since to see what works, the best way is to learn from other people and see what they have done.

2.1 Literature Review

As the first method of background research in this paper, the literature research was used to gather information about adoption of regenerative agriculture measures. Using multiple queries in the used database, Scopus, resulted in 12 papers that included useful information pertaining to adopting regenerative agriculture. There were also a few papers that found kinds of insights and data, that if shared, improve the effectiveness of any sustainable measures.

2.1.1 Adoption drivers

The first thing that influences the adoption of regenerative agriculture are the economic factors associated with it. A big disadvantage of adopting sustainable practices in agriculture is that such measures can incur additional costs and put a financial burden on farmers trying to adopt them [6, 7, 16, 8, 11]. A few examples of this are given by Jordon et al. [6], which researches regenerative practices among British cattle farmers. The first example given is rotational grazing, which splits the pastures into a few separate smaller ones, with the purpose of moving the cattle regularly. This practice increases the productivity of the grass, but also needs to set up in the form of additional fencing. [6] Another example of this, is mixed farming, which involves alternating the field between arable farming and grazing for cattle. While it reduces the dependence on bought feed and improves soil health, the amount of effort and reduced amount of fields growing crops outweighs the savings made, especially when the feed is cheap. [6] In addition to Jordon et al.[6], the research yielded multiple papers [7, 16] that cite the cost of the measure as an important factor in adoption. A few papers [8, 11] also cited profitability of the measures, which also involves the costs. Next to worries to decreased yields, farmers also face the market, which might or might not support the higher cost of regeneratively produced food. [17, 18] Circular economy, which prioritizes refurbishing and recycling among farmers, but also offtakers, is confirmed by Ntawuhiganayo et al. [18] to improve the adoption of regenerative agriculture. Another way that regenerative agriculture affects farmers seem to be the yields. There is conflicting research about this topic. Some newer research conveys that there are no considerable drops in yield [19, 20, 21], but there is also a body of research that states the opposite [22, 23]. The proper conclusion of this conflict is beyond the scope of this research. This conflict in literature also reflects the famers' uncertainty around this topic, as their income is directly linked to the yield. Farmers' worries about yield are observed in Guevara-Fernandez and Olivia Cruz [16], Jordon et al. [6] and Kemp et al. [11]. All of those papers confirm the uncertainty about yield and the effectiveness of sustainable measures.

Many countries have taken notice of the fact that regenerative agriculture costs more to set up. To mitigate the costs and become more sustainable regardless, many governments have implemented grants. The positive effect of such grants is often affected by the next thing that affects adoption, policy. One way that the policy

affects adoption is by being unclear, this makes the more risk-averse farmers unwilling to change their ways. The following papers confirm the effect and the tendency of policy surrounding regenerative agriculture to be unclear: Feng et al. [7], Jordon et al. [6] and Happel et al. [8]. The main part of the problem is that laws and regulations around regenerative measures, while some studies only consider trust in agricultural policy in general [7], some have concrete examples. Such specific example of unclear policy is the classification of microbial treatment of the soil as "biofertilizers" and "biocides" as outlined in [8]. Another problem with unclear policy is that any uncertainties make it hard to rely on any grants.

Next to the influence policy has over farmers, another important gauge for adoption is the level of education of the farmers regarding the topic, which is linked positively by Van Antwerpen et al. [9], Happel et al. [8] and Kreft et al. [24] and Ntawuhiganayo et al. [18]. The effect of educating farmers on adoption have multiple reasons. First one is that the farmer needs to know how to do something before adopting it. [24] [18]. Additionally, trained practitioners of sustainable practices had higher odds of being food secure, according to Ntawuhiganayo et al. [18]. Another reason seems to be clearing up misconceptions [8] which was declared an adoption barrier in other papers [6]

Another thing that is worth researching are social effects, which are mentioned in Feng et al. [7] Li et al. [25] and Kreft et al. [24]. Those effects range from simple cooperation [25] to the surrounding farmers influencing other farmers to adopt regenerative agriculture [24]. Next to that, more effective spread of information, like insights about certain measures and living proof of the effectiveness of measures. The latter is good as the proof of the measures working is also an important factor according to Jordon et al. [6]. In addition, there is a case to be made about the side effects of things happening in neighboring farms, one example of this is the spread of pesticides, pesticides and fertilizers outside the field where they were applied. [26, 27]. Which according to Köthe et al. [27] could decrease biodiversity of plants and animals in affected areas.

2.1.2 Insights to share

Next to things that drive adoption, this paper also looked into knowledge that farmers might have and is beneficial to share. Since some of the papers outlined a few things that could be shared but might or might not drive the adoption of regenerative agriculture. The most often cited thing for farmers to share with each other is the knowledge about how to perform regenerative agriculture. [9, 24, 10] This one is in line with the education point for adoption, but also has the added benefit of sharing skills and thus improving effectiveness. The next thing that is aligned with adoption is the farmers sharing proof of the argued benefits of regenerative agriculture. [6] Because some farmers are not yet convinced that regenerative practices are worth the time [11], they need to see the benefits before jumping on the bandwagon. Speaking of uncertainty, the next kind of information that farmers could share with each other is important information to solve uncertainty about technique, policy and others. [6, 8] Along with that information, knowledge about a particular thing like amount of fertilizer to use could be of use according to Zhang et al. [17] And finally there is evidence that some things like pesticides spread to neighboring farms [26]. So it is important for farmers to share their own agricultural doctrine with their neighbors so they can plan accordingly.

2.2 Available data

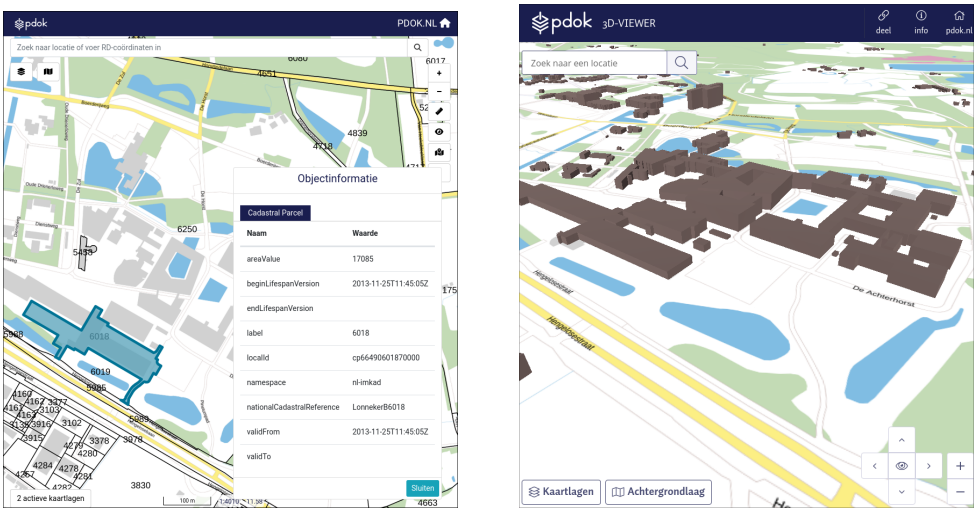
In order to visualize anything, data is required. In the case of this project, the knowledge of the farmer's position and their practices is needed. This section answers SQ 3. During the research stage, it was not known if the stakeholders would provide the information. Because of this, the project was initially based on

publicly available information and complemented by farmer-provided information. This has been later amended following interactions with the stakeholders. Because of the location of the research, the Netherlands have been chosen to be the target of this search.

2.2.1 Nationaal Georegister / PDOK

The Nationaal Georegister[28] and Publieke Dienstverlening Op Kaart[29] are two services that work together to create publicly available data sets for things like land ownership, but also agricultural matters like soil type and the kind of crop grown reported by farmers. They additionally provide a way to view them easily. While the NGR contains datasets from other sources than PDOK, most of those that seem to be useful for the project are hosted by PDOK.

PDOK has data in both 2D and 3D maps, which are also viewable on their website using their respective viewers (See Fig. 1). In addition to the map view, there is also an Application Programmer Interface(API), which allows other programs and services to access the data in a sane way. The API used by PDOK is the API developed by the Open Geo-spatial consortium, which is an organization that tries to standardize the way how data is provided and how external programs access it. The PDOK version of this API is customized, but closely follows regular specification and has its own documentation. [30]



(a) 2D Land registration map

(b) 3D Building map

Figure 1: PDOK-provided maps of the University of Twente

PDOK has many maps that could be of use, here is a list of the datasets that could be of use for the project.

1. Background maps with roads, cities and points of interest and their names
2. Addresses and their location on the map
3. Land plots as polygons and their surface area
4. Type of soil on the map
5. Land use per plot

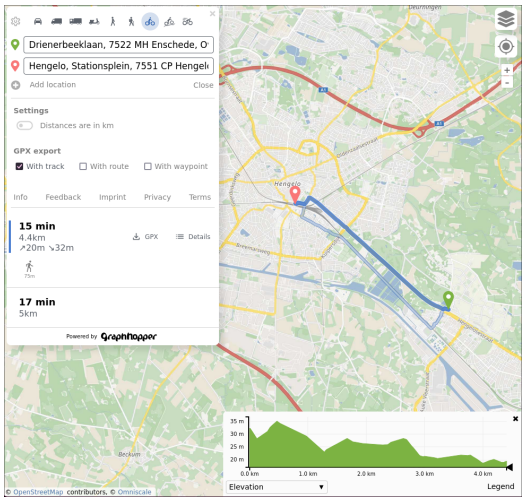


Figure 2: Calculating a bicycle route using Graphhopper

2.2.2 Open Street Map

What PDOK lacks is a good way to use the road information, which could be useful for calculating distances between stakeholders and similar purposes. For that purpose, Open Street Maps [31] can be used, as it provides more workable road information. Open Street maps is a volunteer driven public map of the world, and the data is free to use with attribution.

Using a third party, and also open, program for routes, Graphhopper [32], one can use Open Street Map to find routes and distances between places. It includes distance by car, road bicycle and more. Fig. 2 shows Graphhopper in action. Just like PDOK and Open Street Map, Graphhopper also has an API.

2.2.3 Things that can be provided by the stakeholders

This section is dedicated to the data that can be obtained from the stakeholders. There are a few kinds of data that the stakeholders have little reason to not give, and have given before to other similar tools.

The first kind of data are the addresses of farmers and off-takers. Those are probably either public knowledge, already acquired as contact information or given when asked.

Another part of the data possibly given by stakeholders are the information about the farm is the ownership of land and what crops are growing. The second can be deduced from the other, by simply going to the location given by the farmer and seeing what grows there. This is probably unnecessary, since the farmer would probably give both kinds of data at the same time.

The final dataset is the one that the organizing party holds, namely they know which stakeholders are contacted, which ones are participating and which do not. This is a very powerful information for all stakeholders, because of the social effects discussed in the literature research.

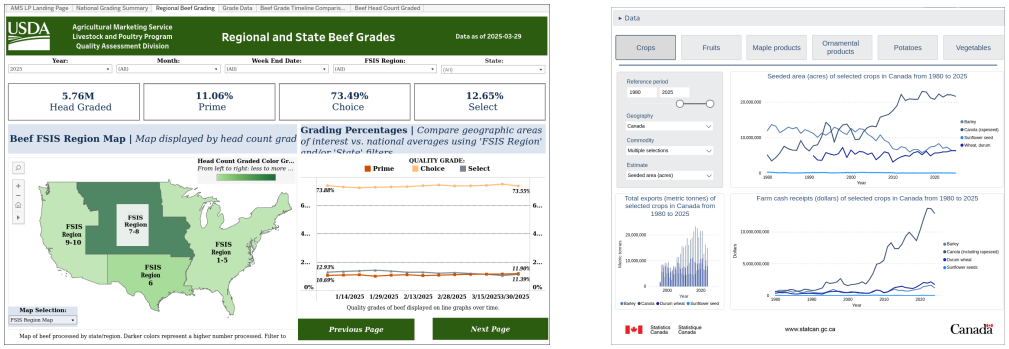
Another limitation found during stakeholder interviews is the amount of time that data entry might cost. The farmers already need to report on many aspects of the farm to the government once a year, and adding excessive amount of data entry on top could dissuade farmers from joining the platform.

2.3 State of the art

In this subsection, prior work that could bring important insights and inspiration for the final product was examined. This could include papers which solve similar issues, but also non-academic use of visualization and other techniques.

2.3.1 Government provided visualizations

The first of the examples are visualizations made by governments to showcase agricultural data. This includes PDOK (see subsubsection 2.2.1) and similar sites from the American (Agriculture Marketing Service [33]) and Canadian (Statistics Canada [34]) governments. All three show how to display many types of data on a map. In addition, both the American and the Canadian sites show a good example of the UX design surrounding choosing the amount and type of data. The Canadian portal is especially good at composing multiple simple visualizations like line graphs, pie charts and histograms together to make the whole more informative. The American portal does that to varying degrees, ranging from 1 to 8 charts per page, with the bigger pages refusing to load. This also brings a negative of all three of the services. The sluggish performance of those platforms, probably related to the volume of data that they need to process, is a major barrier to the user experience. This is something to note when taking inspiration from them.



(a) Beef grading visualization (AMS)

(b) Grain crop visualization (Canstat)

Figure 3: Agriculture related visualizations provided by other governments

2.3.2 Map based solutions for agriculture

Along with those visualizations, there are also a few papers that involve map-based visualizations. Those often serve a clear purpose instead of only showcasing data. The first example created by Laurent et al. [35], ISOFAST is a tool for sharing and aggregating results of on-farm research results and their economic implications The sharing aspect of ISOFAST is aligned with the goals of this project. It also shows that sharing data between multiple farms is feasible, along with the steps needed to get there. Its performance is also notably faster that the websites above, but that could be related to the amount of data. ISOFAST is a web-based solution.

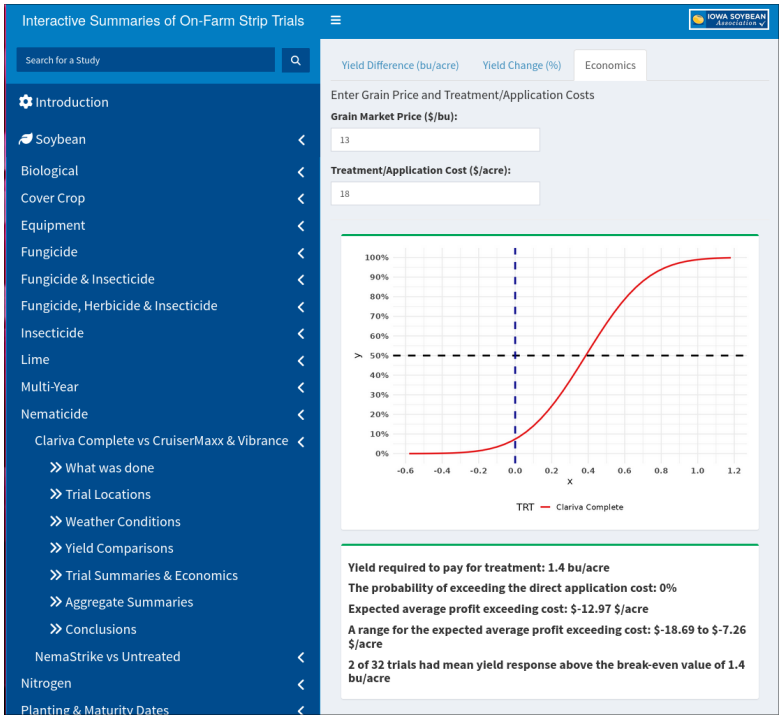


Figure 4: Screenshot of ISOFAST's economic analysis feature.

Another example for map-based visualizations is GEOVIT created by Terribile et al. [36] for the purpose of creating a tool for better decision-making in Viticulture. GEOVIT includes many different data points to accomplish this, which are for the most part related to soil conditions. The interactive part of the visualization is handled by a separate framework, but this example shows the usefulness of such visualizations for making decisions on the farm. Terribile et al. [36] also highlight difficulties with obtaining the large amounts of data needed for the visualization, citing the lackluster maintenance of data gathering climactic stations as a major problem.

2.3.3 Web based LiDAR visualization

The visualization of Mao and Cao [1] is in 3 dimensions as opposed to ISOFAST and GEOVIT, but is also web based. The goal of this visualization is to visualize Light Detection And Ranging (LiDAR) measurements for agricultural purposes. As mentioned by Mao and Cao [1], LiDAR is becoming a more important asset in agriculture. This paper was written in 2013 and showed that even back then creating 3D visualizations was possible on the web. Mao and Cao [1] outline the technical challenges they faced with moving the data and also the limitation of the browser that made them implement the visualization in a certain way. One of the

techniques of interest in that paper is the use of Level of Detail (LoD) which is a technique that involves changing the amount of detail, based on distance.

(a) (b) (c)

Figure 5: Figure 3 from Mao and Cao [1]

2.3.4 3D visualizations using game engines

Next to using the browser, using a game engine is also an option. This is what Maulana and Kanai[2] did with their Geographical Information System (GIS) for agriculture. In their case, Unity3D game engine along with the MapSDK extension was used. Using a game-engine allowed them to support mobile devices more effectively, while also providing them with all the necessary tools to bring the map to the third dimension. The use of a game engine also made it possible to explore the visualization in first person, which the Maulana and Kanai recommend further research for. This approach also has limitations, namely bad performance on weaker systems and the requirement for a steady network connection to load the data into the visualization.

