LEGUMINOSE web-based platform

- Training manual -

Date of Deliverable

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Summary

This training manual allows users to create and run the InterCrop model for simulating intercropping systems using the LEGUMINOSE web-based platform. It provides detailed instructions on how to identify and define the boundaries of the field, create a scenario for running a simulation based on input datasets (crop, soil, weather and management practices), and visualise the simulation outputs in graphical format.

Summary of Deliverable

We provided a detailed demonstration of how to create and run a simulation in the LEGUMINOSE web-based platform. We presented two case studies involving a field in the Czech Republic. In the first example, users were guided through all the necessary steps that need to be completed on the platform for running a basic simulation where only the field location was known. In the second example, users had access to soil measurements and a weather dataset collected from a nearby weather station. Finally, we demonstrated how to compare intercropping with monocrop simulations.

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1 Introduction

Welcome to the training manual for the LEGUMINOSE web-based platform!

The LEGUMINOSE web-based platform is an interactive system that assists farmers, agronomists, decision-makers, and other interested stakeholders to draw strategies and make decisions about intercropping systems across Europe. Users can explore various features related to intercropping practices, such as identifying suitable mixtures of crop species/cultivars and management practices for specific sites.

They can also investigate the impact of intercropping designs on crop growth and the dynamics of water and nitrogen over time and space. This is of critical importance for the design of sustainable and resilient cropping systems, as well as for the establishment of a knowledge-sharing platform.

Users can create multiple scenarios by selecting different legume-cereal combinations, intercrop configurations, and management practices. This tutorial will introduce you to creating and running your simulations using the LEGUMINOSE web-based platform.

The objective of this tutorial is to allow all members of the LEGUMINOSE project and interested stakeholders to use the LEGUMINOSE web-based platform to create and run intercrop simulations for any agricultural field in Europe.

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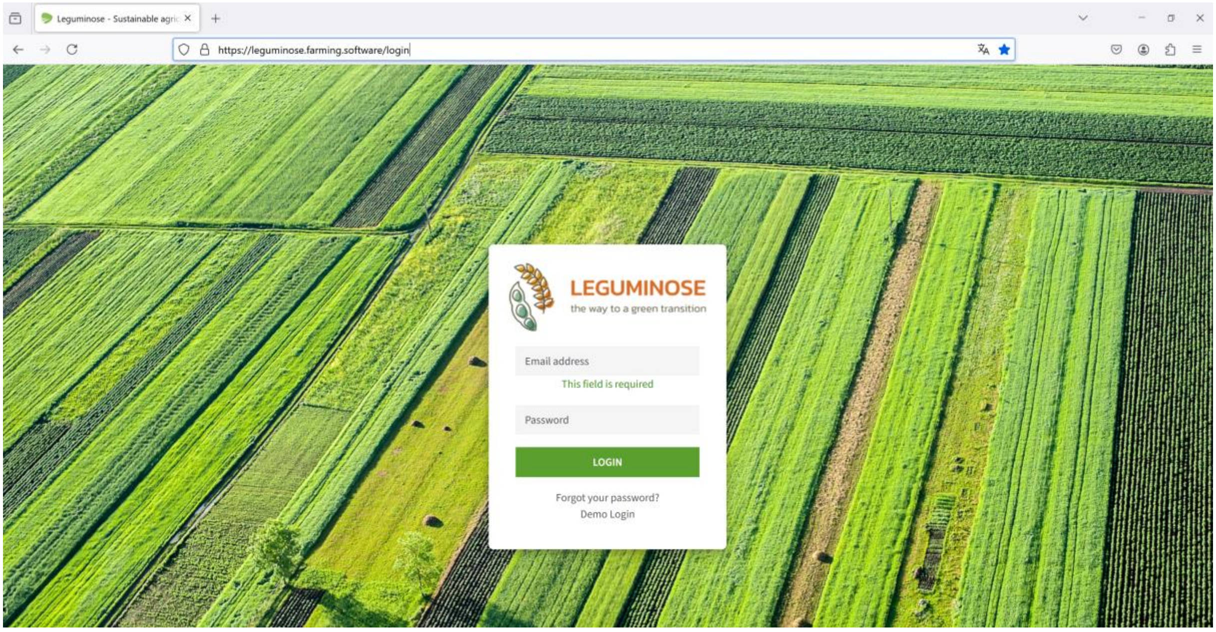
2 Preparation

Before running an intercropping simulation, a few preparatory steps are required. The first is logging into the system:

1. Open your preferred web browser and navigate to the following web application:

https://leguminose.farming.software

2. You should now see this view:



3. Enter your credentials (i.e., registered email address and password) in the boxes and click the LOGIN button.
4. You are now logged into the system.