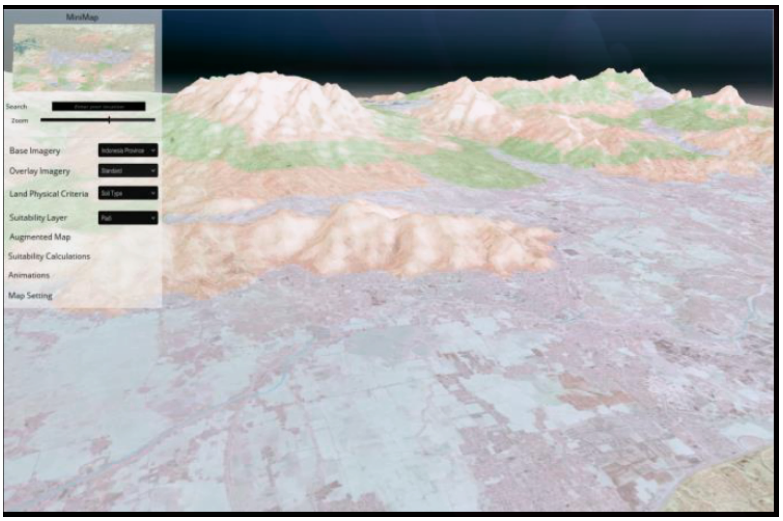


Figure 6: Figure 10 from Maulana and Kanai [2]: First person mode of 3D-GIS

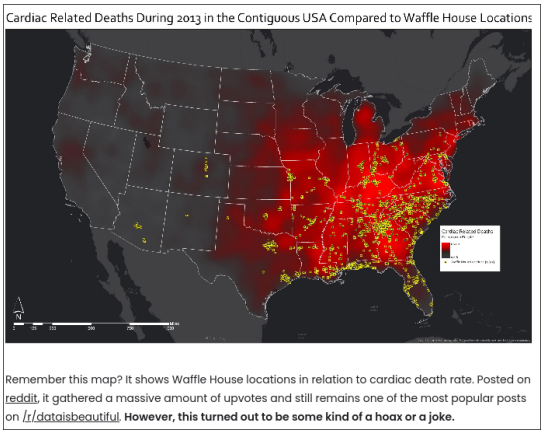
2.3.5 Creative ways of visualization

If you can use a game engine for visualization, why not use an actual game. The You-tuber "Gneiss Name" [37] who creates many videos related to geology in his Geology of Minecraft series. There he often shows geological processes and scale of things in a very creative way. An example of such video is the episode about iron [38], where he shows the amount of iron created in each year but also it's uses inside of Minecraft. Those visualizations are often animated, showing the potential of colorful animations in visualization.

Figure 7: Visualizations in Minecraft

Another creative use of visualizations can be found on the website `https://foodydata.com`, which collects visualizations about food in general. What sets FoodyData apart is the surrounding story of each visualization, which helps paint the picture. Many visualizations are not accompanied by any story, which undermines their effectiveness and can create misconceptions around the data. An example of misleading visualizations is can be found on FoodyData itself. The post *"Heart Disease Deaths and Waffle House Locations"*[39] correlates locations of the "Waffle House" restaurant chain with the amount of heart disease in America. Without the context of the article, the visualization would make people agree with the hypothesis, but the rest of the post explains why the first map is misleading. Another post based visualization website is `https://forkranger.com/`. ForkRanger is a Netherlands based blog that shows ways to reduce food related carbon footprint of its readers. ForkRanger's visualizations tend to be simple, but they make it up with their creativity and style.

(a) ForkRanger



(b) FoodyData (including explanation)

Figure 8: Example of visualizations on blogs.

2.4 Background Conclusion

The background research had the aim to find out what data the farmers need to make a decision, how much of that data is available and how to visualize it properly. This threefold goal can be considered as reached with some caveats.

The first part seeks out to find out what data is considered important for adoption of regenerative farming. This chapter is a literature review, and aside from finding drivers of adoption, it also gathered three kinds of insights that could improve the outcomes of regenerative agriculture among the Regenerative Innovation Portfolio participants.

The motivation part has found four major factors that influence adoption. Which include the economic factors, market influence, insights on government policy, other farmers' actions, and education on generative methods. The farmers' actions include the current agricultural methods and their successes.

Next to insights drawing adoption, there is also the knowledge that is generally good to share between stakeholders. This is generally split between farm state and education. The first, mainly involves things that the farmer is doing and what their results are. The second kind of information are the best practices and techniques surrounding regenerative agriculture, this supports the education part of the previous part.

Despite the large amount of insights obtained from the research, there are still many loose ends. That is because the field of agriculture is so diverse and has many variables at work, from socioeconomic to the mix of molecules and organisms in the soil.

After the literature research, a simple search for data availability in the Netherlands was done. The majority of the data can be found through the Nationaal Georegister and PDOK. This dataset includes the cadastral data, the kind of soil under the farm and the use of each land plot, according to the government. Next, depending on the level of involvement of the farmers and other stakeholders, some more data could be obtained from them as a supplement to publically available data. This data mostly contains the current operations of the farmers, their farming methods and land ownership. More research needed to be done to know how much data the stakeholders are willing to give. This part also highlights the importance of stakeholders sharing information in the final implementation of this project, since most of the data is not publicly known but can be extracted from the stakeholders that happen to be users.

The last phase of the background research revolves around finding examples of visualization, mostly focussing on map-based visualizations. The search yielded many map-based and non-map-based visualizations to draw inspiration from. Multiple examples showed that creative visualization is feasible on consumer devices with accessible technologies (web and game-engines), while also acknowledging the performance problems related to 3D map visualizations, along with some ways of mitigating them. The state-of-the-art section also showed that visualizations often work better with context, since there is a chance that data is misrepresented or misses the mark on informing the user. In conclusion, the search of for the valid examples of visualization to draw inspiration from.

3 Methodology

This chapter explains how the background research was utilized to answer the main research question. The rest of this research is structured along the lines of the CreaTe research method, outlined by Mader and Eggink [40]. The CreaTe research method is based on iterative phases, which each phase can be reentered during the design. The further phases are outlined below, and a diagram from Mader and Eggink [40] can be seen in Fig. 9. The stages are also the scaffolding for further chapters which are explained in detail below.

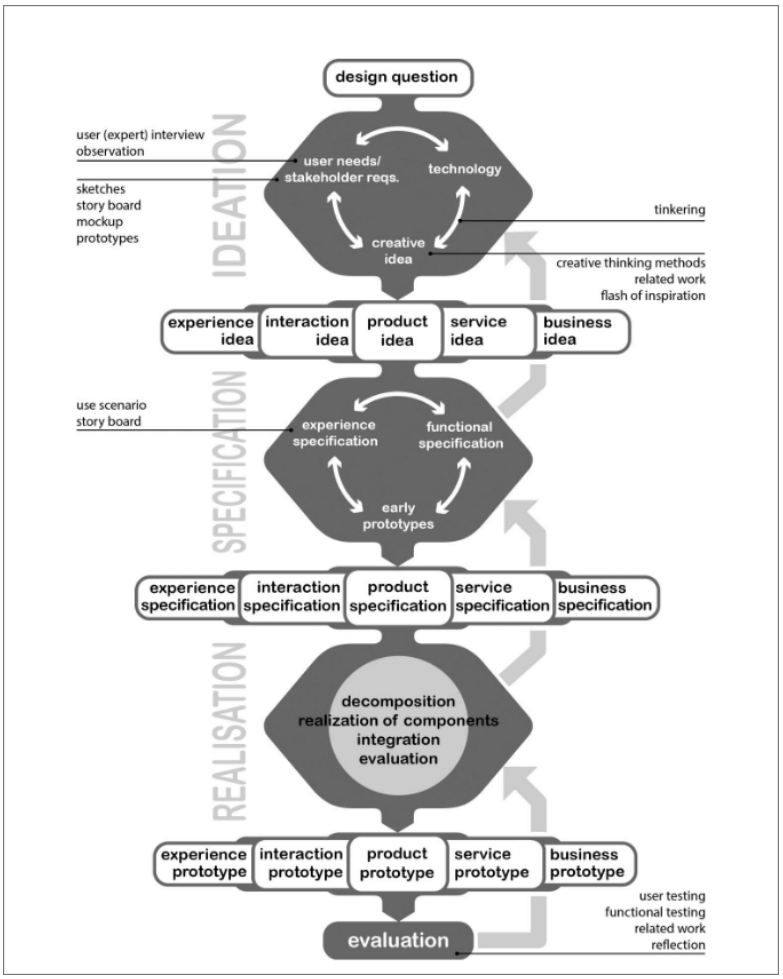


Figure 9: The graph of the CreaTe research method

3.1 Ideation

The first thing to do when designing was to come up with an idea. But even before that, the designer often needs to get the stakeholders and the constraints of the project straight. For that, a short analysis of the stakeholders was performed by listing out all stakeholders involved. To get insights from two of the main user groups, a semi-structured expert interview was performed. Then, the stakeholders were put into a power-interest matrix(PIM) and explaining their involvement in the finished product and the development of the prototype. A power-interest matrix, as described in Mendelow [41], is a matrix which puts involvement or interest of the stakeholder on one axis and their power over the project on another. This can be then used to assess the approach for each stakeholder. Afterward, a set of

preliminary requirements was gathered based on the stakeholder descriptions and base requirements from Foodvalley. The requirements were prioritized using the MOSCOW method[42], which has a set of priority levels: Must, Should, Could and Won't. This set of requirements is preliminary and were expanded upon during the specification phase. This can be done in many ways, but Mader and Eggink [40] point out that creating smaller ideas, through concept generation, and then converging to a final idea is one of the best ways to go about it. Therefore, this research started with multiple kinds of brainstorming before narrowing down what was to be implemented further along. The concept generation techniques that were used in this paper are structured freewriting, mind-maps and collaborative brain-writing. Using those concepts, three potential implementation concepts were made, with only one of them being selected at the end. To solidify the choice, a semi-structured interview was done with the most important stakeholder group to see if all the assumptions about them hold, and the concept fits them.

3.2 Specification

After the concept generation yielded a final concept, this section fleshes it out. To accomplish this, the final concept was iterated on as recommended by Mader and Eggink[40]. That was done through a second round of requirement elicitation, along with use scenarios and persona's. After refining the requirements, the whole concept was refined through creating mockups of the most important interfaces and using the Universal Modeling Language[43] to model the critical parts of the project. With the refined concept, a plan for implementation was made. The plan is made using the Work Breakdown Structure [44, 45], which divides projects into more manageable parts. The components are separate parts of the implementation that each hold one of the aspect of the final concept. WBS is often used in larger teams, but for this project it was used to make the implementation more manageable.

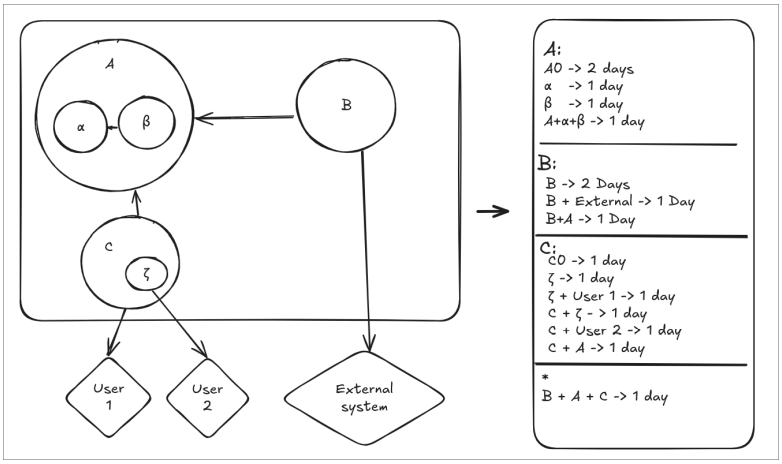


Figure 10: A depiction of WBS as used in this project

3.3 Realization

After creating a concrete plan for implementation of the concept, it is time to execute on that plan. This also includes regular check-ups with the client and iteration. The realization was divided into two parts, initial realization and refined realization. This was done in order to get a minimum viable product out of the door as fast as possible. This minimal viable product holds most of the needed functionality and was used to show the client, supervisors and fellow students, with the goal of getting as much feedback on the design as possible. As mentioned in the

Specification phase, the concept was divided into multiple components. In this phase, those components were explained in depth, including the tools and techniques. In addition to being explained in depth, the components were implemented, and refined in this part. At the end of the realization, the functional requirements were assessed as well.

3.4 Evaluation

The final part of any design process is testing if the design fulfills the non-functional requirements and if it became the thing that the stakeholders need. In this paper, the evaluation was done by testing the prototype with a sample of stakeholders. The test consists of a list of tasks for the user to perform, while thinking aloud.

4 Ideation

In this section, the background knowledge from previous chapters was turned into ideas and later concepts. But before that, the bounds and requirements for the final design had been established, in order to make the selection of a proper concept possible. After the stakeholder analysis and requirements elicitation, multiple brainstorming techniques were used to come to multiple concepts. At the end a combination of concepts has been chosen to the become the prototype.

4.1 The stakeholders

The first step of that is to enumerate the stakeholders in the projects. The stakeholders, groups of people that are influenced or influence the project in some meaningful way. As mentioned in Chapter 3.1, all of the stakeholders have their own section with addition to being placed in the power-interest matrix in Fig. 11

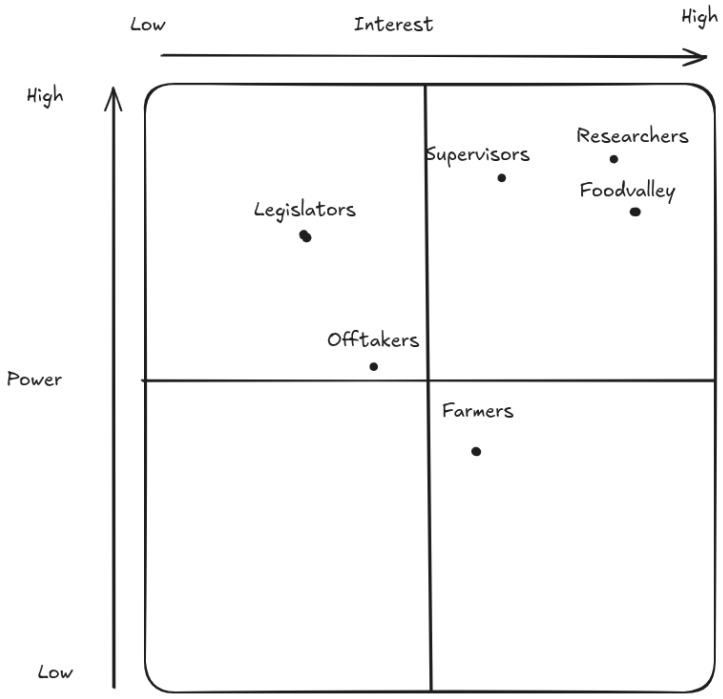


Figure 11: The power interest matrix for the project

4.1.1 Researchers

This is one of the two smallest stakeholder groups. The researchers are the authors of this project and hold almost ultimate authority over the project. The goal of the researchers is to see the project succeed as the fate of their educational carreer depends on it. The researchers are also the project owners, which means that they also have the goal of creating a successful tool.

4.1.2 Supervisors

The supervisors are the people who keep watch over the Researcher group and assess their academic performance, because of that they have a big sway over the project. Arguably, their power is comparable to that of the Researchers. Their role in the project is more based on feedback and background work, so while this contact with them is constant, they are not mentioned in this project often.

4.1.3 Client: Foodvalley

Foodvalley is the one in need of the tool, which makes them the Client for this project. They are the group that sets most of the requirements and evaluates the project in the practical sense. Clients often have high influence over the project. But their power does not exceed that of the researchers, since the researchers have the authority to disobey their requests if they have a good reason for it. So far, Foodvalley insists on the researchers making most important choices for the project.

4.1.4 User group A: Farmers

The farmers and their organizations are the biggest farming stakeholder targeted by the project and are therefore the most important to design around. They do not have as much direct power over the project, since the contact with this group of stakeholders goes primarily through Foodvalley. But the farmers' interests are supposed to be aligned to those of Foodvalley, according to Foodvalley. Outside the contact with Foodvalley, additional contact with the Farmer group was made through interviews and evaluation.

4.1.5 User group B: Offtakers

Since the farmers are at the whims of the market, the people buying from the farmers are also important stakeholders. Their role is more involved in the sister project, which visualizes supply chains. In this project they are not important to contact.

4.1.6 Legislators

Regulations often make or break what is possible in farming [46]. They are the second major factor for farmers aside from the market they sell to. Therefore, it is important to see the Legislators as a stakeholder group with a lot of influence. Some of them were contacted during an networking event.

4.2 Expert interview

In addition to researching the stakeholders. A 30 min semi-structured interview was performed to get a more direct source about the two stakeholder groups that end up user groups, the farmers and organizers. The interviewee is part of the organizer group but also has direct contact with the farmer group, which make them a useful subject for interviews. At the point of interview, a very early version of the prototype was shown as well.

The interview had the aim to improve understanding about the farmer's perspective and the following points were discussed.

- The motivation for farmers to put their information on the map
- How proud the farmers are for being sustainable
- Distinction between farmers that get their income from farming and those who do it for the sake of doing it.
- The amount of effort that can be asked from farmers when it comes to data entry.
- A similar map application that is being deployed across Europe.
- A bit of feedback on the criteria system and the mapping

The interviewee expressed that farmers are proud of the things they are doing, and many of them would opt in to joining a map. They also outlined that because of how busy the farmers are, they often do not enter their information in the maps without being contacted first, since their first priority is farming, this also applies to sharing that they are sustainable in any way. The interviewee then explained that there are two categories of farmers that end up on such maps. The first and most populous group of farmers are professional farmers, they are the ones that create most of the food that enters the supply chain and are often busy performing that task. The second category, which might be overrepresented in some of the example maps, are farmers that farm in order to farm sustainably. There is some overlap in this category, but most of the farmers of the second category do not farm as a primary source of income. In order to create change in the agricultural sector, the first category should be primarily targeted. The interviewee then said that because of the amount of administration they already have to do for the government, they are not ready to be filling in too many forms, and they outlined that this is why the final design should be kept simple. Afterward, the interviewee was shown the early prototype, which encompasses the categorization and the mapping of the farms. As feedback, the interviewee pointed out that the farmers should not be too burdened by those categories, and most of the inputs should be simple checkboxes.

4.3 Contact with other stakeholders

As a part of the project, the researcher went to a conference on agriculture and climate. During this event and additional information on farmers and how the agricultural industry works was obtained. During the event, multiple experts confirmed the willingness of farmers to change their approach, provided the farmers can do it at their own pace and the bar for the participation is low. This aligns with the finding of the literature research, where farmers were hesitant to adopt larger measures because of uncertainty.

4.4 Requirement elicitation

Each of the stakeholders might pose their own requirements, which is outlined in this chapter. As mentioned in Chapter 3, the MOSCOW [42] method is used. This leaves space for the ideation that follows. The requirements have two major sources. The first, and the most important, source is Foodvalley, since the project is meant for them to use. The second source is the background research, the resulting set of requirements from this source is based on the takeaways from the literature and the limits on data found in the search for available data.

Priority	Requirement	Source
Must	The project must visualize the distinction between farms doing Regenerative agriculture, only applying some measures and applying no measures.	Foodvalley
Must	The project must visualize a whole region.	Foodvalley
Must	The project must contain a map-based visualization.	General
Should	The project should help farmers with the decision of adopting Regenerative Agriculture by informing them about the practices of RA.	Foodvalley
Should	The project should help farmers with the decision of adopting Regenerative Agriculture by giving them an low-effort way to start.	Interviews
Should	The project should involve the farmer in the process.	Research
Should	The project should be able to gather data from the farmer.	Research
Should	The project should be able to keep any data gathered safe.	Researcher
Could	The project could fully integrate with the sister project that focusses on supply chains.	Researchers
Could	The project could differentiate between types of agriculture.	Foodvalley
Could	The project could utilize data from existing agri-environmental organizations.	Foodvalley
Could	The project could be made extensible as to make the handoff to the client easier.	Researcher
Won't	The project won't fully implement data protection measures, like GDPR.	General

Table 1: The initial list of requirements

4.5 Brainstorming

With the boundaries of the project set, the ideation phase can begin proper. As outlined by Mader and Eggink [40]. In this paper this is done through collaborative Mindmapping and Brainwriting and solo Focussed Freewriting, is followed by a converging phase that puts all the ideas together into multiple concepts.

The first of the three brainstorming methods is Focussed Freewriting, which is done by removing any distractions for 20 minutes and writing as many ideas down as come to mind, with no filter or limit. [47] Results of this method can be found in Appendix Appendix B. This method was quite successful for getting a basic list of ideas, with some outliers to be considered. The other two methods were performed with the author of the sister project. The first of which was to make a mind map around regenerative agriculture, which can be found in Appendix Appendix C. The second was Brainwriting, which was done for both projects together. Brainwriting involves writing ideas down using post-its, which means that instead of regular brainstorming the ideas created are less influenced by other people's ideas. [48] The results of the brainwriting for this particular project can be found in Appendix Appendix D

4.5.1 Resulting ideas

The brainstorming resulted in three idea groups, the form-factor, the visualization targets and the interactions. This section outlines each of those and give the ideas that fit each of them.

The first important group of ideas is the form-factor or the medium the project is built on. It is dominated by mostly digital and interactive media, since the interactivity is emphasized in the requirements. The most interesting of those interactive media are: Web-based map visualizations, Video game and standalone computer visualization. The non-digital media include a physical map visualization and an actual map.

Another group is the things that could be visualized, where two families of things to visualize were found. The first family is based on what to visualize, and the second is based on how to visualize something. Examples of the first kind are the ideas to visualize things like the biodiversity of the region and participation of farmers. On the other side, the idea of using droplets to visualize the use of fertilizers, pesticides and other inputs was pitched during freewriting. In addition, visualizing the kind of land use through putting down grass with cows, fields of grain and greenhouses for their respective kind of agriculture is also proposed.

The third and last group of ideas focusses on the interaction with the project, mostly with the farmers in mind. This includes all kinds of ways to share information between farmers, from blogs of farmers to simply asking certain data from them to participate.

4.6 Creating and evaluating concepts

After the brainstorming, the ideas are to be combined into full concepts for the project. Those concepts have their advantages, disadvantages and nuances. Those were also evaluated for each concept to facilitate each choice.

4.6.1 Concept #1: 3D-Landscape explorer

The first idea is based on the 3d visualizations as shown by Maulana and Kanai [2] and Mao and Cao [1]. The main goal of this idea is to leverage how real and intuitive 3-dimensional environments feel. In this concepts everything is visualized close to what it appears on in the real world. It aims to show the important information in as of an intuitive way as possible. The main goal of this visualization would be to show if each farm is regenerative. That would be done by showing flowers and butterflies on the regenerative crops. And showing off-putting droplets, representing pesticides on farms that are not regenerative. A middle-ground for the category that applies some sustainable measures needs to be found. to display what kind of agriculture is performed by showing cows in a pasture for example of a farm specialized in creating dairy and/or meat.

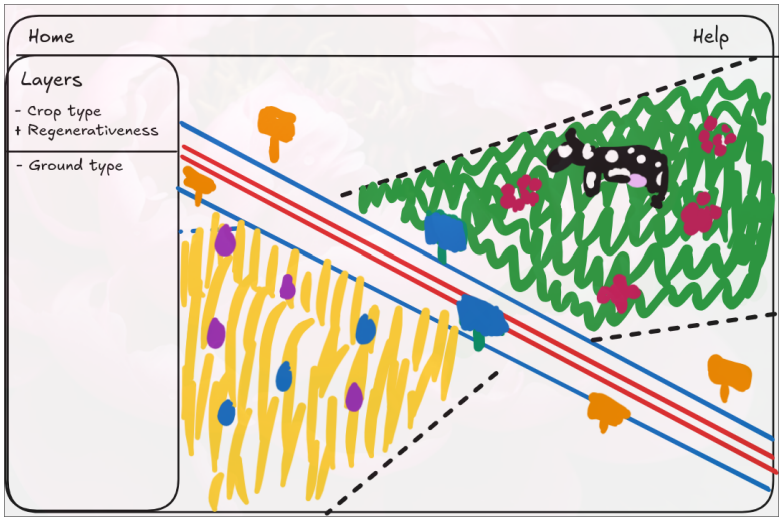


Figure 12: Illustration of concept #1

This concept fulfills all the "Must" requirements since it can contain as big of a region as needed and is a map. The last of the "Must" requirements depends on data availability. If there is no dataset that shows who is regenerative this concept has no way to cope with this. Additionally using just public data would make the amount of

useful visualizations quite small. For the "Should" requirements, the decision making part would need more development due to the previously mentioned issue. It also would only implement the minimum when it comes to involving the farmer in the visualization, but makes the amount of data that needs to be safeguarded lower. This concept could also suffer from performance issues, as outlined in the State of the art. Displaying the type of agriculture is also made easy with this one, because of 3d visualizations.

4.6.2 Concept #2: Interactive physical visualization

What could also be a good option for the project realization is to create a physicalisation, that would go even further than the first idea in terms of being real, since this visualization is real. This concept would involve a small landscape split into separate farm, with all of them having led's around the borders of each. Those LED's would indicate if the farm is regenerative, only applying a few measures or not doing anything special. Along with the LED's the fields would be decorated as their respective kind of farm, ranging from pastures to greenhouses. Each kind would have supplementary physicalizations that show additional information specific to the kind of agriculture performed.

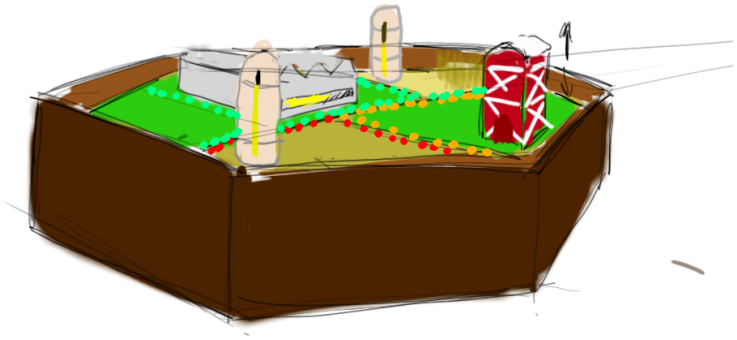


Figure 13: Illustration of concept #2

This concept fulfills all the "Must" requirements due to the same reasons as the first concept. But the issues start when the regions is larger, since the size of the physicalization scales with the size of the region. Also this also makes it so the data in the visualization is mostly static and limited in possiblilities of interaction. The interaction options that are available for physicalization are more worth-while in general, as they are more memorable and understandable [49, 50]. This also makes involving the farmer more difficult but it could be a good way to show potential participants something tangible.

4.6.3 Concept #3: Web-Based social platform for farmers

This idea, while having less intuitive visualizations, mostly utilizing flat maps and colors is still worth-while, because it focusses on something different, while keeping the visualization concept basic, but clear enough. The main goal of this visualization is to make sure that the farmers are very much involved in the process of sharing and gathering information for eachother and to build up the dataset for the visualization. This approach is mostly informed by the overlap of information that farmers need to make a good decision about becoming regenerative and what data could be obtained from other farmers as part of a larger data collection effort. Multiple initiatives can use the platform. The schema of the data is determined by

the organisation making the initiative and is not shared between initiatives. The custom schema is created by the organisation in form of milestones, which also determine how the data is visualized. Each milestone has critera, which are the data fields and conditions for the milestone to be considered as reached.

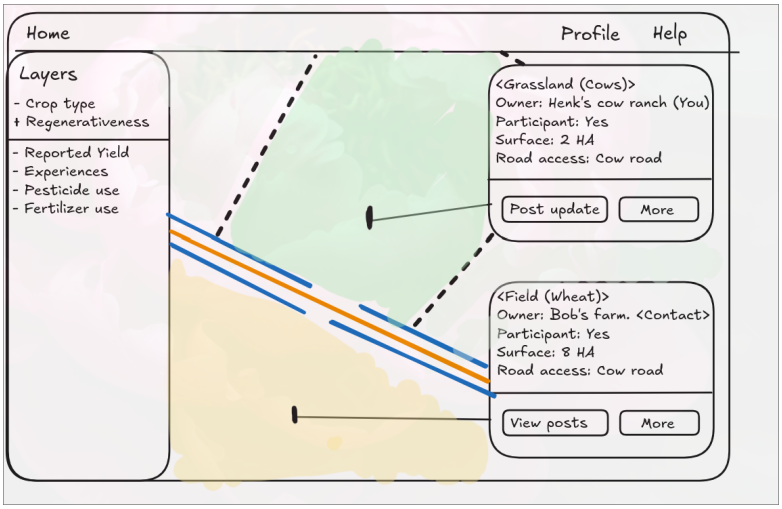


Figure 14: Illustration of concept #3

This concept share a lot with concept #1, the visuals are a bit less appealing, but it is also less dependent on the data that is already out there. The bigger issue of this concept is the reliance on data from farmers, which are not guaranteed to give it. This data would also need to be protected way more, since the data is currently not out in the public, and making it public could add additional issues. This concept fulfills the requirement of farmer involved way better than the first concept with and additional potential for more data thus more visualizations.

4.7 Choice of final concept

The ideas were also discussed with the client and the client showed interest in concepts 1 and 3, which are both web-based maps. In addition a decision was made to retire the physicalization concept entirelydue to the possible size constraint and non-expandability. The decision between the concepts leans on the amount of cooperation that farmers are willing to do, since concept #3 leans on that, while being superior participation-wise.

Because of this the final concept is a hybrid of the two concepts instead of one of the two. The two concepts are similar enough for it to not be a major change. the hybrid idea is the combination of the participation features with the symbol based visualization of the third concept. The map has been designed to be 2d. The amount and depth of the participation features depend on user demand. To determine this, contact with stakeholders was estabilised during a networking event and separate interviews.

5 Specification

5.1 Requirement review

After the interviews, a full list of requirements can be created. These are the requirements that were evaluated in the later sections of the project. The rest of the project was built towards satisfying as many of them as possible. This table is the final requirements table and also has some requirements added in later sections.

5.1.1 Changes to requirements

One addition to the requirements can be derived from the base requirements from Foodvalley and the research. As one of the requirements is to group farmers into the category of "regenerative", "conventional", and "conventional with agri-environmental measures". Because regenerative agriculture is not clearly defined [12], the exact criteria for each initiative are difficult to know during the making of the map application. With the concept chosen to be dynamic, this requirement can be safely added.

Another set of requirements can be derived from the persona's and scenarios, which can be found in subsection 5.3. One of the farmer persona's is a bit behind on technology, shows a potential flaw in potential user adoption, this needs to be address by adding the requirement that accommodates people with older hardware. The second farmer scenario also adds another requirement, namely the need to allow farmers to join on their own accord. This is not a hard requirement, but could be useful for driving adoption and helping expand initiatives through creating a funnel for recruitment. The organizer scenario shows how the farmers are gathered for initiatives, and it also reinforces the need for public previews and editable criteria.

The requirements are also split into Functional Requirements that were assessed in the Realization part of the project and Non-Functional requirements which are assessed during the evaluation.

Priority	Requirement	Source
Functional requirements		
Must	The project must visualize the distinction between farms doing Regenerative agriculture, only applying some measures and applying no measures.	Foodvalley
Must	The project must contain a map-based visualization.	General
Must	The project must be able to associate farmers with the groups that they are part of.	General
Should	The project should let users join the map as independent and as part of a group.	User scenarios
Should	The project should be able to gather data from the farmer.	Research
Should	The project should have a publicly available preview.	User personas
Could	The project could utilize data from existing agro-environmental organizations.	Foodvalley
Could	The project could differentiate between types of agriculture.	Foodvalley
Could	The project could give the option to aggregate data about any ongoing initiatives.	User scenarios
Could	The project could be made extensible as to make the handoff to the client easier.	Researcher
Won't	The project won't fully implement data protection measures, like GDPR.	General
Non-Functional requirements		
Must	The bar for farmer participation needs to be low enough for farmers to join on their own accord.	Interviews
Must	The farmers need to understand what steps they need to take to become more regenerative	Research
Should	The project should involve the farmer in the process of creating the map.	Research
Should	The project should help farmers with the decision of adopting Regenerative Agriculture by informing them about the practices of RA.	Foodvalley
Should	The project should help farmers with the decision of adopting Regenerative Agriculture by giving them an low-effort way to start.	Interviews
Should	The project should be able to keep any data gathered safe.	Researcher
Could	The farmer-facing part of the project could work on older computers to some extent.	User personas

Table 2: Final table of requirements

5.2 Personas

As an approximation of the users, three personas were created. One models an early adopter, while the other models someone who would be more skeptical of using the application or becoming a regenerative farmer. The personas were informed using Kemp et al. [11], Feng et al. [7] and Jordon et al. [6]. Those papers show what kind of factors influence the adoption, namely age, training, amount of available labor and personal motivation. The face images were created using the site `thispersondoesnotexist.com` [51], which uses an AI model to create faces of fictional people that look realistic.

Organic cattle farmer: Harry van Beckhoven

Harry was always a hopeful person. He knew that he wanted to work with animals since he was little. Four years ago he finished his study in Agriculture. Since student loans did not have any interest, he had the option to take a loan to buy a farm from a farmer that wanted to retire. Since the start, he wanted his animals to live a good life, so he decided to sell his products under the organic label. His study prepared him well for adopting most new agricultural technologies.
Profile:

- **Age:** 26 years
- **Gender:** Male
- **Interests:** Saving the environment, animal welfare, model trains.

Table 3: Description of the first persona

Senior Wheat Farmer: Samanta ten Berge

Samanta is a farmer since she was 22, which means she has 26 years of experience on the farm. Almost from the start she saw the march of technology in farming, but she did not really bat an eye since doing things the old way always worked. She only buys new tools for the farm if the old ones do not do their job correctly, her tractor is from the early 90s and her computer runs Windows 7. Her son asked about making the farm sustainable, but her research did not show that sustainable farming would pay the bills.
Profile:

- **Age:** 48 years
- **Gender:** Female
- **Interests:** Preparing her oldest son to take over the farm, keeping things simple, antique furniture.

Table 4: Description of the second persona

Regenerative Agriculture Promoter: Kassandra Schotel	
	Kassandra really wanted to make the world more sustainable, especially in agriculture. But unlike Harry, her talents do not lie in performing the agriculture, but rather in connecting people with each other. This different talent steered her to start a company with a few other people that enables many farmers to cooperate on projects. The company often needs government funding, and for that, the company needs to show that they actually bring results. **Profile:** • **Age:** 32 years • **Gender:** Female • **Interests:** Improving the food industry, connecting people, cats.

Table 5: Description of the third persona

5.3 Scenarios

The personas on their own do not bring much useful insight. To use the personas to get more insights, they are put through scenarios. There are three scenarios that are important for the project.

5.3.1 Scenario 1: Joining the map independently

In this scenario, Harry finds the website where the map is hosted and decides to see what's on it. He sees that the map has some nifty features related to showing what the farmer is doing, and even discovers some new things about his farm, like the kind of soil his farm appears to stand on. After some looking, he also discovers that some people down the road are part of the map, and he finds out that they also apply some sustainable techniques. Harry did not join a farming collective yet, but he can join the map as an independent and also see what collectives are active nearby. He makes an account selects which plots are his, what he is farming and the sustainable measures he takes. At the end of the process, he looks at his farm on the map and is happy that his efforts to be sustainable are recognized.

5.3.2 Scenario 2: Joining through collective

In this scenario, Samanta gets a letter from the farmer's collective. She got an invitation to join a map that connects farmers to make the whole collective more sustainable. She does not see the appeal, but decides to discuss it with her family over dinner, and she realizes it is worth checking out. She logs onto her old trusty computer and opens the map. It looks intuitive enough, and she can see the surrounding land, even though it is a bit slow on her old computer. She decides not to register since some of the things the website asks are the exact locations of the plots she is farming grain on. She does this despite the site reassuring her that this tool keeps all the information about her secret and that only the collective can access most of it, she does not trust the computer. Samanta also sees that a few people in the collective already signed up and decides to discuss it when they see each other. The people from the collective reassured her that the site would keep her information. That reassures Samanta to register anyway, just to put in basic

information about her farm. Since her son convinced her to save on fertilizer though letting the neighbor's cows graze on their resting plots, she can also put down she does some things sustainably.

5.3.3 Scenario 3: Creating a landscape

Kassandra is very busy, she is creating another regional initiative to encourage farmers to be regenerative. She's busy with gathering information, so that she can present this initiative to farmers, coworkers and legislators. But everything seems to be tangled together, and it is difficult to put into a presentation or a report. One day Kassandra found the map application, and decided to see if it could be used to make the sense of the mess, as that part was the most difficult to measure. She contacted a few farmer groups to join the map under the banner of their new regenerative project, helping some of them to sign up. After a month most of the farmers joined and Kassandra could see what where and how the farmers were doing, zoom around and even make a solid prediction on how the farmers would do. This let her show her findings effectively, making all the parties happy to cooperate.

5.4 Concept refinement

In this section, the idea is refined. This is done through describing the concept in depth, creating key definitions. To visualize the way the application works, UML[52] diagrams are used.
All diagrams include the following terms for users:

- Farmer: The type of user who will contribute to the map by putting down their own farm.
- Organizer: Any user that has ownership over a group, most likely to organize an initiative.
- Visitor: Any user that does not have an account or is otherwise not logged in.
- User: A catch-all for all users.
- Authenticated user: All users that have an account on the map and are logged in.

Besides the interfaces the interaction needs to be modelled as well, for that two kinds of UML diagrams are used. The use case diagram and the activity diagram. Those diagrams are displayed below.