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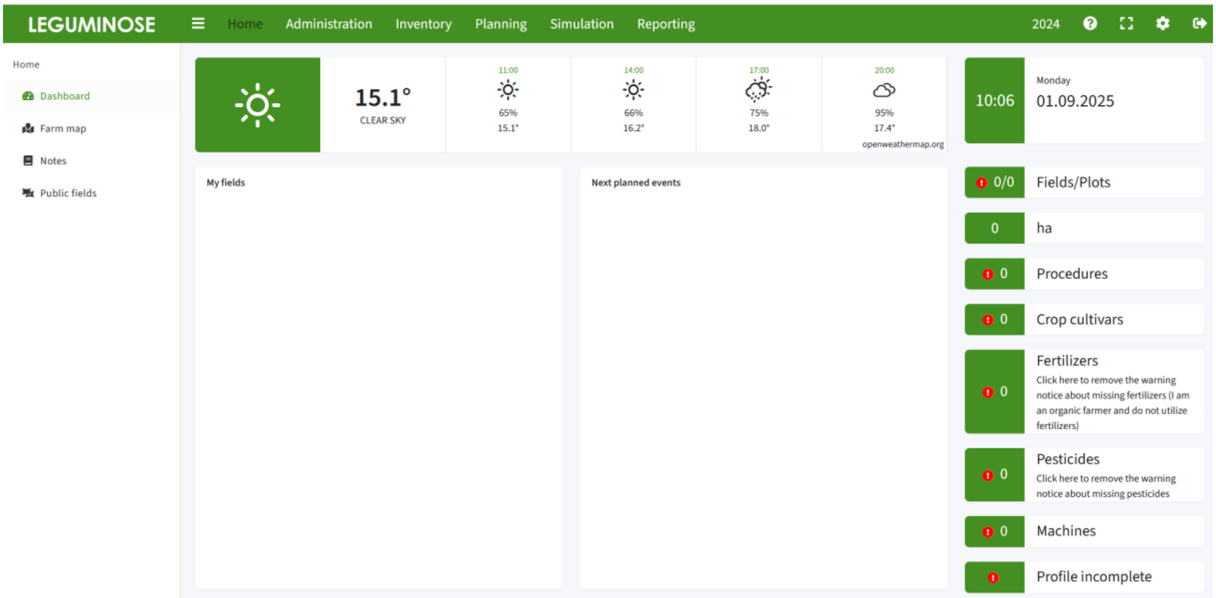
Next, you need to create a field to define the simulation's point of interest. This field location is used to retrieve the appropriate weather dataset and derive soil data.