The first diagram is the use case diagram, which is used to relate the user groups to tasks they might need to perform with the system, also known as use cases. Functional requirements loosely translate to use cases and are therefore important. It can be found in Fig. 15

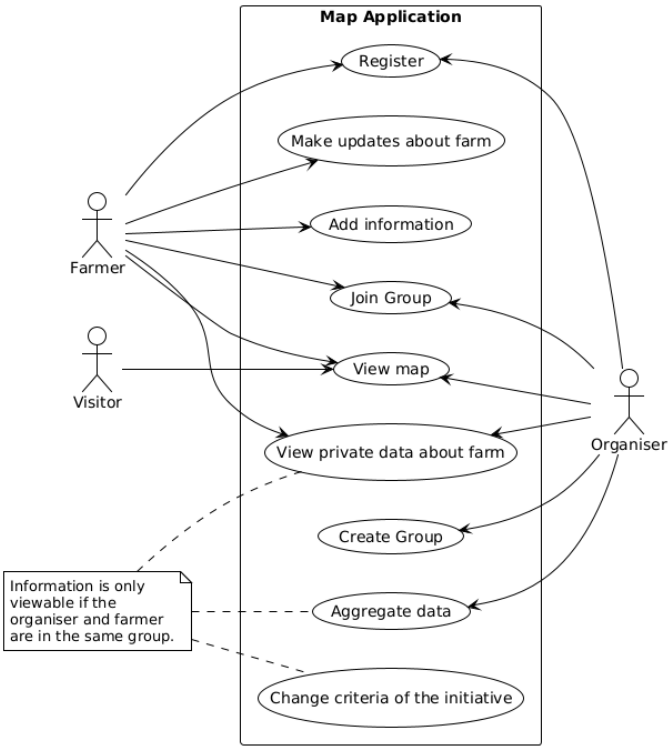


Figure 15: Use case diagram for the project

The second diagram outlines the flow of the Organizer and Farmer user groups. This flow-chart or activity diagrams shows the important activities and decisions. It can be found in Fig. 16. This flowchart outlines the main interactions but does not show how the system works. This is described in the next subsection.

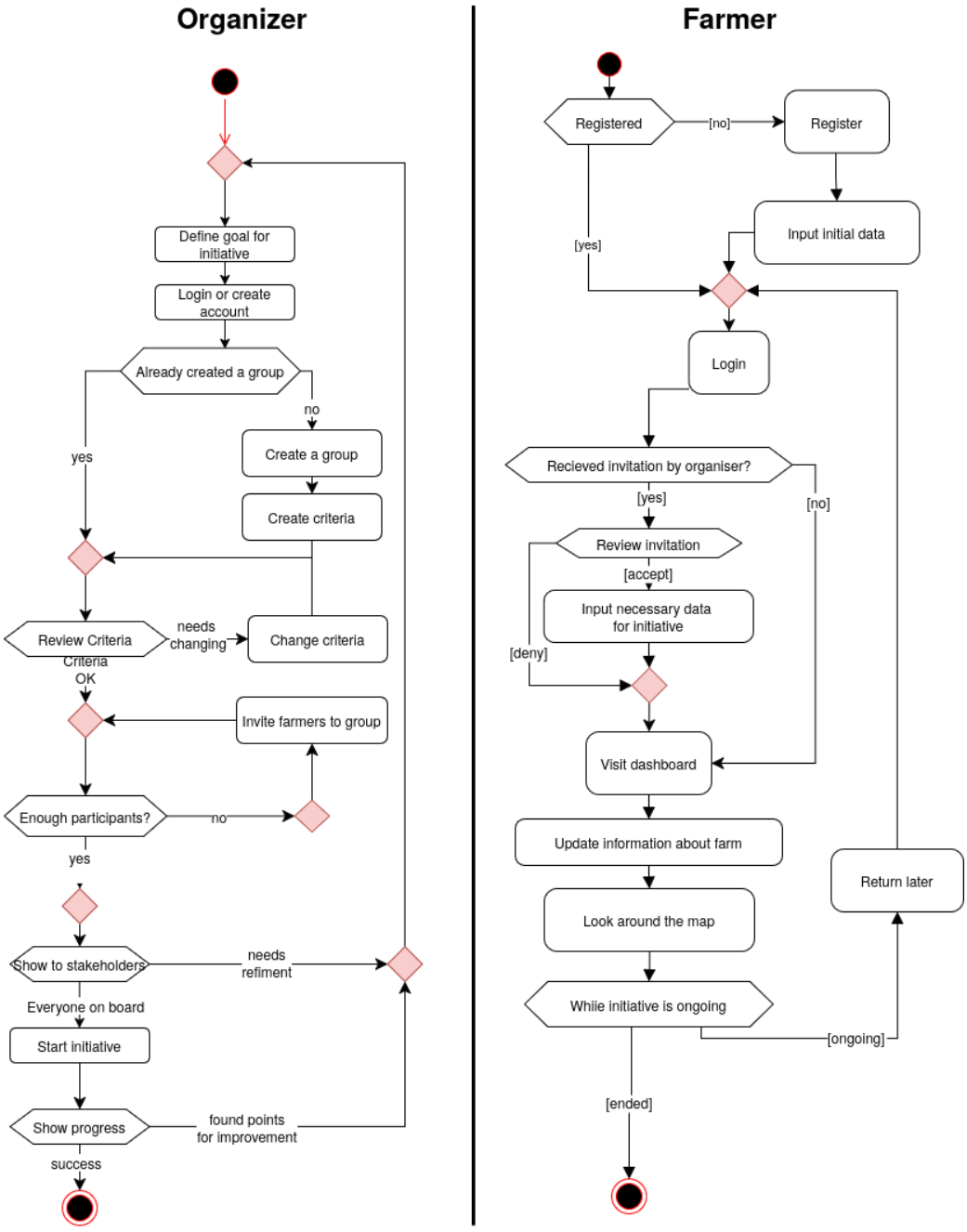


Figure 16: Activity diagram for main user groups

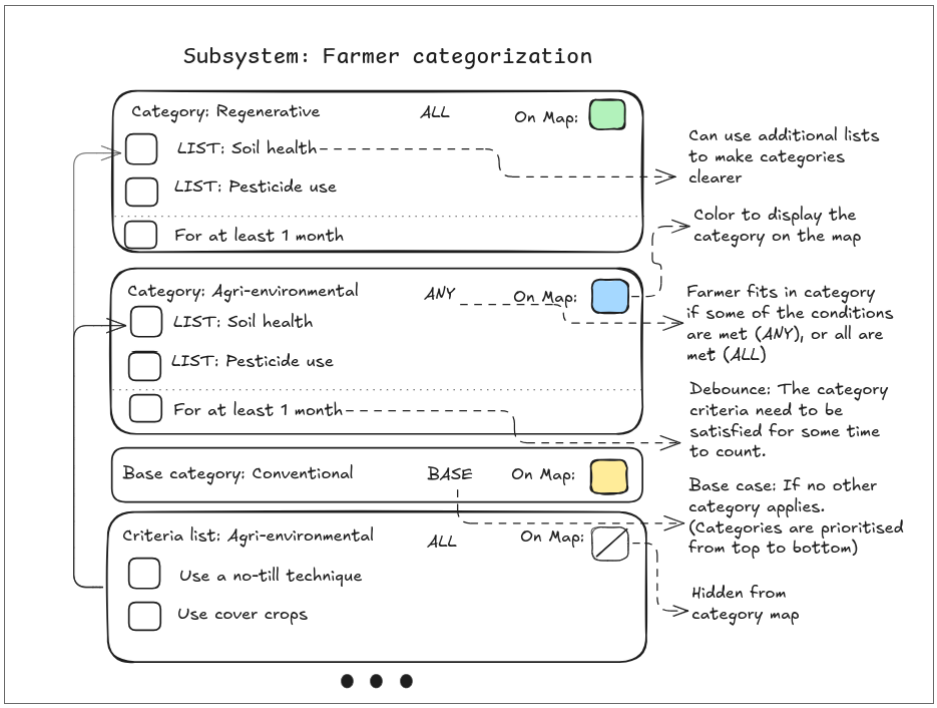


Figure 17: Depiction of the criteria system.

With the diagrams outlining the general interations and flow, the interfaces can be desinged with the diagrams as context. The first thing to add to the idea is how the concept distinguishes the farmer's activity. This is done through the usage of criteria. The criteria subsystem is a system that lets organizers create the rules that categorize each farmer by their level of sustainability. The scope of this subsystem should remain small as to not consume excessive development time. The satisfaction of the criteria could be enforced by organizers by requiring confirmation from them, or fully self-reported by farmers. The criteria subsystem is sketched out in Figure Fig. 17 Through the eye of the farmer the criteria are more like milestones, and are called as such in later figures, when they use the farmer's perspective.

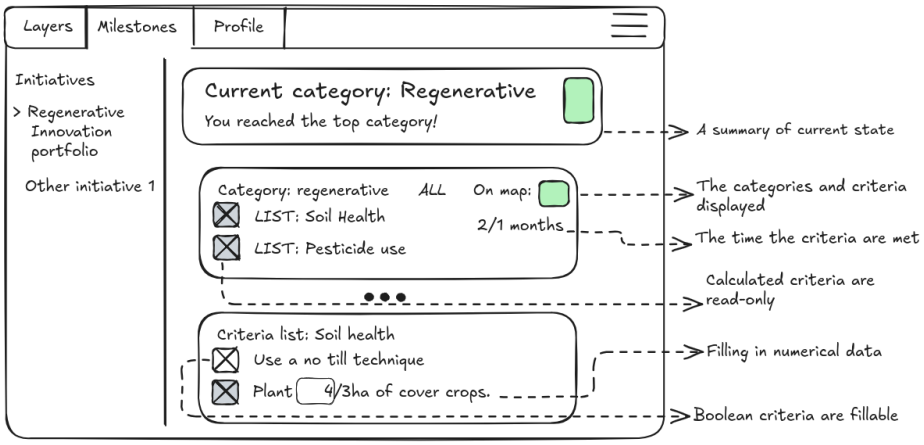


Figure 18: Depiction of the criteria system from the farmers' side

From the perspective of the farmer, this system looks different. As from their side, it is a portal for entering data. This can be seen in Fig. 18. The important thing is that the farmers can see which of the criteria are met, and which category they fit

in. This is done through a summary of the current category and clear checkmarks for each criterion.

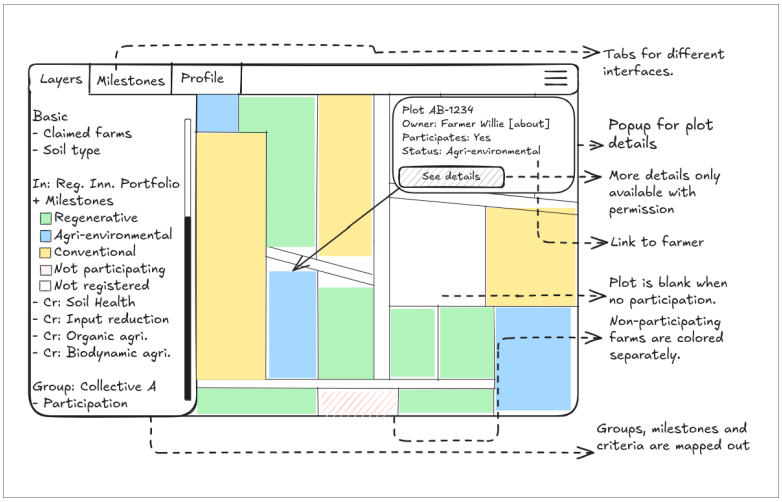


Figure 19: Depiction of the map view for the farmer.

The criteria system is one of the three main interfaces that the users will be in contact with. The second of which is the map. The map itself is a fairly simple system on the outside. It can be seen in Fig. 14 and Fig. 19. It has a side menu for choosing layers, but in addition an initiative search option will be added, since layers are dependent on the initiative you are viewing. Initiatives where the user takes part in are made more prominent. The popups for farmers are also featured, with the addition of a list of initiatives they are taking part in. If an initiative is selected, only the participating farms will be highlighted and the map will zoom in to the area where the initiative takes place.

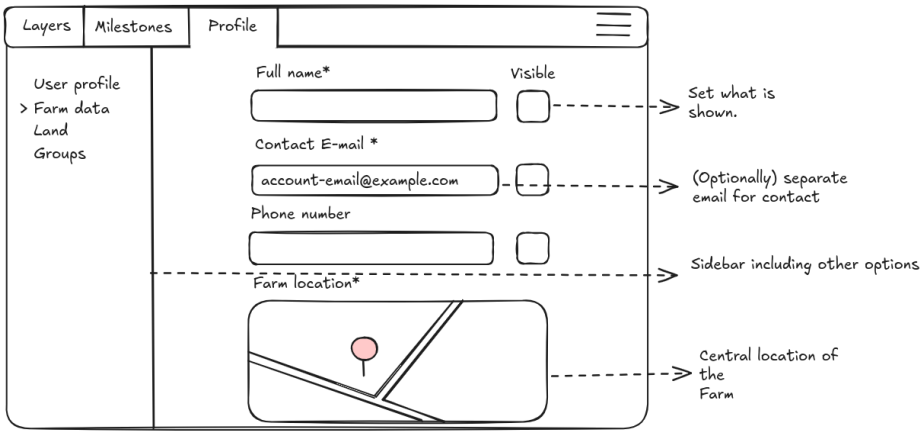


Figure 20: The dashboard for farm information

The last interface is the profile page, where all the share information for farmers and organizers is being shown, sorted per initiative, with the addition of plot ownership and other general data for farmers and organizers. All the data also has controls on how public it is. Sharing most data publicly is made opt-in instead of opt-out to prevent any accidental leaking of information.

A part of the farmer's data entry experience would be picking their land plots on the map. At the end, this has been scrapped due to the time it would take to make the interaction work in an intuitive way.

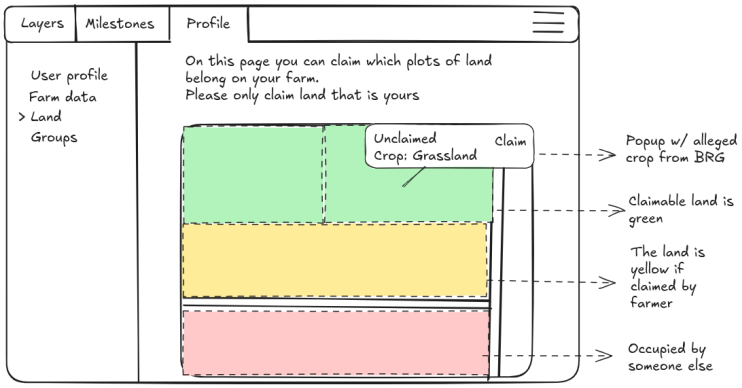


Figure 21: Tile picker for the farmer

5.5 Project structure

This section models the prototype by dividing it by components and creating diagrams describing their structure. At the end, a summary and a list of things of implemented is obtained, which was implemented in the Realization chapter to create the prototype.

The first design decision for implementing the prototype is to use the Model View Controller pattern [53]. The MVC pattern is a design pattern for websites that separates data from how it's processed and how it is displayed by the user.

The first kind of Components are the interfaces, which were described in the previous subsection. The interfaces are what the user interacts with, those can also be seen as the views in the MVC model.

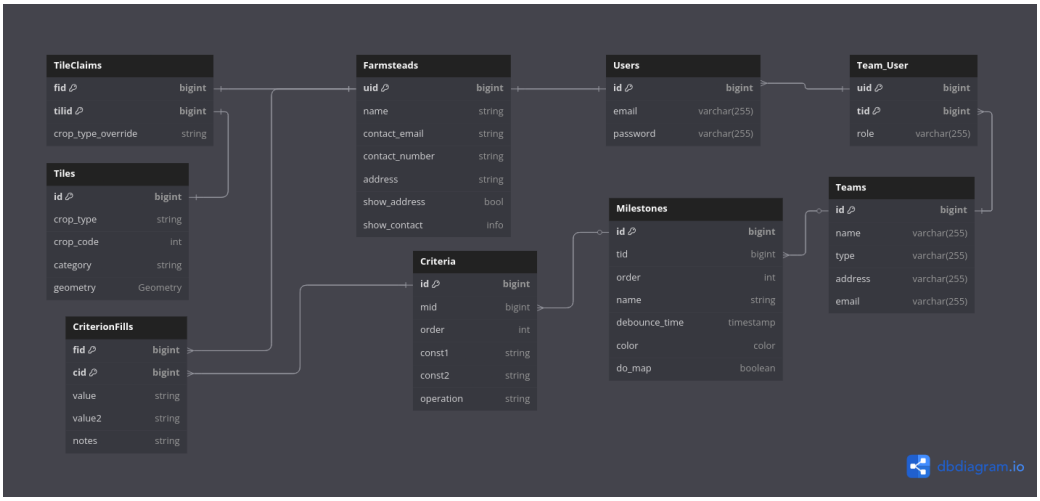


Figure 22: The database schema for the prototype. [1]

The second type of components are the models. Models are the data and how it is stored in the database, the database is thus the context in which the models work in. Each of the models has a corresponding table in the database, that means that all models together can be grouped as the Database component. The relationships and the content of each model can be seen in Fig. 22. Each of the model has a meaning as what it represents:

[1] This schema excludes some supplementary tables and columns

- User: Each individual user
- Team: A group of farmers and organizers that make up an initiative
- Team_User: A associative table[54] for the User-Team relation
- Milestone: A grouping of criteria, so either a category or criteria list
- Criterion: A single criterion as outlined in Figures 17 and 18
- Criterion Fill: A data that a farmer fills in for each criterion
- Farmstead: The farm data like the farm location and contact information
- Tile: A plot of land as a part of the Basisregistratie Gewasparcelen(BRP)[55] dataset.
- Tile Claim: An association from farmer to tile, with additional information.

The controllers the third type of component that tie everything together. Controllers are groupings of functions that process requests from the client, make the necessary mutations on the models, and return the response. Because the prototype is built for the browser, that makes a controller something that takes a HTTP request, processes it and returns an HTTP response. Each model has it's corresponding controller and the role of the controller is to display all [2] models, display one model instance and add, modify and delete a model instance. Some controllers only implement a subset of this functionality. Because of those roles, the controllers house all the important logic.

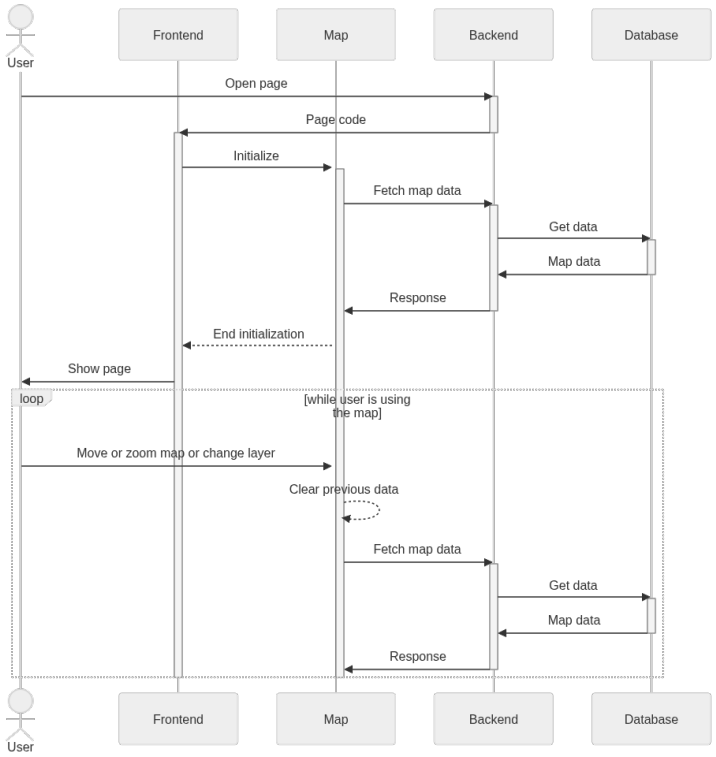


Figure 23: Sequence diagram for map elements

Another component, one that does not fit within the MVC framework, is the map component itself. While the map has its corresponding models, controllers and

[2]Often filtered

views. The map needs to display a background map, receive data from the server and display it, while also being interactive. Because of this, the map has its own distinct way of working.

The map endpoint receives the bounding box of the viewing area of the user and picks up points from within this box.

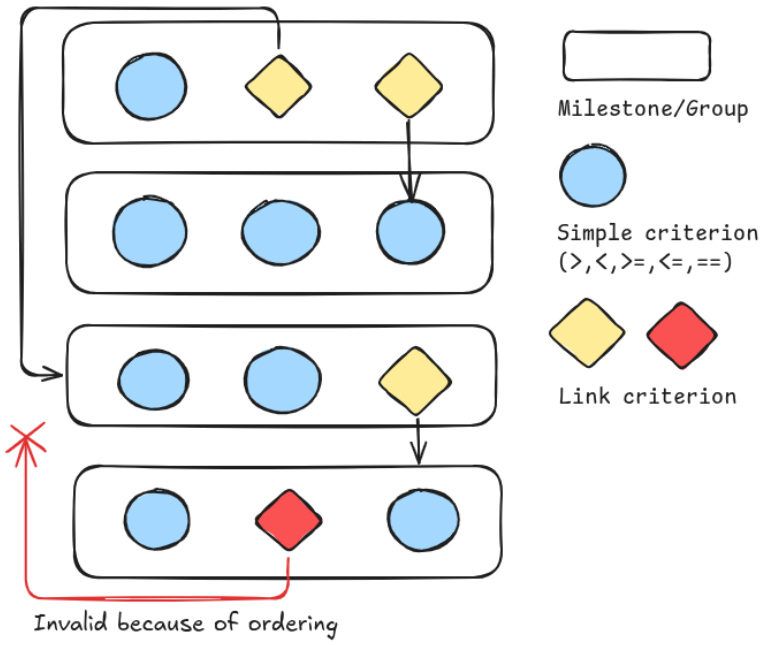


Figure 24: An example graph of a milestone list

The next important component is the evaluation of the criteria. This is where the data of the farmers is processed to know what level or milestone they have reached. The criteria are grouped into milestones, which are the final levels depending on the selected visibility options. Criteria can be either simple number comparisons, checkboxes or links to milestones. The latter option makes the system way more flexible and makes the set of milestones interlinked with eachother.

The main limitation of this approach is the possibility of creating a cycle. To avoid this, the criteria can only point to milestones that are below the milestone they are a part of, as can be seen in Fig. 24 This rule makes the graph of all connected milestones and criteria an Acyclic digraph as defined in Bang and Jensen [56, p. 31]. Because the flow of criteria can only go in one direction. This approach also makes it so that no criterion or milestone has to be evaluated more than once if the milestones are evaluated from the bottom when caching is implemented.

6 Realization

This chapter outlines the construction of the finalized prototype and its workings. The first section lists the used software and technologies. The next section shows what the implementation looks and works like. The source code of the project can be found on GitHub[3].

6.1 Tools and software

After the blueprint for the prototype has been laid out, the software for the prototype was chosen. The main criteria for choosing the software, are as follows:

1. Quick setup
2. Prior experience of the researcher
3. Security, authorization and authentication are built in.
4. Easy to iterate.

At the end of the search, the Laravel framework was chosen, because of familiarity and the ease of setup. The Laravel[57] framework is a framework for websites and web-services written in the PHP programming language, this framework allows for using the Model View Controller pattern. The Controller and Model part are covered by Laravel itself. In addition, the project was initialized with the Laravel Jetstream starter kit because of it having authorization and authentication built in.

For the user interface, the Vue framework was chosen due to familiarity. Vue[58] is a templating and component framework for creating user interfaces in the browser. This takes the View role in the MVC pattern.

Another piece of software to consider is the Database. Because the application has a map built in and requires geometry/geography data, PostgreSQL with PostGIS was chosen. PostgreSQL is a popular SQL database, and the PostGIS[59] extension provides the Geometry data type, along with helpers and indexes for making geometry-related queries quicker.

6.2 Finalized views

This section contains screenshots from the finalized prototype, along with an explanation of changes as compared to the design. This chapter shows the realized use cases as displayed in Fig. 15. This also makes the actions done in the views part of Fig. 16

The screenshots were taken from the latest version of the prototype, after the last evaluation. Additionally, some views were excluded due to not being implemented or due to the views being unedited templates from Laravel Jetstream.

[3] https://github.com/Wilkuu-2/CreaTeGP2025

		Used By		
Use case(Fig. 15)	Section	U[4]	F[5]	O[6]
View map	Map view	Yes	Yes	Yes
Register	Registration	Yes	Yes	Yes
Make updates about farm	Farmstead editor	No	Yes	No
Add information	Farm criteria input	No	Yes	No
Change Criteria	Registration	No	No	Yes
Join Group	**Not shown**	No	Yes	Yes
Create Group	**Not shown**	No	No	Yes
Aggregate Data	**Not implemented**	No	No	Yes

Table 6: A reference table linking views below to Fig. 15

In the table above, you can see the overview for each use case from Fig. 15 to the views below.

6.2.1 Map view

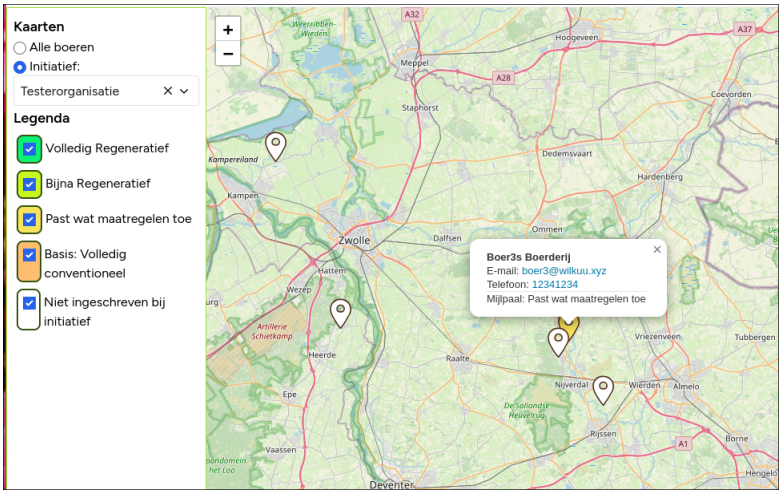


Figure 25: Finished map view

The most important and the first view that the user sees when they navigate to the website is the map view. It is accessible to everyone, and is featured in all flows, this view is also available without being logged in. One of the prominent changes that can be seen in this view is that the farms are displayed as pins, rather than displaying each of the land plots of the farmers. This made the implementation and user experience simpler. More reasons for removing the tile feature can be found in subsection 6.3.

The legend has also been simplified to the form that can be seen in the image. This was a decision made to save time. The map has two modes, with the option for more. The first mode just displays all farms as white. The second mode fetches the evaluated milestone for each farmer, per chosen initiative. Those are then visualized by coloring each farmers' pin with the organizer-defined color for the milestone the farmers reached. If the farmer is not a part of an initiative, their pin remains white.

[4]Regular User
[5]Farmer
[6]Organizer

6.2.2 Registration

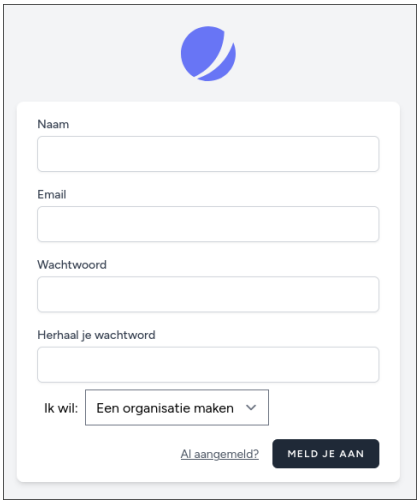


Figure 26: Finished registration view

The registration view is a simple form, as expected for a web app. Organizers, Farmers and regular users all register on the same page, and this is the page where the distinction between the three is made. The only addition is the choice of registration type, which puts the user into one of the three classes. This choice is mandatory during registration and determines the next page the user sees:

- **Farmer** ⇒ Farmstead editor
- **Organizer** ⇒ Group creation (An Laravel Jetstream view)
- **Regular user** ⇒ Map view

6.2.3 Farmstead editor

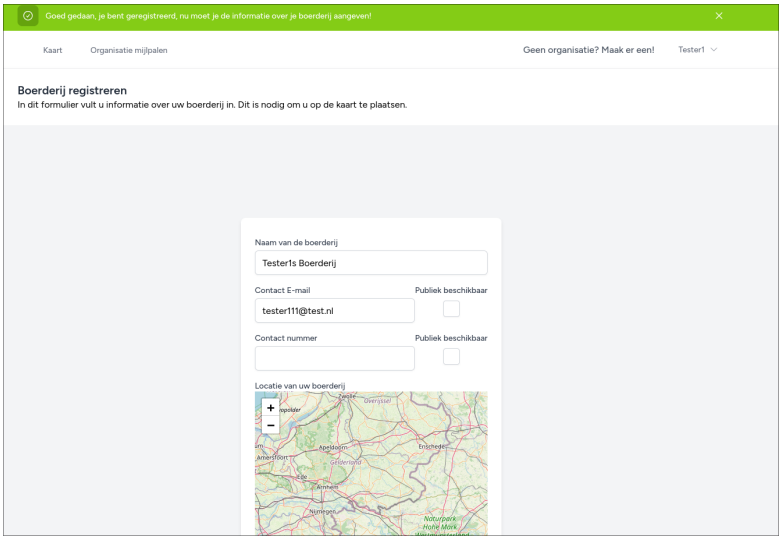


Figure 27: Finished farmstead editor view, when visited after registration.

The next view is the farmstead editor page, where the farmer can determine what information about the farm is visible on the map. This information is not related to

any criteria, and is universal for each initiative. The farmstead editor has not been changed relative to the initial design, besides the tile picker being dropped along the tile feature.

6.2.4 Farm criteria input

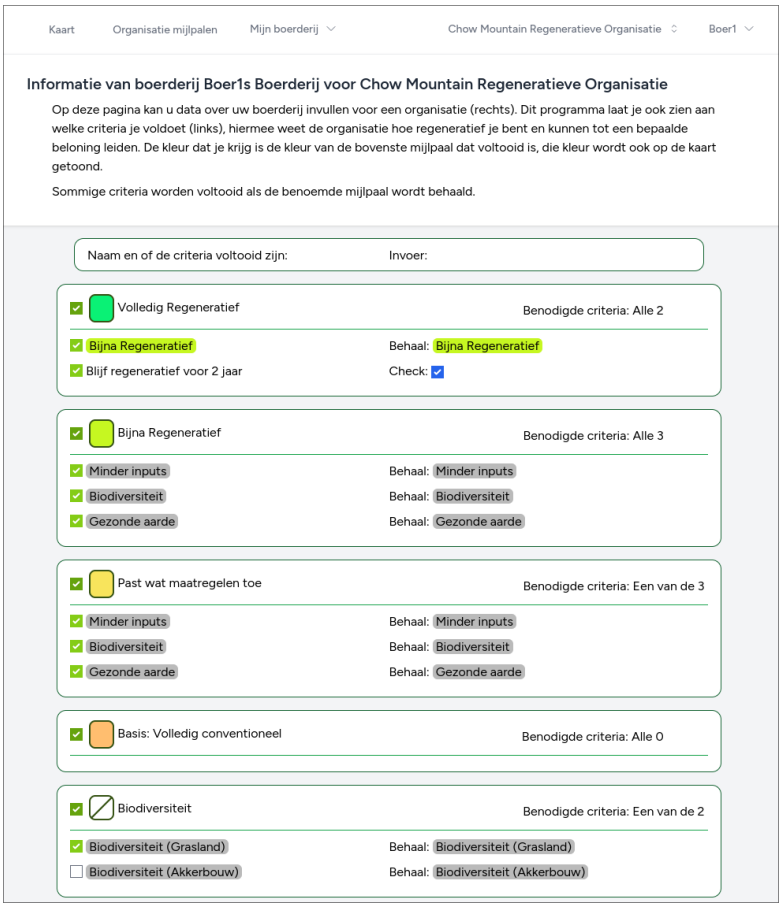


Figure 28: Finished data entry view for the farmers

The criteria input view is the view that lets the farmer input the data needed to place them in a milestone of each initiative. This was the view with the most iteration, this can be seen in chapter 7, table 9. This view took the most development time due to the amount of information that needs to be dynamically displayed to the farmer and the amount of actions they need to perform in this dynamic system. The sheer amount of the interactions is not as big as the organizer side, but it was absolutely required for this view to be intuitive as to satisfy the non-functional requirement of making the bar as low as possible for the farmers.

The first important interaction is the action of displaying the page itself, which means fetching all the milestones, criteria and farmer-specific data to the page and organizing them into a tree, based on the order and displaying the elements for the milestones and the criteria. Another part of this are the left checkboxes which display if the farm satisfies the criterion or milestone, this is evaluated both on the server for map purposes and the client for this view.

For the client, the code can be in Appendix E here, the server-side code is very similar.

6.2.5 Criteria editor

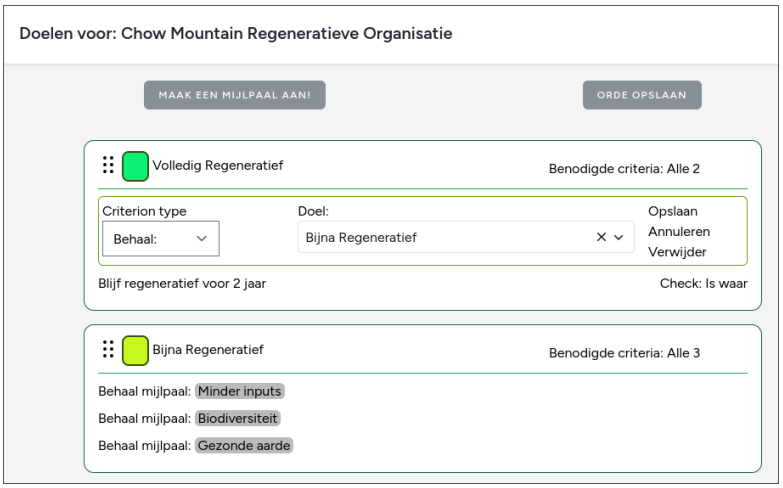


Figure 29: Finished criteria editor menu

With all the universal and farmer-only views handled, it is time to describe the only important organizer-only view, which is the criteria editor. The criteria editor can be used by organizers to change the criteria of the whole initiative. This view is one of the iterative parts of the organizer flow that can be seen in Fig. 16, namely the "Change criteria" step. The editor view did not change much from the design. The duration requirement for milestones were cut, due to time constraints and the amount of effort needed to test the feature using the testing suite. This view has the most possible interactions, and thus took a lot of development time to get right, more than expected initially. One of the interactions, like dragging the milestones to order them, is an example of increasing complexity, due to needing to maintain a tree, that can be then submitted to the server to update the order of the milestones and the criteria. The other interactions that this view has is the adding, removing, editing and reverting last changes of the milestones and the criteria. This adds 8 separate interactions in total. There is also changing the type of the criterion, which could lead to data loss, among other complexities related to changing the markup of the page when changing criterion type. An example of this is the need to impose the ordering requirements outlined in Fig. 24 The end product is still limited in explanation or user experience, like the need to refresh after saving a milestone of a criterion.

6.3 Dropped functionality

As mentioned before, the development was severely limited by time, this lead to some features being cut. The reason for some features being cut was not only time, but also other reasons.

One of the examples is the use of land plots, the feature has been also dropped because it would make the experience of the farmers worse. Interviews with one of the stakeholders revealed that many farmers already need to do a lot of data entry and that picking tiles would probably take a lot of effort for the farmers.

Another the feature that was dropped is the link to farm profiles, and links to them in the map popups. This has been cut due to adding complexity, but also the need to implement multiple views just to let the users see each other's farmstead profiles.

Other features like the milestone's duration requirements, displaying numerical criteria as a separate map layer and automatic creation of base criteria

were dropped because they costed developer time without being needed to satisfy any requirement.

6.4 Functional requirements assessment

The prototype does meet most of the criteria. All the must and should criteria are met, the lower priorities were mostly not met though. Despite that, a lot of work would need to be done to turn the prototype into something that can be tested on a larger scale, as has been made clear in the evaluation chapter. Most of the functionality around the requirements are implemented in a basic way, and lack intuitive UX design.

Priority	Requirement	Status
Must	The prototype must visualize the distinction between farms doing Regenerative agriculture, only applying some measures and applying no measures.	Milestones and legend in Map view
Must	The prototype must contain a map-based visualization.	See Map view
Must	The prototype must be able to associate farmers with the groups that they are part of.	Initiatives and groups made by organizators
Should	The prototype should let users join the map as independent and as part of a group.	Invitations and regular Registration
Should	The prototype should be able to gather data from the farmer.	See Farm criteria input
Should	The prototype should have a publicly available preview.	The Map view is open
Could	The prototype could utilize data from existing agro-environmental organizations.	Not implemented
Could	The prototype could differentiate between types of agriculture.	Depends on how the organisers lay out the Criteria
Could	The prototype could give the option to aggregate data about any ongoing initiatives.	Not implemented
Could	The prototype could be made extensible as to make the handoff to the client easier.	Not evaluated properly, but the prototype is extensible
Won't	The prototype won't fully implement data protection measures, like GDPR.	Not done

O	X	?
Fully satisfies requirement	Does not satisfy requirement	Not clear if requirement is satisfied

Table 7: Assessment of the functional requirements

7 Evaluation

This chapter contains the evaluation of the user experience of the prototype, and it's usability using one-on-one walkthroughs of the application. The first section outlines the tasks to be done by the users and how they relate to the evaluation. The second contains the results of the evaluation. With the last section being left for the conclusion.