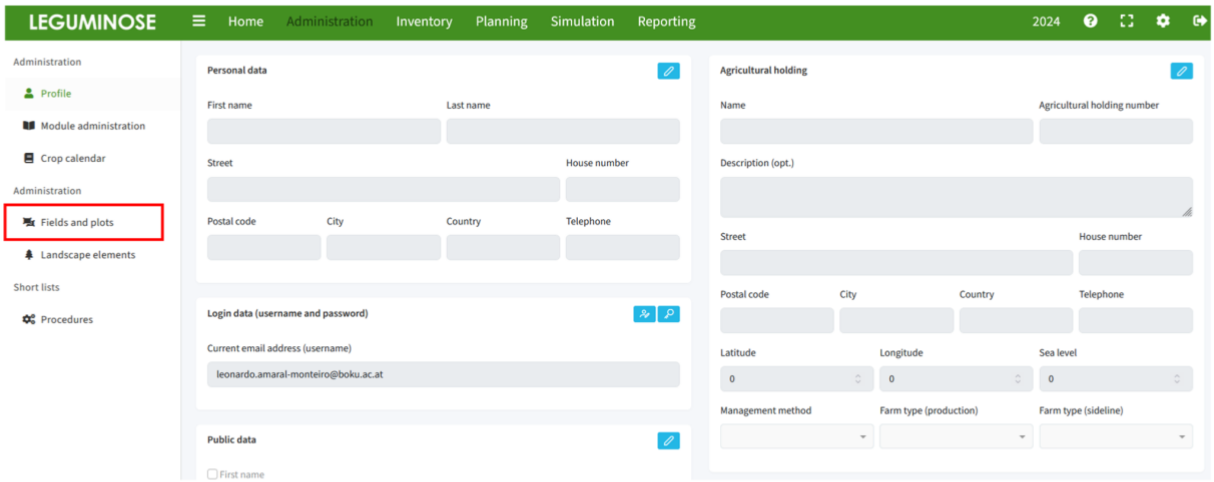


You will now be guided through the process of drawing a polygon to identify an agricultural field located in the Czech Republic. The geocoordinates of the field are:

- **Latitude:** 49.7906758
- **Longitude:** 16.9115911

1. Select the **Administration** top menu item.

2. On the left side menu, press **Fields and plots** (in red).



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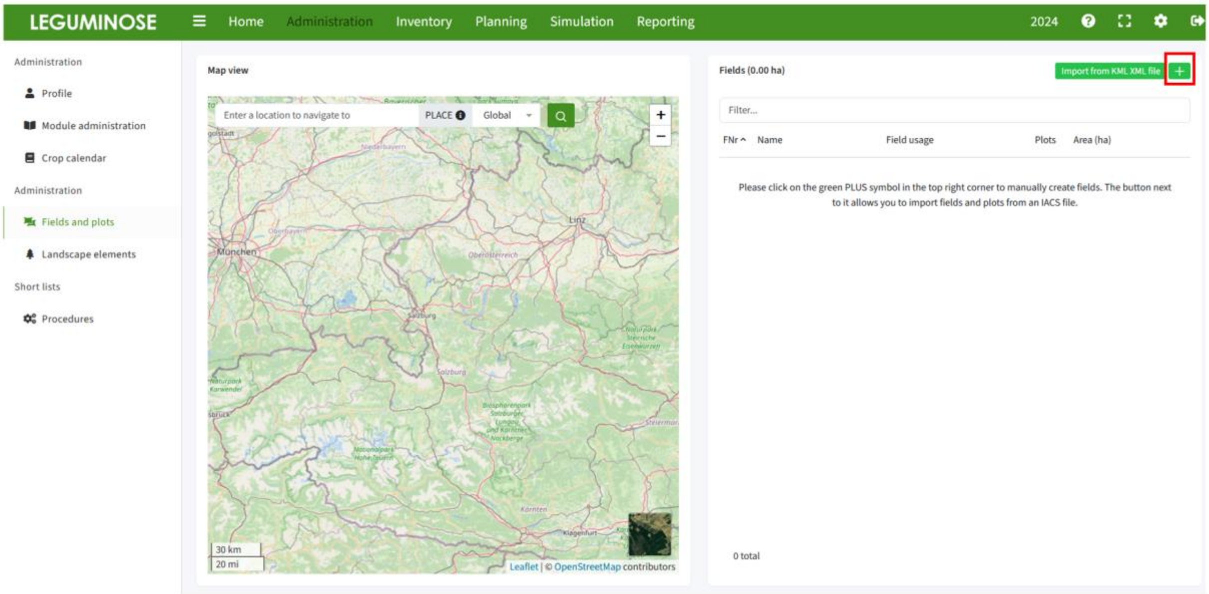
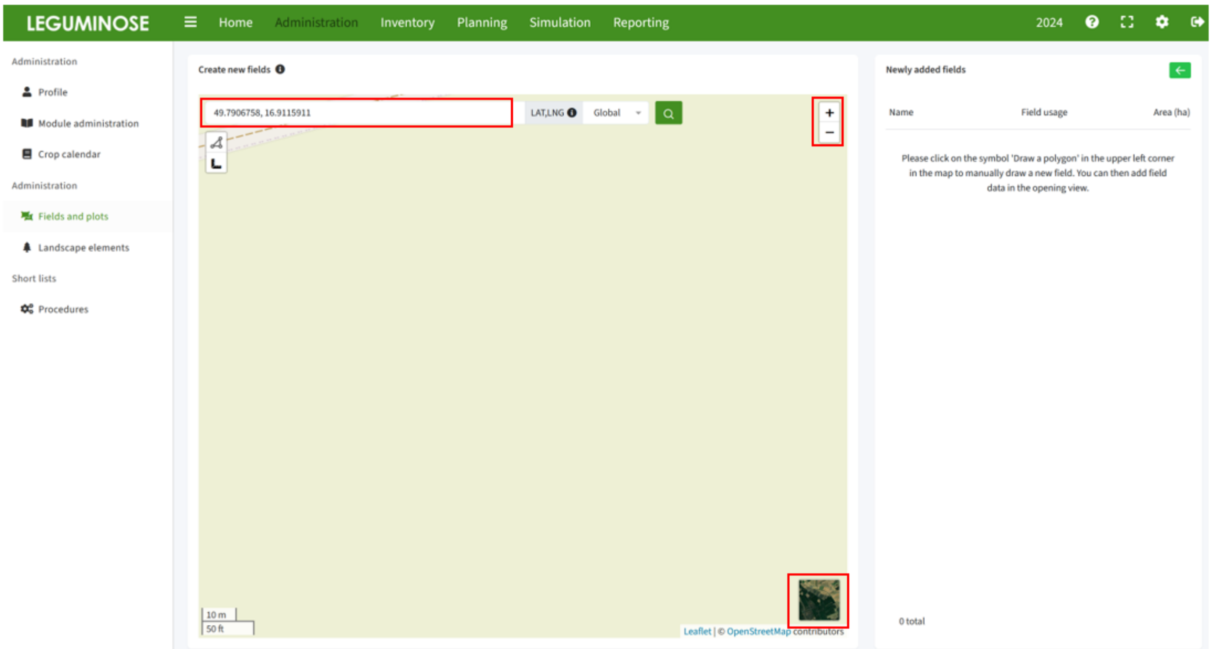
3. You should now see a similar screen:



4. Click the + button in the top right corner and the following screen will be presented:

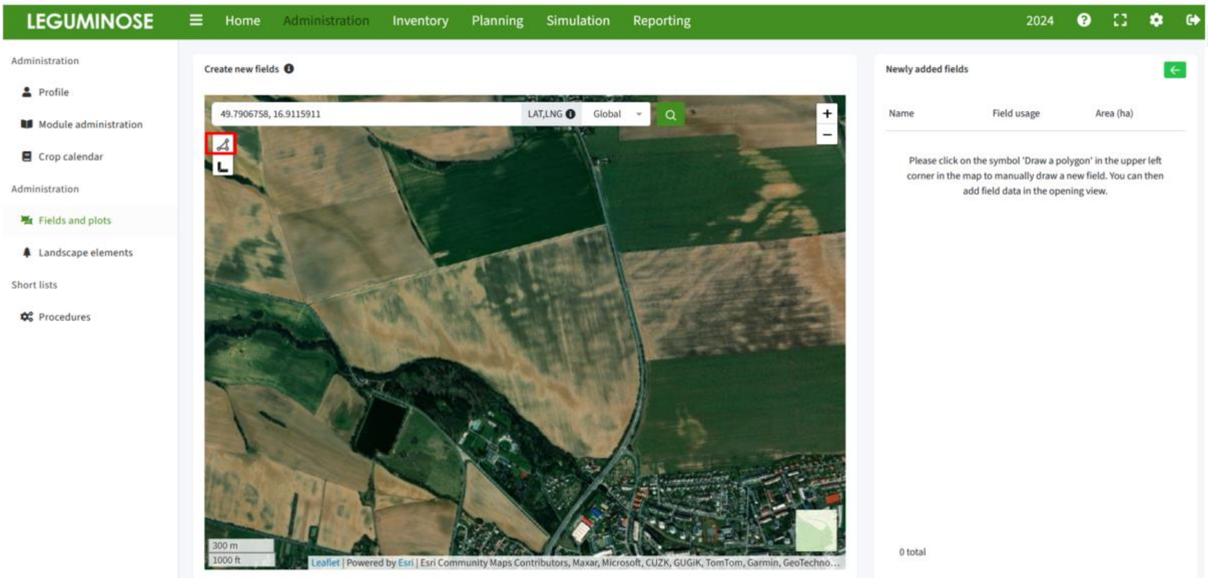


5. Enter the following geocoordinates of the field into the search bar:

49.7906758, 16.9115911

and then press ENTER or click the button. For simplicity, we use decimal degrees for the geocoordinates of the field. However, other formats of coordinates can be chosen (see the icon next to the geocoordinates search bar).