7.1 Subject demographics

At the end of the sourcing period, 4 participants have been recruited. Each of them have consented to the research and signed a copy of the form in Appendix F The demographics are important since the evaluation is targeted and there are two stakeholders group present.

Two participants are male and two female.

Profession-wise, the two male participants are dairy farmers, one participant was a farmer at a small social garden/farm project and the last participant was one of the client company workers, who works on the Regenerative Innovation Portfolio.

The age of the participant was not asked, but 3 of the participants seem to be in the 28-38 range and one participant is significantly older.

Because of the small sample and the fact that only one participant belongs to the organizer user group, only the farmer path was evaluated.

7.2 Preparation

For the evaluation, both the farmer user group and the organizer group were approached. Due to the geographical distance and the busy schedule of farmers, some of the evaluation had to be done over an online meeting. The users were not required to fill in data truthfully for the test. The only thing processed during this evaluation is their email and phone number, which were wiped from the prototype's database after the evaluation if finished. Most evaluations were performed online using conventional meeting software like Microsoft Teams and Google Meet, with the subject sharing their screen. The prototype was opened on the subject's computer by connecting to the researcher's computer running the prototype using a reverse proxy. A reverse proxy in this case is a separate machine that forwards traffic from the researcher's computer so that this computer can be in any location, the participants connect to the proxy machine, and get access to the prototype on the researcher's computer through it.

During the evaluations, a set of criteria was either created or used. In Table 8 the example set of criteria is displayed. The organizer test group gets some degree of creativity, but they will be guided to create something similar.

Milestone name Criterion name	Any or All Operator	Is mapped Value to compare
1: Fully regenerative	All	Yes
- Keep being regenerative for 2 years	Link Check	`milestone:2` `true`
2: Almost regenerative	All	Yes

-
-
-
	Link
	Link
	Link
		`milestone:5`
		`milestone:8`
		`milestone:9`

3: Applies some regenerative practices	Any	Yes

-
-
-
	Link
	Link
	Link
		`milestone:5`
		`milestone:8`
		`milestone:9`

4: Fully conventional	All	Yes
5: Biodiversity	Any	No
- -	Link Link	`milestone:6` `milestone:7`
7: Biodiversity (Pasture)	All	No
Sow at least 10 ha of herb-rich grassland Sow more than half of your land as herb-rich grassland	At least At least	10 ha 50%
6: Biodiversity (Arable)	All	No
Rotate your crop at least two times	At least	2 times
8: Healthy Soil	Any	No
Cultivate 10ha of arable farms without plowing Cultivate more than half of your land without plowing	At least More than	20 ha 50%
9: Less inputs	All	No
Cut fertilizer use by half Reduce pesticide use	At most At most	`50 %` `1 t/ha`

Table 8: The criteria and milestone set used for the evaluation.

7.2.1 Requirements to be evaluated

The evaluation seeks to evaluate the non-functional requirements (Table 2), while also testing the system for any gaps, inconsistencies or bugs that could stand in the way of the functional requirements.

7.2.2 Tasks for the Farmers

The farmers followed the scenario of the farmer being approached by the organization first, as described in subsubsection 5.3.2, since that is the scenario which was deemed the most probable according to the interview with the expert. (See subsection 4.2).

Registration flow: The first task is to register to the map while being invited. This can be done with the view shown in subsubsection 6.2.2 This can be done either by opening the prototype on their own or being guided by the invitation email.

Farmstead creation flow: Afterward, the user had been tasked to fill out the necessary data for the farm using the view in subsubsection 6.2.3, which includes farm location, contact information and a name for the farm. This page also contains the visibility settings for each of them. The user has been tasked to set them to their preference.

Finishing this task marks the end of the full registration flow. The users will be asked if the process was straight-forward, and directed to the map.

First look at the map: If this process is successful, the farmers are free to look at the map (See Fig. 25) and explore. The prototype informed them that they should look at the criteria page next, when the user was ready they could move there and start the criteria flow test.

Criteria flow: In there, they could look at the criteria they had to meet according to the mock organization using the page outlined in subsubsection 6.2.4. The criteria that were shown to the farmers can be seen in Table 8. They had been asked to fill in the criteria as to become more and more regenerative by filling in all the fields on the page with arbitrary information, starting with information that matches their farm, if they have one.

Free section: At the end, they had been given 5 minutes to explore the prototype further.

7.2.3 Asked questions

At the end of the tasks, the users were asked a few questions as to get more information about the user experience.

- What do you think about the experience?
- Were there places where it was unclear where to go?
- Was the registration process easy for the farmer?
- When given a list of the criteria, do you think the farmer would have any difficulty knowing what to do next?
- Would you use this kind of app (as a farmer), and why (not)?

Additionally, the users were asked about their current opinion on the prototype in the middle of the test, after they have seen their map. This was done to see their reaction to the map, which most users will see first.

7.3 Observations

The observations of evaluations are organized into the next four sections in a chronological order, because each evaluation had slight tweaks to the prototype. The answers to questions are collected in the section after. And finally, the non-functional requirements are evaluated.

7.3.1 Iteration 1

The first evaluation was performed online, with a cattle farmer.

The subject quickly got to work with the account and farm registration. With minimal guidance, they had some issues with picking their farm on the map, but they prevailed with no help needed. After this, they were directed to look at the map to see to find themselves. They could locate themselves almost instantly. They looked at which milestone they reached and were directed to the criteria input page, where they encountered a bug that made navigation difficult (See Table 9).

When the subject could navigate to the criteria page, they were confused at first. The researcher explained the page and what the task was, namely to just fill in anything into the criteria fields. The subject had no major issues with filling the criteria in, besides trying to press the evaluation checkboxes first. This issue prevailed up until the last evaluation and has been marked as a major User experience(UX) mistake in the prototype.

The subject needed some help with understanding the logic of the criteria, but after initial explanation they could manipulate the criteria to change the outcome with no problem. The position of the submit button was unclear.

Because of this evaluation was first, this means that most of UX issues and bugs were encountered here. The problems encountered can be found in Table 9.

Problem	Fix status
A bug in the checking of checkmark based criteria, where check always ends up being false.	Fixed
A bug where a navigation dropdown for the farm was covered by the map.	Fixed
It was unclear that the logo was the button to the map,	Fixed[7]
There were some oversights in the displayed criteria and milestones.	Fixed
The input label on the location picker at farm registration was missing	Fixed [8]
It was unclear that the left checkboxes show if the criteria and milestones are satisfied,	Fix attempted [9]
A lot of explanations were missing.	Fix attempted.
Redirect from farm registration to the milestones was broken	Not attempted.
Numerical criteria with the less than operator evaluated as satisfied when empty.	Not attempted.
Unclear positioning of the submit button in the criteria input page	Not attempted.

Table 9: Problems found during the first test.

7.3.2 Iteration 2

The next evaluation was also performed online, with a cattle farmer. The farmer was accompanied by their children during the initial part of the test, which was a minor distraction for them. Despite it, the evaluation went smoothly.

This farmer had no major issues with the registration, neither the initial registration and the farm registration. They later said that it would be better if the choice of user registration type should be forced, instead defaulting to a guest registration. On the map, they had some confusion around the colors, since the milestones had two shades of green in use, this has been rectified afterward. Afterward, they were redirected to criteria. There, this user was confused by the format of the criteria input, but with clarification that the number on the right of the input box is the goal amount, they understood instantly. They also were confused around the wording of the checkbox input. Because of this, the word "Als"("If") was changed to "Check" in the final version.

7.3.3 Iteration 3

This evaluation was performed by visiting the subject, which makes it unique setup-wise. The subject is part of a small biological farm that employs disabled people.

This participant was less experienced with computers than the first two and needed some more help to locate buttons and filling in fields, which also raised

[7] Fixed by changing the logo to text.
[8] Fixed after the second evaluation
[9] Added a header and re-coloring the checkboxes. Ultimately not enough.

questions about the prototype being usable for older people. The age-related usability issues were not assessed further. The participant had issues with finding their farm on the map, because they did not know they could zoom in the map. It is unclear if this can be addressed in this design, but could be looked up if many users stumble on this in further tests.

After the user and farm registration, it was time to proceed to the map. When the user saw the word regenerative, they decided to google it since they did not know that word and wanted to know more. The researcher had to explain what the term regenerative means from the standpoint of the project.

The user was also confused about the criteria. They correctly pointed out that it was unclear that the organization determines the criteria and that it was unclear what regenerative is. In addition, they also pointed out that you have to scroll quite a lot to get to the criteria they can actually submit data for, since all the linking criteria are above. And finally, this participant also had issues with knowing which checkbox was used to show the result of the criteria data being evaluated and manual checkboxes, despite an explanation being added at the top of the page. This calls for a redesign of the milestone of criteria screens, where the way that the system shows which criteria are satisfied is changed.

7.3.4 Iteration 4

The last evaluation performed online, like the first two. This one was performed with the client, namely a representative of Foodvalley. The involvement of this participant made this evaluation the longest, the most insightful evaluation, with the most criticism involved.

This participant had no issues for with the registration, and they remarked that the process was clear. When looking at the map, they had a lot of questions. Their first question was the meaning of the milestones on the legend. What does "Almost regenerative" mean, as opposed to "Fully regenerative"? This could be alleviated with a popup with an explanation of the milestone, with the addition with a link to the milestones page where the milestone could be seen in context of the whole criteria list. The farmer popup on the map also lacked content, in the opinion of the participant. The participant also remarked that it would be better if the link farm criteria page on the navigation bar would be visible directly instead of being hidden in a dropdown.

When filling in the criteria, this participant was also confused about the checkboxes on the left of the screen. The participant also explained that from the client perspective, regenerative agriculture is not better than conventional agriculture and expressed worries about this map making a judgment of which is better, because of the color gradient. They also expressed that some things in regenerative agriculture are not as simple as just numbers and that some measures are implemented differently by different farmers. Both of the two issues could be solved by setting different criteria, making those more of an evaluation setup flaw than anything else. The second issue does outline that the number inputs could be a bit redundant and that most organizations would set their criteria using simple checkmarks.

7.4 Summarized results

Each of the participant was asked the same question during the test and the same 6 questions after the test. This section outlines the answers from each participant while also summarizing the observation above.

7.4.1 Observations

The observations made during each evaluation are expressed in detail in the previous section. This subsection is dedicated to summarizing them. In general, it is evident that the participants struggled with how unfinished the prototype was. Expecially in the criteria section of the prototype, people needed a lot of explaination that was not there for them. This also permiated to the rest of the prototype, and this would need to be rectified in any future trials with this concept.

Statement	P1	P2	P3	P4
The participant considers registration and data entry easy.	O	O	O	O
The participant understands what steps they need to take to become more regenerative.	O	O	?	X
The participant had a good experience over-all	O	O	O	X
The participant went through the registration process without significant help.	O	O	O	O
The participant went therough the map view without significant help.	O	?	O	?
The participant went through the milestones/criteria view without significant help.	X	X	X	X

O	X	?
Not true for participant	Not true for participant	Not clear if true for participant

Table 10: Summary table of observations per participant

7.5 Questions

This subsection aggregates all the question answers and categorizes them into a few topics.

Steep learning curve
All the participants saw the registration process easy. This is expected as most of the registration process strongly resembles regular websites. The map view had no major interations that the users could not understand, and all users had no major issues. The novel part of the prototype, the criteria, had some user experience issues and unclarities. This meant that the user needed significant help to use the subsystem for the first time. All participants expressed confusion with the criteria satisfaction checkmarks in the criteria section. And, at the end, all participants mentioned that the prototype needs more work in some way or the other to make things clear.

Acceptable UX after initial hurdles
A remarkable thing is that the users had no major issues when using the criteria subsystem. Three of the four participants expressed that the tool was easy to fill in at the end. with the last participant having a bad experience because of the lack of polish and explanations. This shows promise for the concept of the criteria, as some UX work could make the learning experience better.

Unclarities and gaps
One of the problems was the vagueness of the concept regenerative, one of the participants found it completely unclear what regenerative means, with the rest of the participants finding it a little bit vague. The fourth participant had issues with the color gradient, lack of explanations of the colors and what they represent and the lack of details in the farmer popups as explained in the previous section.

Overall experience
The first half of the users found the map a good tool to show the farms and how far they are with the process of becoming regenerative. This has been after they crossed the initial hurldles.

Future use
The first two participants would use this kind of website, since they found it easy to fill in, on the condition that there was something to get out of this, since farmers value their time. On the other hand the third participant said that a reminder would be enough because of the ease of filling things in. Finally the third participant said that farmers would use this, if the goals of the app were more clear.

7.6 Non-Functional requirement assessment

Most of the non-functional requirements have been met, with others being either hindered by the user experience or lack of additional testing. Just like with the functional requirements in Table 7, Table 11 contains a summary of the non-functional requirements and how well they were met.

Priority	Requirement	Status
Must	The bar for farmer participation needs to be low enough for farmers to join without major resistance.	See Future use
Must	The farmers need to understand what steps they need to take to become more regenerative	Table 10 shows unclear results
Should	The project should involve the farmer in the process of creating the map.	All displayed data is farmer-supplied
Should	The project should help farmers with the decision of adopting Regenerative Agriculture by informing them about the practices of RA.	This prototype gives the farmer a place to start and make the decision
Should	The project should help farmers with the decision of adopting Regenerative Agriculture by giving them an low-effort way to start.	See above
Should	The project should be able to keep any data gathered safe.	no one but the farmer can see the exact data from milestones
Could	The farmer-facing part of the project could work on older computers to some extent.	Not tested, but the page does not require significant processing power to work

O	X	?
Fully satisfies requirement	Does not satisfy requirement	Not clear if requirement is satisfied

Table 11: Assessment of the non-functional requirements

7.7 Evaluation Conclusion

To conclude the evaluation, the prototype was successfully tested, despite the steep learning curve at the start of each iteration. Most participants in the evaluation were enthusiastic and found the project a nice way to keep track of an initiative, which is a good sign for the future iterations of the prototype. Most users found the usage of the prototype's farmer-oriented system simple and doable on a regular basis (few times per year). In addition, most users did see the milestones as steps to become more regenerative. The evaluation shows promising results in the short term, with more long-term evaluation needed for the next iteration, since the real-world use would imply using the prototype for many years.

8 Discussion

8.1 Implications and Limitations

8.1.1 Successful implementations

This section seeks to discuss the efficacy of the research results and show successes and the gaps that could be filled in future work. The prototype itself was a successful proof of the idea, while having user experience issues, which stem from the lack of time.

The prototype demonstrated a way to define, create, store, edit and evaluate(See Appendix E) custom criteria and group them into groupings called milestones, along with the implications of having these groupings. The prototype also introduced the idea of linking criteria to milestones, making a more complex but also more potent way to create criteria. The assessment of the functional and non-functional requirements, found in Table 7 and Table 11 respectively, shown that the prototype did a lot right.

8.1.2 Regenerative agriculture as a large term

Despite the large list of adoption factors found in background research, the paper only seems to scratch the surface on the complex issue of making farming more sustainable through regenerative farming. This it has been made apparent during interactions with Foodvalley representatives and other people involved in making agriculture sustainable.

Interaction with farmers also shed light on the different motivations for sustainability in agriculture, along with differences in their techniques and scale of farming, that stem from those differences in motivation.

8.1.3 Limitation in comparing agricultural methods and environment

Although many of the papers cited in the background research look at countries outside Europe that have different approaches and techniques. It could be that European farmers benefit less from working together due to the more mechanized farming techniques. This possibility is not covered enough in this research and should be investigated further.

8.1.4 Lack of additional data

Despite finding a many sources of external data, the prototype does not use almost any of them.

This makes the prototype only rely on farmer supplied data. There is certainly more public data to be found for the Netherlands and other countries. However, due to the public data not being used in the prototype, it is unknown if this data would be beneficial to this kind of map.

8.1.5 User experience limitations

The research yielded interesting ideas and tried to implement them, during this, it became apparent that this idea would take more time to iterate on and test than expected. The evaluation conclusions are quite clear that with the additional fixes the prototype shows a lot of promise. The research would benefit from research into the user experience of the prototype, the problems with usability and lack of explanations in some steps ended hurting the results.

8.1.6 Amount of participants

Expanding its pool of evaluation participants from 4 to something around 40 if not more would also help. That would make it possible to test the idea in a more rigorous and statistically significant way, aside from just testing the prototype qualitatively.

8.2 Future Work

This section outlines possibilities for future research stemming from the gaps in knowledge and new questions that were uncovered during this research.

8.2.1 Quick-fixes and short-term improvement

The project had a time overrun, that is something that happens in many projects. This left a lot of low-hanging fruit for improvements that could be quick to implement if another iteration of the prototype was built for any of the possible work below. The first quick-fix is the positioning of the evaluation result checkmark in the criteria input view shown in Fig. 28 could be moved to the right to make the actual inputs more prioritized, since many if not all European cultures read, and thus prioritize things from left to right [60]. Another thing that needs to be improved in the project is adding explanations and tutorials for using the more involved features of the project. This is what held the evaluation back and is not very hard to implement. The next short-term improvement is to add organizer-made-made explanations for criteria and milestones to give organizers the possibility to add context. The final improvement would be to make the link criteria occupy less space on the page. As can be seen in Fig. 28, the link criteria, which the user cannot influence directly, take a lot of upper real-estate on the page. That forces the users to scroll down.

8.2.2 Linking value-chains

A sister project was developed along-side this project that visualized value chains. A value chain is the chain of production that goes from the raw materials, like crops, to the shelves of retail stores that store the finished product. A link could be made between those projects where the farmers would report where they sell their crops to make a start to the regenerative value chain that could be visualized.

8.2.3 Creating definitions for steps needed to become regenerative

The first thing that was not investigated in depth in this research is the exact content of the criteria and milestones that the farmers need to abide by, this goes along with the issues of regenerative agriculture having multiple definitions.

The prototype could, with a lot of fixes and improvement, prove to be a good test bed for such research, but testing the effects of the content of the milestone list is outside the scope of this research.

8.2.4 Merging farmer-supplied data with public data

This relates to the cancelled functionality of the prototype, where the user could also view more than the milestones on the map. Some of the data available for public use could be proven beneficial to the farmers in future research. This would involve re-evaluating what data farmers need through additional literature research or a survey, and then improving the prototype by adding hard-requirements for public data importing. It could provide a good reference for criteria, like the amount of land used for pasture and arable land for each farmstead and soil and pasture types.

8.2.5 Improving and testing user experience

The final prototype was fraught with small and big user experience flaws, partly due to time constraints, but also due to lack of iteration before the evaluations. Improving this could become its own research due to it being a very dynamic system, that is proven difficult to get right. Such iteration of the prototype would need to add non-functional requirements, focussing on ease and speed of use of the prototype. Those requirements could be evaluated using more statistically significant methods.

8.2.6 Long term and large scale trial

Due to the sheer volume of food being produced and the amount of stakeholders involved in it. A group of four participant is not enough to show that this system could have the impact that it hoped to have. Therefore, it is important to try a similar concept with a real initiative on a real scale.

Additionally, successfully adopting regenerative agriculture and reaping the benefits could take years, this concept needs to be tested on a long term as well, with real farmers using the system to improve their farms.

8.2.7 Manuals for creating criteria

One of the most important lessons that came from evaluations is that the criteria need a lot of context to be clear. This means that the organizers would need instruction on how to make criteria, how to name them and how to describe them, when the descriptions are added as a feature for criteria and milestones. This means that an additional future work opportunity for this project would be finding best practices for using the criteria system as the organizer.

9 Conclusion

This thesis sought to answer a complex question and design a great solution that would connect farmers and organizers together. Namely, it sought to visualize the information needed to assess the adoption rate, an individual farm's progress and the steps needed to improve. This has been done by creating a system that could create tailored criteria sets for each organization seeking to coordinate the transition to regenerative farming.

The conclusion will be made by answering all the sub-questions and then the main research question from chapter 1.3. The research questions will be repeated.

9.1 SQ 1: Adoption drivers

> "What drives an agricultural stakeholder to adopt regenerative agriculture practices?

The major information drivers of adoption found in chapter 2.1. The research yielded three major types of information that farmers use to make a decision on adopting regenerative farming or similar regenerative measures. The first source of information is related to the cost of the measures. The second is the amount of (un)certainty around adoption, any examples of successful measure results improves adoption. The last source of information is the technical knowledge or clear steps to adopt measures.

9.2 SQ 2: Data sharing

> "What kind of information is beneficial to share between farmers?"

The benefits of sharing information between farmers and farmers cooperating is apparent and well-supported.

Sharing input use to know the amount of spillover effects, along with the technical knowledge from neighbors, could benefit the farmers in the whole region.

The prototype did not end up capitalizing on those benefits, due to time constraints, but adding information sharing would be an additional system that could be added in next iterations of the prototype.

9.3 SQ 3: Public data

> "What kind of agriculture-related data can be found publicly?"

This paper found a small list of potentially useful public datasets for Dutch farmers. This includes soil type, plot location and crop type, background maps and routes between locations found on PDOK and other platforms.

The prototype did not use any of them in the end, besides the map.

9.4 SQ 4: Farmer privacy

> "How can the project safely visualize or make use of data that is not meant to be public?"

Due to the lack of data on how much data farmers are willing to share, privacy was a big requirement in the research. During further development and testing, farmers tended to not object to sharing data and would fill in data that is truthful, including Personally Identifiable Information(PII), like email-addresses and phone numbers. This could be due to the information already being public. The prototype included functionality to hide PII from the map, but it's rate of use would need to be tested.

9.5 SQ 5: Visualization methods

> "How can the important data pertaining to sustainable agriculture adoption be visualized on a map?"

The initial design intended to use BRP[61], while also requiring the farmers to select each of the plots that belonged to them. At the end, that was replaced with simple pins for each farmstead. This seemed to be a good choice for simplifying adoption input, but could harm the efficacy of the visualization. From initial impressions of the farmers and organizers alike, when enough farms are enrolled in the visualization, this kind of visualization could be valuable.

9.6 SQ 6: Clear adoption steps

> "How can a map application give the farmers clear steps to adopt a more regenerative approach?"

The criteria seemed to be simple enough for the farmers to understand what the next steps of becoming more regenerative were, but this was only a short test and only shown that the farmers knew what numbers they needed to fill in. For them to know what to do on the farms, there is a need for more explanation that the prototype failed to provide, therefore this question is not answered with certainty in this research, but rather gives a possible answer through the concept of criteria and milestones as a way to give a roadmap towards regenerative agriculture.

9.7 RQ: Map-Based tool

The main question that this thesis answers is the following:

> How to design a map-based tool that visualizes data related to adopting sustainable practices in an informative way?

The research did successfully implement the core of the idea of organizer-created data schema for farmers to fill in. It also successfully shown that such data entry method could be a low enough bar for farmer adoption, on the condition that the user experience is improved. The prototype showed that it could create informing visualizations using the schema. It also proved that the bar for farmers to enroll is low enough for the farmers to benefit from a list of things to do to become more regenerative, while them and their progress being constantly visible. Due to the innovative nature of the project, this is one of the first projects to attempt to solve this problem, making problems in user experience and other hurdles expected. This project had its own share of them, but nonetheless, this project answers the question above by example. One way to design a map-based tool to visualize data related to adopting sustainable practices in an informative way is to create a flexible system of criteria for the farmers to address the open-ended nature of regenerative agriculture, and display the progress along those criteria in a map using pins for each farmstead.

References

[1] B. Mao and J. Cao, "HTML5 Based 3D Visualization of High Density LiDAR Data and Color Information for Agriculture Applications," in *Social Media Retrieval and Mining*, S. Zhou and Z. Wu, Eds. Berlin, Heidelberg: Springer, 2013, pp. 143–151.

[2] H. Maulana and H. Kanai, "Utilizing Game Engine for Development Interactive 3-Dimensional Geographic Information System (GIS) Agriculture Commodity Selection and Land Evaluation," in *Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics*, 2021, pp. 3361–3366.

[3] E. Parliament, "Greenhouse gas emissions by country and sector (infographic)," Dec. 2024. [Online]. Available: https://www.europarl.europa.eu/topics/en/article/20180301STO98928/greenhouse-gas-emissions-by-country-and-sector-infographic

[4] L. Gensch, K. Jantke, L. Rasche, and U. A. Schneider, "Pesticide risk assessment in European agriculture: Distribution patterns, ban-substitution effects and regulatory implications," *Environmental Pollution*, vol. 348, p. 123836, May 2024. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0269749124005505

[5] M. H. Zwart, A. E. J. Hooijboer, B. Fraters, M. Kotte, R. N. M. Duin, C. H. G. Daatselaar, C. S. M. Olsthoorn, and J. N. Bosma, "Agricultural practice and water quality in the Netherlands in the 1992-2006 period," National Institute for Public Health and the Environment (RIVM), Netherlands, Tech. Rep. 680716003/2008, 2008.

[6] M. W. Jordon, D. M. Winter, and G. Petrokofsky, "Advantages, disadvantages, and reasons for non-adoption of rotational grazing, herbal leys, trees on farms and ley-arable rotations on English livestock farms," *Agroecology and Sustainable Food Systems*, vol. 47, no. 3, pp. 330–354, Mar. 2023, publisher: Taylor & Francis _eprint: https://doi.org/10.1080/21683565.2022.2146253. [Online]. Available: https://doi.org/10.1080/21683565.2022.2146253

[7] Y. Feng, Y. Feng, and Z. Liu, "Normative Influences on Carbon Offset Behavior: Insights from Organic Farming Practices," *Sustainability*, vol. 17, no. 4, p. 1638, Jan. 2025, number: 4 Publisher: Multidisciplinary Digital Publishing Institute. [Online]. Available: https://www.mdpi.com/2071-1050/17/4/1638

[8] M. Happel, F. Orsi, T. Hartmann, and M. Bakker, "Fertile ground, complex matter: Plurality of farmers' attitudes towards green waste application as sustainable soil management," *Sociologia Ruralis*, vol. 62, no. 3, pp. 509–541, Jul. 2022. [Online]. Available: https://onlinelibrary.wiley.com/doi/10.1111/soru.12381

[9] R. van Antwerpen, D. Watt, W. Gillespie, and P. van Heerden, "Promoting Adoption of Soil Health Related Regenerative Agriculture Practices Amongst Small-Scale Sugarcane Grower Communities in South Africa," *Sugar Tech*, vol. 26, no. 3, pp. 635–638, 2024.

[10] H. Zheng, J. Ma, Z. Yao, and F. Hu, "How Does Social Embeddedness Affect Farmers' Adoption Behavior of Low-Carbon Agricultural Technology? Evidence From Jiangsu Province, China," *Frontiers in Environmental Science*, vol. 10, Jun. 2022, publisher: Frontiers. [Online]. Available: https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2022.909803/full

[11] R. Kemp, R. Nijhoff-Savvaki, R. Ruitenburg, J. Trienekens, and S. Omta, "Sustainability-related innovation adoption: the case of the Dutch pig farmer," *Journal on Chain and Network Science*, vol. 14, no. 1, pp. 69–78, Jan. 2014. [Online]. Available: https://www.wageningenacademic.com/doi/10.3920/JCNS2014.0240

[12] P. Newton, N. Civita, L. Frankel-Goldwater, K. Bartel, and C. Johns, "What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes," *Frontiers in Sustainable Food Systems*, vol. 4, Oct. 2020, publisher: Frontiers. [Online]. Available: https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2020.577723/full

[13] UN, "About SDG's | Department of Economic and Social Affairs." [Online]. Available: https://sdgs.un.org/about

[14] Foodvalley, "Regenerative Innovation Portfolio." [Online]. Available: https://foodvalley.nl/en/initiative/regenerative-innovation-portfolio/

[15] pauline, "Foodvalley, EIT Food and Food Innovation Hub Europe launch regenerative farming initiative," Jul. 2024. [Online]. Available: https://foodvalley.nl/en/foodvalley-eit-food-and-food-innovation-hub-europe-launch-regenerative-farming-initiative/

[16] F. Guevara-Fernandez and M. Oliva-Cruz, "Determinants of adoption of sustainable agricultural practices by small-scale coffee farmers in amazonas, Peru," *Asian Journal of Agriculture and Rural Development*, vol. 15, no. 1, pp. 11–29, Jan. 2025, number: 1. [Online]. Available: https://archive.aessweb.com/index.php/5005/article/view/5276

[17] B. Zhang and S. Fu, "Do market pressure and social network affect farmers' adoption of low-carbon fertilization practices? Evidence from China," *Environmental Science and Pollution Research*, vol. 30, no. 18, pp. 51 804–51 815, Apr. 2023. [Online]. Available: https://doi.org/10.1007/s11356-023-25664-8

[18] E. B. Ntawuhiganayo, E. Nijman-Ross, T. Geme, D. Negesa, and S. Nahimana, "Assessing the adoption of regenerative agricultural practices in Eastern Africa," *Frontiers in Sustainability*, vol. 4, Jun. 2023, publisher: Frontiers. [Online]. Available: https://www.frontiersin.org/journals/sustainability/articles/10.3389/frsus.2023.1105846/full

[19] L. Ellman-Stortz, K. Lewis, T. Gentry, P. DeLaune, E. Pierson, and N. Boogades, "Early impacts of cover crop selection on soil biological parameters during a transition to organic agriculture," *Agrosystems, Geosciences & Environment*, vol. 7, no. 2, p. e20532, 2024, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/agg2.20532. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/agg2.20532

[20] M. W. Jordon, K. J. Willis, P.-C. Bürkner, N. R. Haddaway, P. Smith, and G. Petrokofsky, "Temperate Regenerative Agriculture practices increase soil carbon but not crop yield—a meta-analysis," *Environmental Research Letters*, vol. 17, no. 9, p. 093001, Aug. 2022, publisher: IOP Publishing. [Online]. Available: https://dx.doi.org/10.1088/1748-9326/ac8609

[21] M. Raseduzzaman and E. S. Jensen, "Does intercropping enhance yield stability in arable crop production? A meta-analysis," *European Journal of Agronomy*, vol. 91, pp. 25–33, Nov. 2017. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1161030117301399

[22] J. M. Deines, K. Guan, B. Lopez, Q. Zhou, C. S. White, S. Wang, and D. B. Lobell, "Recent cover crop adoption is associated with small maize and soybean yield losses in the United States," *Global Change Biology*, vol. 29, no. 3, pp. 794–807, 2023, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/gcb.16489. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.16489

[23] S. Knapp and M. G. A. van der Heijden, "A global meta-analysis of yield stability in organic and conservation agriculture," *Nature Communications*, vol. 9, no. 1, p. 3632, Sep. 2018, publisher: Nature Publishing Group. [Online]. Available: https://www.nature.com/articles/s41467-018-05956-1

[24] C. Kreft, R. Huber, D. Schäfer, and R. Finger, "Quantifying the impact of farmers' social networks on the effectiveness of climate change mitigation policies in agriculture," *Journal of Agricultural Economics*, vol. 75, no. 1, pp. 298–322, 2024, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/1477-9552.12557. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/1477-9552.12557

[25] X. Li, L. Yang, and Q. Lu, "Does Social Learning Promote Farmers' Cooperative Pest Control?—Evidence from Northwestern China," *Agriculture*, vol. 14, no. 10, p. 1749, Oct. 2024, number: 10 Publisher: Multidisciplinary Digital Publishing Institute. [Online]. Available: https://www.mdpi.com/2077-0472/14/10/1749

[26] C. Honert, K. Mauser, U. Jäger, and C. A. Brühl, "Exposure of insects to current use pesticide residues in soil and vegetation along spatial and temporal distribution in agricultural sites," *Scientific Reports*, vol. 15, no. 1, p. 1817, Jan. 2025. [Online]. Available: https://www.nature.com/articles/s41598-024-84811-4

[27] S. Köthe, N. Bakanov, C. Brühl, B. Gemeinholzer, T. Hörren, R. Mühlethaler, M. Sorg, H. Sumser, S. Swenson, and G. Lehmann, "Negative spill-over effects of agricultural practices on plant species conservation in nature reserves," *Ecological Indicators*, vol. 149, p. 110170, May 2023. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S1470160X23003126

[28] "Nationaal georegister." [Online]. Available: https://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/home

[29] "Datasets - PDOK." [Online]. Available: https://www.pdok.nl/datasets

[30] "Geo services en APIs — PDOK / NGR documentatie documentatie." [Online]. Available: https://pdok-ngr.readthedocs.io/services.html

[31] "OpenStreetMap." [Online]. Available: https://www.openstreetmap.org/about

[32] "GraphHopper Directions API with Route Optimization," Jan. 2017. [Online]. Available: https://www.graphhopper.com/

[33] "AMS Dynamic Information Visualization Page | Agricultural Marketing Service." [Online]. Available: https://www.ams.usda.gov/services/ams-data-visualization

[34] S. C. Government of Canada, "Crop production: Visualization tool," Jan. 2021, last Modified: 2021-01-12. [Online]. Available: https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2020025-eng.htm

[35] A. Laurent, X. Lyu, P. Kyveryga, D. Makowski, H. Hofmann, and F. Miguez, "Interactive Web-based Data Visualization and Analysis Tool for Synthetizing on-farm Research Networks Data," *Research Synthesis Methods*, vol. 12, no. 1, pp. 62–73, 2021, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/jrsm.1440. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/jrsm.1440

[36] F. Terribile, A. Bonfante, A. D'Antonio, R. De Mascellis, C. De Michele, G. Langella, P. Manna, F. A. Mileti, S. Vingiani, and A. Basile, "A geospatial decision support system for supporting quality viticulture at the landscape scale," *Computers and Electronics in Agriculture*, vol. 140, pp. 88–102, Aug. 2017. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0168169917303253

[37] "Gneiss Name - YouTube." [Online]. Available: https://www.youtube.com/

[38] Gneiss Name, "Geology of Minecraft: Iron Ore, Facts and Fiction," Dec. 2024. [Online]. Available: https://www.youtube.com/watch?v=OfHLsqaHJoo

[39] ADMIN, "Heart Disease Deaths and Waffle House Locations – FoodyData." [Online]. Available: https://foodydata.com/heart-disease-deaths-and-waffle-house-locations/

[40] A. Mader and W. Eggink, "A DESIGN PROCESS FOR CREATIVE TECHNOLOGY," in *INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION*, University of Twente, Sep. 2009.

[41] A. L. Mendelow, "Environmental Scanning–The Impact of the Stakeholder Concept," in *Environmental Scanning–The Impact of the Stakeholder Concept*. Cambridge, Massachusetts, US: Association for Information Systems, 1981.

[42] A. Business, "Chapter 10: MoSCoW Prioritisation - DSDM Project Framework Handbook | Agile Business Consortium." [Online]. Available: https://www.agilebusiness.org/dsdm-project-framework/moscow-prioririsation.html

[43] C. Brummitt, C. Mathers, R. Keating, K. O'Leary, M. Easter, M. Friedl, M. DuBuisson, E. Campbell, R. Pape, S. Peters, and A. Kumar, "Solutions and insights for agricultural monitoring, reporting, and verification (MRV) from three consecutive issuances of soil carbon credits," *Journal of Environmental Management*, vol. 369, 2024.