6. Click on the button to switch to the satellite background. You can adjust the zoom factor using the buttons or with the mouse wheel:



7. Click the button, and then click on the vertices of the field. You do not need to be overly precise when setting the vertices, just make sure that the boundaries are reasonably accurate. To finish drawing the polygon, simply click on the first vertex of the polygon again.

8. A form will automatically appear on your screen:

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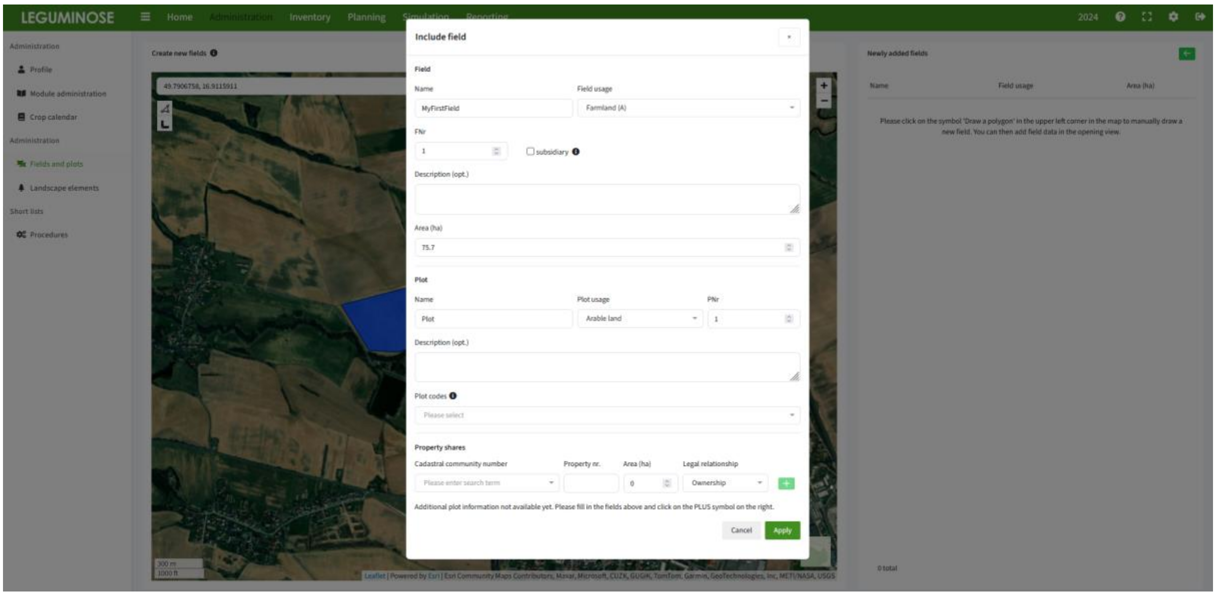
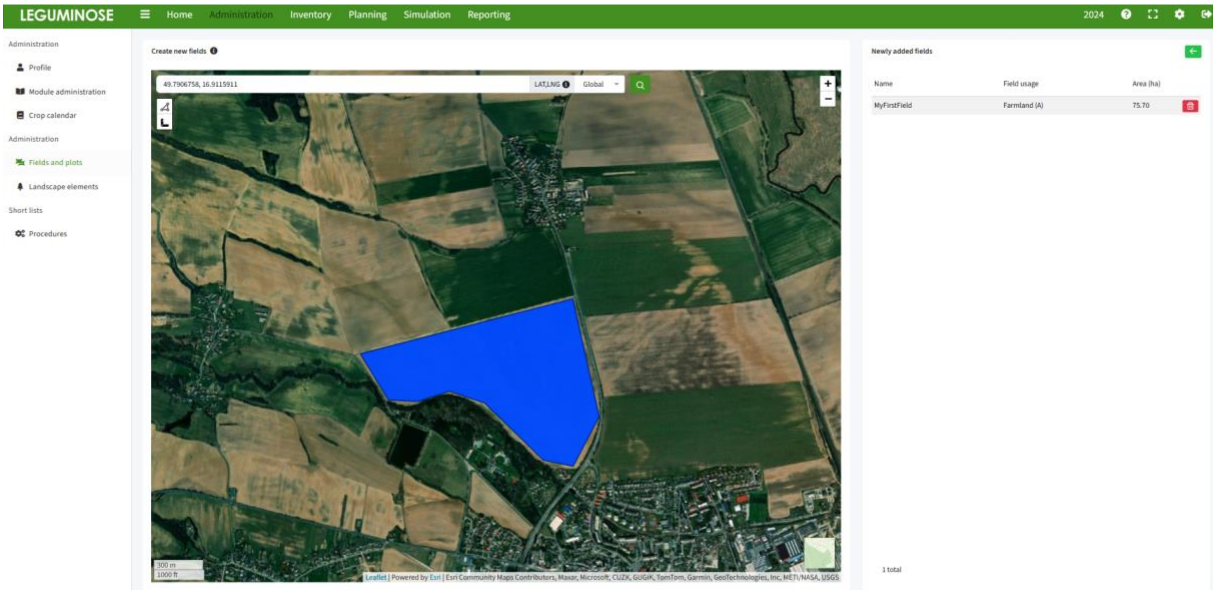


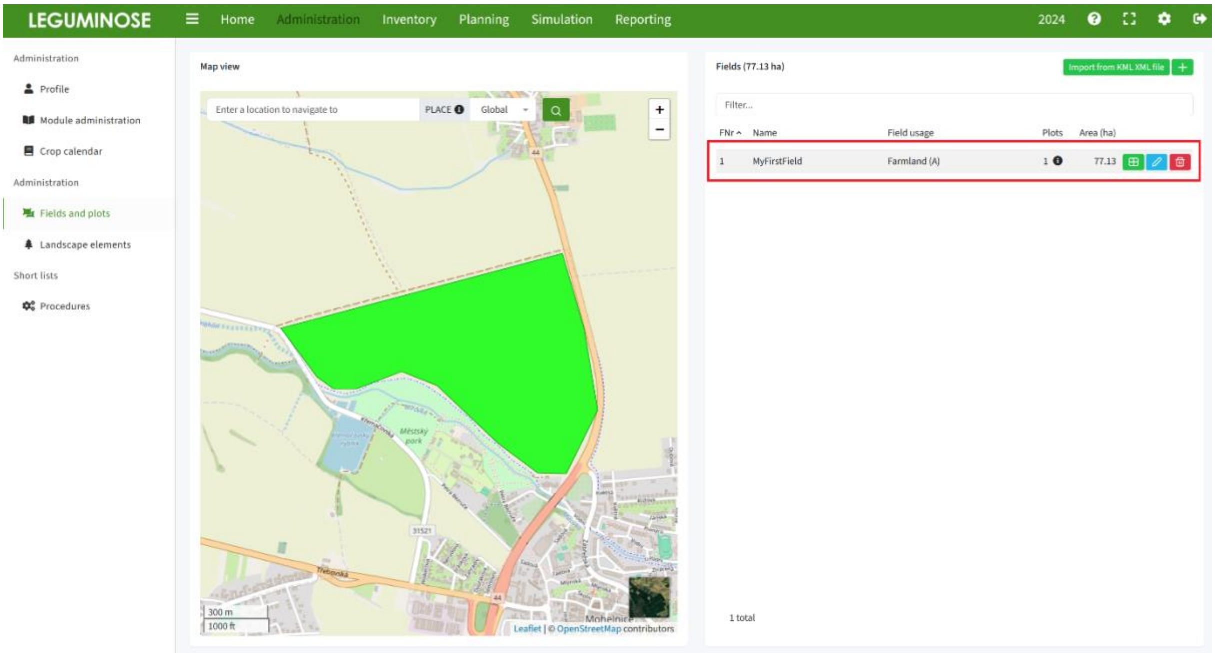
9. Enter all relevant information about your field in the respective boxes (name, field and plot numbers, field and plot usage, etc). The majority of the required fields are preset, only add an appropriate name for the field for this example (e.g. **MyFirstField**).

10. Press the Apply button and DONE! You have created the polygon that identifies the field trial in the Czech Republic:



11. Return to the previous view by clicking on the green arrowed button (**Return to existing fields)** in the top right corner. You can change the field name or any other parameters (except for the geometry) at any time later on by clicking on the blue pencil button. Since each field can be divided into several plots, a default plot with the same size is created automatically for this field. Click on the green grid button to enter the plot view of the field, if you want to change the plot details.