[44] J. Feng, F. Zhang, and M. Li, "Research on Work Breakdown Structure of IT Project," in *2009 International Conference on Management and Service Science*. Beijing, China: IEEE, Sep. 2009, pp. 1–5. [Online]. Available: https://ieeexplore.ieee.org/document/5303208/

[45] A. Sharon and D. Dori, "A Project–Product Model–Based Approach to Planning Work Breakdown Structures of Complex System Projects," *IEEE Systems Journal*, vol. 9, no. 2, pp. 366–376, Jun. 2015. [Online]. Available: https://ieeexplore.ieee.org/document/6748857

[46] C. M. Eidt, L. P. Pant, and G. M. Hickey, "Platform, Participation, and Power: How Dominant and Minority Stakeholders Shape Agricultural Innovation," *Sustainability*, vol. 12, no. 2, p. 461, Jan. 2020. [Online]. Available: https://www.mdpi.com/2071-1050/12/2/461

[47] U. o. N. C. The Writing Center, "Brainstorming." [Online]. Available: https://writingcenter.unc.edu/tips-and-tools/brainstorming/

[48] P. A. Heslin, "Better than brainstorming? Potential contextual boundary conditions to brainwriting for idea generation in organizations," *Journal of Occupational and Organizational Psychology*, vol. 82, no. 1, pp. 129–145, 2009, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1348/096317908X285642. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1348/096317908X285642

[49] Y. Wang, Y. Liu, L. Yu, C. Ji, and Y. Liu, "A comparative study of table-sized physicalization and digital visualization," *Journal of Visualization*, Apr. 2025. [Online]. Available: https://link.springer.com/10.1007/s12650-025-01056-7

[50] S. Stusak, J. Schwarz, and A. Butz, "Evaluating the Memorability of Physical Visualizations," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. Seoul Republic of Korea: ACM, Apr. 2015, pp. 3247–3250. [Online]. Available: https://dl.acm.org/doi/10.1145/2702123.2702248

[51] T. Karras, S. Laine, and T. Aila, "A Style-Based Generator Architecture for Generative Adversarial Networks," Mar. 2019, arXiv:1812.04948 [cs]. [Online]. Available: http://arxiv.org/abs/1812.04948

[52] Object Management Group, "What is UML," Jul. 2005. [Online]. Available: https://www.uml.org/what-is-uml.htm

[53] "Model-View-Controller Pattern," in *Learn Objective-C for Java Developers*, J. Bucanek, Ed. Berkeley, CA: Apress, 2009, pp. 353–402. [Online]. Available: https://doi.org/10.1007/978-1-4302-2370-2_20

[54] "Associative entity," Jan. 2025, page Version ID: 1267893326. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Associative_entity&oldid=1267893326

[55] "Basisregistratie Gewaspercelen (BRP)." [Online]. Available: https://www.nationaalgeoregister.nl/geonetwork/srv/api/records/b812a145-b4fe-4331-8dc6-d914327a87ff

[56] J. Bang-Jensen and G. Z. Gutin, *Digraphs*, ser. Springer Monographs in Mathematics. London: Springer, 2009. [Online]. Available: http://link.springer.com/10.1007/978-1-84800-998-1

[57] "Laravel - The PHP Framework For Web Artisans." [Online]. Available: https://laravel.com/

[58] "Vue.js." [Online]. Available: https://vuejs.org/

[59] "PostGIS." [Online]. Available: https://postgis.net/

[60] L. Rinaldi, S. Di Luca, A. Henik, and L. Girelli, "Reading direction shifts visuospatial attention: An Interactive Account of attentional biases," *Acta Psychologica*, vol. 151, pp. 98–105, Sep. 2014, publisher: Elsevier BV. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0001691814001346

[61] PDOK, "BasisregistratieGewaspercelen Dataset," Jun. 2024. [Online]. Available: https://www.pdok.nl/introductie/-/article/basisregistratie-gewaspercelen-brp-

10 AI Statement

During the preparation of this work, the author used ChatGPT during programming in order to augment the documentation of the software used for developing the prototype. The author also used LanguageTool plugin for overleaf in order to spell check the work during writing, outside of small corrections this tool was not used to generate text. After using those tools, the author reviewed and edited the content as needed and take(s) full responsibility for the content of the work.

A Literature research matrix

Paper	Adoption data[10]	Data to share[11]	Data source [12]
Feng et al. [7]	Economic incentives, cost reduction and trust in policy are very important.		China
Van Antwerpen et al. [9]	Education of RA techniques.	The techniques and how-to's	South Africa
Guevara-Fernandez and Olivia-Cruz [16]	Direct yield or quality benefits of a certain technique. Potential of preventing damage, like soil erosion. Amount of labor needed.		Colombia
Jordon et al. [6]	Existing infrastructure vs infrastructure needed for new measures. Economic costs and changes in output. Cost of buying inputs vs cost of creating those inputs. Proof of the measures working.	Success of RA in neighboring farms could drive adoption. Knowledge exchange reduces uncertainty and conflicting information.	Cattle farmers in Great Britain
Ntawuhiganayo et al. [18]	Circular economy in the region increases the odds of practicing RA.	Training and knowledge sharing increases odds of adoption.	Africa
Li et al.[25]	Distance from major roadways encourages social learning and cooperation in agricultural setting.		China
Kreft et al. [24]	Insights from other farmers, network effects between farmers	Knowledge sharing might reduce costs for farmers.	Swiss dairy farmers
Happel et al. [8]	Practical information, economic payoff of measures, clarity of agricultural policy.	Information about local policy.	Netherlands
Zhang and Fu [17]	Strengthening the social network and using the market and organizational network.	Suitable amounts of fertilizer	China
Zheng et al. [10]	Support from government, awareness of low-carbon technologies, social embeddedness	Spreading information about technologies	China
Honent et al. [26]	Neighboring farms can spread pesticides, especially down-wind	Farms which use pesticides	Germany
Kemp et al. [11]	Age of the farmer, size of the farm, distance from sensitive areas, profitability		Dutch pig farmers.

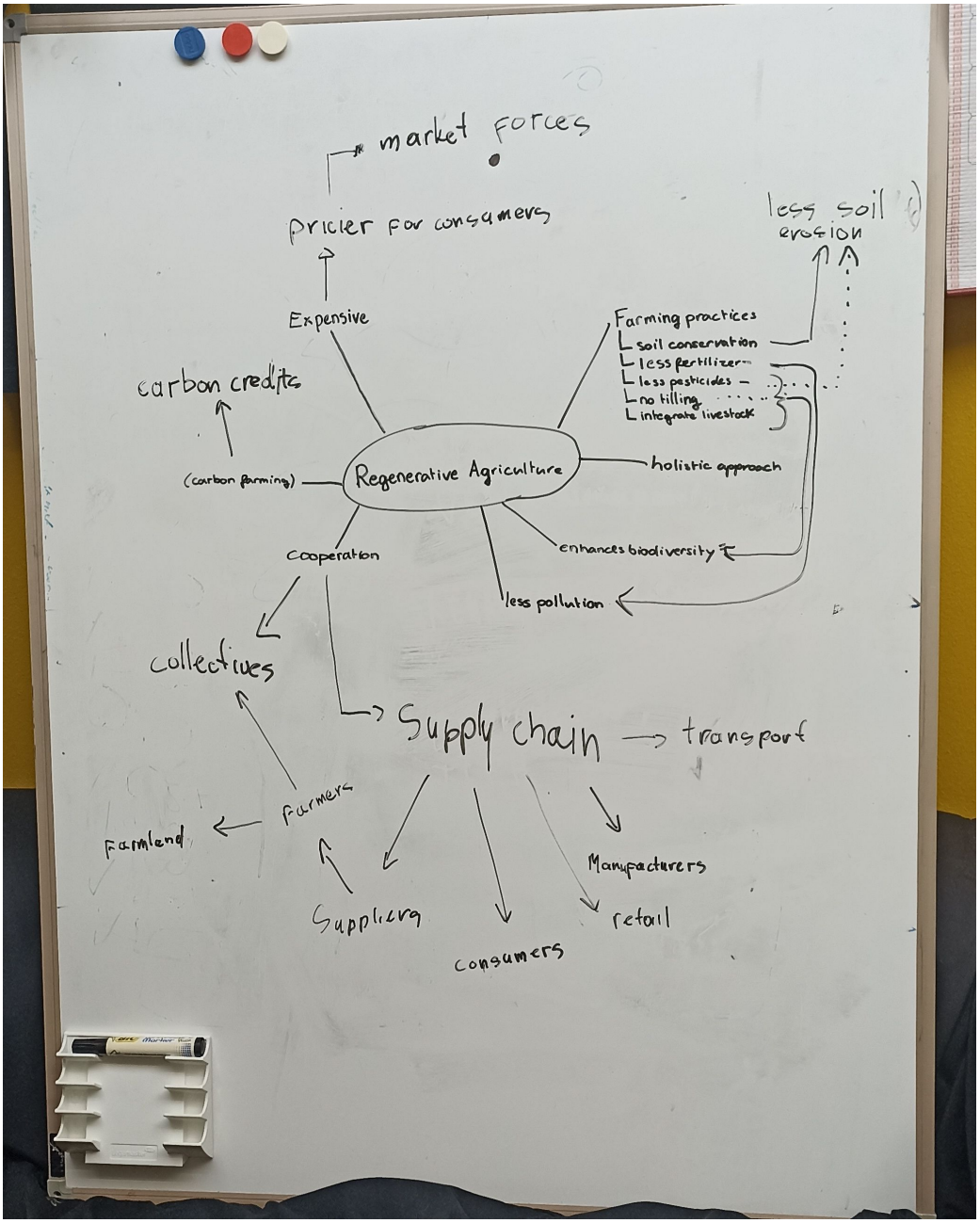
[9] Answering question SQ 1
[10] Answering question SQ 2
[11] Most of the papers gather information from farmers, this column shows where the farmers are situated.

B Results of Focussed freewriting

```
Profiles for farmers?
Profiles for stakeholders
Open platform
Little farm icons per farm
Ownership view, based on farmer provided data
Routes to offtakers
Side menu for non-mappable information and info of plot/farm
Collective participation
Participation in the project
Letting farmers post little postits in their farms/ notes
Like-Dislike system for said notes
Linking farmers socially
Note/insights aggregation
Icons/Models for type of agriculture:
- Cow for dairy
- Bull/Pig/Chicken for meat
- Grain for regular agriculture
- Flowers for horticulture
- etc.

If 3d/ Bars charts for yields
Tips and tricks
Pest reporting
Experiment/Trials
Posts on trials
Visualization of trial vs control farms
Visualization of results
Biodiversity as animal/bug/shrub score/density
Biodiversity from sites tracking animals. plants insects etc.
There are many stakeholders, that share and consume data.
Just let the input the data themselves
Bulk data input
Permissions for bulk input
Preventing people from lying/griefing the dataset
What-If mode: Proposing potential changes without getting the database dirty
Travel distance between farmers/offtakers in general
X farmers that do y thing in z km of distance
Placement of farm homes
Farmers showcasing what they can borrow to people (sharing is caring after all)
```

C Mindmap for the initial phase of ideation



D Brainwriting for the initial phase of ideation

E Code for client-side evaluation of criteria

```
// Create an evaluation table from a milestone-criteria( and fill) tree
export function make_eval_table(tree) {
    const evals = {}
    tree.slice().reverse().forEach(mst => {
        evals[mst.id] = {
                milestone: false,
                criteria: {},
            };

        evals[mst.id].milestone = evaluate_milestone(mst, evals);
    });

    return evals;
}

// Evaluate a single milestone with the help of evaluation table of all the milesto
export function evaluate_milestone(mst, evals) {
    var answer = !mst.is_any;

    // Go through all the criteria
    for (var i = 0; i < mst.criteria.length; i++) {
        const crit = mst.criteria[i];
        const comp = evaluate_criterion(crit, evals);
        // Add to the cache of criteria
        evals[mst.id].criteria[crit.id] = comp;

        // Anwswer yes if the milestone is of ANY type and one of the criteria is
        if (mst.is_any){
            if (comp) {
                answer = true;
            }
        }

        // Anwswer no if the milestone is of ALL type and one of the criteria is n
        else {
            if (!comp) {
                answer = false;
            }
        }

    }
    return answer;
}


// Evaluate a single criterion, the eval table is needed for link criteria
export function evaluate_criterion(c, evals) {
    switch (c.operator) {
        case 'link':
            // Use pre-evaluated milestones to get the link criterion checked off
            return evals[parseInt(c.constant)].milestone;
        case 'gte':
            return c.fill.double1 >= Number.parseFloat(c.constant);
        case 'gt':
            return c.fill.double1 > Number.parseFloat(c.constant);
```

```
            case 'lte':
                return c.fill.double1 <= Number.parseFloat(c.constant);
            case 'lt':
                return c.fill.double1 <= Number.parseFloat(c.constant);
            case 'check':
                const ev = c.constant == 'true';
                const v = c.fill == true || false;
                return c.fill.bool1 == (c.constant === 'true');
            default:
                log.warn('invalid operator: ' + c.operator)
                return false;
        }
    }
```

F Information letter and consent form for evaluations

See pages below...

Samenwerking Kaart voor Boeren: Evaluatie

Inleiding

Geachte heer/mevrouw,
Wij vragen u vriendelijk om mee te doen aan een onderzoek van Universiteit Twente met de samenwerking van Foodvalley getiteld:
“Cooperation map for Farmers: Testing en evaluation”
Voordat u de beslissing neemt, is het belangrijk om meer te weten te komen over het onderzoek. Lees deze informatiebrief rustig door. Hebt u na het lezen van de informatie nog vragen? Dan kunt u terecht bij de onderzoekers, die onderaan deze brief vermeld zijn.

1. Wat is het doel van het onderzoek?

De onderzoeker ontwikkelt een kaart applicatie, die het organiseren van regeneratief land makkelijker maakt, daarvoor heeft hij uw inzicht nodig.
Het doel van het onderzoek is om de prototype van de applicatie te evalueren bij de doelgroep, waar u bij hoort.
De samenwerking houdt in dat u wat data deelt en meedoet aan een korte test met het prototype.

2. Hoe wordt het onderzoek uitgevoerd?

Dit onderzoek wordt uitgevoerd in 30 minuten waar u een paar taken voltooid met de hulp van het prototype.

3. Wat wordt er van u verwacht?

Indien u toestemming gaf voor het onderzoek, vragen we voor 30 minuten van uw tijd om de evaluatie uit te voeren.
Wij vragen ook om een toestemming om de resultaten te gebruiken in het onderzoek, in een geanonimiseerde vorm.

4. Wat gebeurt er als u niet wenst deel te nemen aan dit onderzoek?

U beslist zelf of jullie meedoen aan het onderzoek. Deelname is vrijwillig. Als u besluit niet mee te doen, hoeft u verder niets te doen. U hoeft niets te tekenen. U hoeft ook niet te zeggen waarom u niet wilt meedoen. Ook tijdens het onderzoek. Er hoeft geen reden te worden gegeven voor het stoppen.

5. Wat gebeurt er met uw gegevens?

Voor dit onderzoek worden uiteraard geen persoonsgegevens gebruikt. De persoonsgegevens worden alleen gebruikt voor contact doeleinden. Alle persoonsgegevens worden binnen twee weken na de test verwijderd.

Vertrouwelijkheid van uw gegevens

Om jullie privacy te beschermen krijgen uw gegevens een code. Uw naam en andere gegevens die direct aan jullie kunnen worden herleid, worden weggelaten. Alleen met de sleutel van de code zijn gegevens tot u te herleiden. De sleutel wordt voor 2 weken bewaard en daarna vernietigd. Hierdoor kan niks naar u geleid worden. De gegevens die naar de partners van het project worden gestuurd bevatten alleen de code, maar niet uw naam of andere gegevens waarmee u kan worden geïdentificeerd.
Ook in rapporten en publicaties over het onderzoek zijn de gegevens niet tot u te herleiden.

Bewaartermijn gegevens

Uw gegevens moeten 10 jaar bewaard worden op de onderzoekslocatie.
Hierna worden de gegevens vernietigd.

Intrekken toestemming

U kunt uw toestemming voor gebruik van uw persoonsgegevens altijd weer intrekken. De onderzoeksgegevens die zijn verzameld tot het moment dat u uw toestemming intrekt, worden nog wel gebruikt in het onderzoek.

Meer informatie over uw rechten bij verwerking van gegevens

Voor algemene informatie over uw rechten bij verwerking van uw persoonsgegevens kunt u de website van de Autoriteit Persoonsgegevens raadplegen. Bij vragen over uw rechten kunt u contact opnemen met de verantwoordelijke voor de verwerking van uw persoonsgegevens. Bij vragen of klachten over de verwerking van uw persoonsgegevens raden we u aan eerst contact op te nemen met de onderzoekslocatie. U kunt ook contact opnemen met de Autoriteit Persoonsgegevens.

6. Zijn er extra kosten of krijgt u een vergoeding wanneer u besluit aan dit onderzoek mee te doen?

Dit onderzoek wordt niet vergoed en heeft geen extra kosten verbonden.

7. Wordt ik later voor meer onderzoek gevraagd?

Nee, de evaluatie is de laatste onderzoek rondom dit prototype.

8. Wilt u verder nog iets weten?

Als u na het onderzoek besluit niet meer deel te nemen, dient u binnen 24 uur dit kenbaar te maken
aan de onderzoekers, dan wordt alle data van u vernietigd. Als u na het onderzoek meer informatie wil over het onderzoek zoals de resultaten kunt u ook contact opnemen met de onderzoeker Jakub Stachurski (j.stachurski@student.utwente.nl) of de begeleider, Erik Faber (e.j.faber@utwente.nl)
Met het geven van uw toestemming verklaart u deze persoonsgegevens vrijwillig te hebben verstrekt. U heeft het recht om de gegeven toestemming ook weer in te trekken. De door u verstrekte persoonsgegevens zullen uitsluitend voor het doel worden gebruikt waarvoor u deze heeft verstrekt. U heeft het recht op inzage, verwijdering, correctie of beperking van de verwerking van persoonsgegevens, alsmede het recht om bezwaar te maken en het recht op gegevensoverdraagbaarheid. Indien u specifieke vragen heeft over de omgang met persoonsgegevens kunt u deze ook richten aan de Functionaris Gegevensbescherming van de UT door een mail te sturen naar dpo@utwente.nl.
Dit onderzoek wordt uitgevoerd vanuit de Universiteit Twente, faculteit Electrical Engineering, Mathematics and Computer Science.

Bijlage A: Toestemmingsformulier

Samenwerking Kaart voor Regenerative Boeren: Evaluatie

05-05-2025

Check wat van toepassing is.

- ☐ Ik heb de informatiebrief voor deelname aan het onderzoek gelezen en begrepen.
- ☐ Ik kon aanvullende vragen stellen en mijn vragen zijn goed beantwoord.
- ☐ Ik had genoeg tijd om goed te beslissen of ik meedoe.
- ☐ Ik weet dat meedoen volledig vrijwillig is, en ik op ieder moment zonder reden de toestemming kan terugtrekken.
- ☐ Ik weet dat de onderzoeker notities maakt over mijn ervaring van de prototype
- ☐ Ik geef toestemming om de resultaten van de test te gebruiken, voor de doelen die in het informatiebrief staan.
- ☐ Ik geef toestemming om de onderzoeksgegevens tot aan het einde van het onderzoek te bewaren.
- ☐ Ik wil meedoen aan dit onderzoek.

Naam deelnemer:
Handtekening: Datum : __ / __ / __

Ik verklaar hierbij dat ik deze deelnemer volledig heb geïnformeerd over het genoemde onderzoek.
Als er tijdens het onderzoek informatie bekend wordt die de toestemming van de deelnemer zou kunnen beïnvloeden, dan breng ik hem/haar daarvan tijdig op de hoogte.

Naam onderzoeker (of diens vertegenwoordiger):
Handtekening: Datum: __ / __ / __

---

* Doorhalen wat niet van toepassing is.