12. Alright! You have correctly created your field in the LEGUMINOSE web-based platform.



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3 Steps for running a simulation

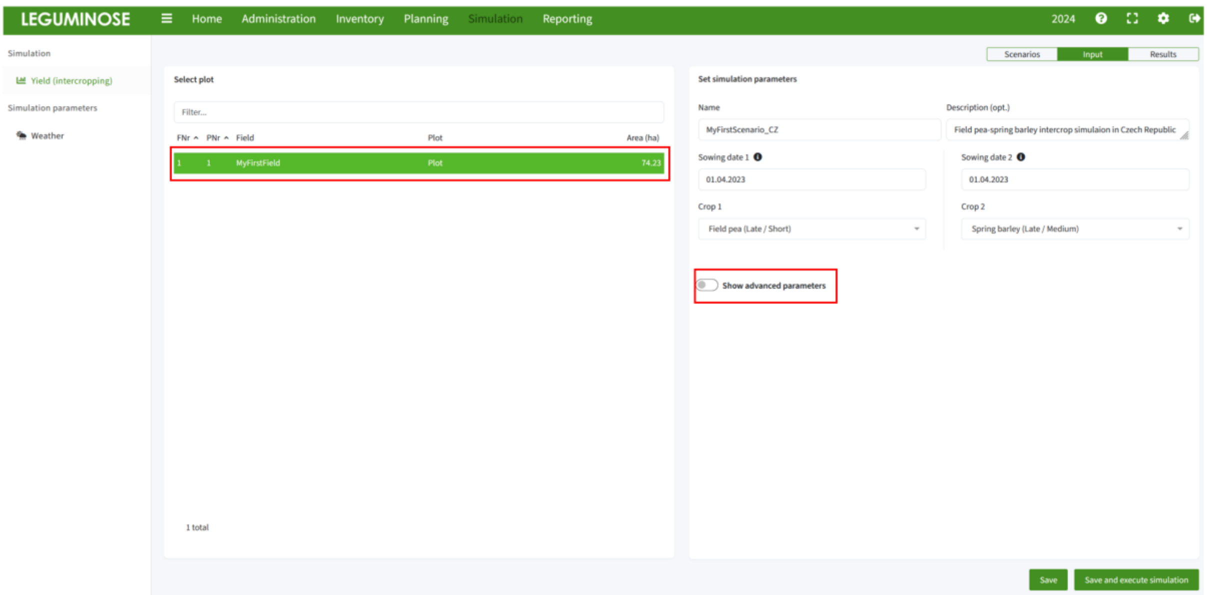
Once the field location is set, we can continue with the setup of the actual simulation scenarios.

3.1 Exercise 1: A basic intercropping simulation scenario

Now that you have created a polygon to identify your field (called **MyFirstField**), let's set up a scenario which will be used for running your first simulation on the LEGUMINOSE web-based platform.

1. In order to create our first scenario, select the **Simulation** view by clicking on the corresponding link in the top nav bar and then click the + button. A window will automatically pop up in your screen.
2. Enter the name **MyFirstScenario_CZ** of the scenario. If you like, you can also add an optional description.
3. Click the Create button and you are **DONE!** Your first scenario was created and selected. You can return to the list of scenarios if you click on the **Scenarios** link in the top right corner. If you want to again select the scenario, click the ✓ button.

Let's investigate the input parameters for this newly created scenario:



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1. On the left, select the plot of interest by clicking on the name of the field you have created (**MyFirstField**). The selected plot will be displayed in green.

2. In the **Set simulation parameters** menu on the right, note that the system has created the simulation scenario with the following default settings:

   - Sowing date 1: 01.04.2023
   - Sowing date 2: 01.04.2023
   - Crop 1 (maturity / max plant height): Field pea (Late / Short)
   - Crop 2 (maturity / max plant height): Spring barley (Late / Medium)

   These parameters are sufficient to quickly get started with the intercropping simulation. The system provides feedback when any of these parameters are invalid, e.g. when the sowing dates' years do not match or when two legumes are selected (one legume and one non-legume crops are required). For now, let's keep the default settings.

However, the LEGUMINOSE web-based platform supports modifying more advanced parameters when required. Click on the **Show advanced parameters** switcher to display the advanced parameters. It will show the following options:

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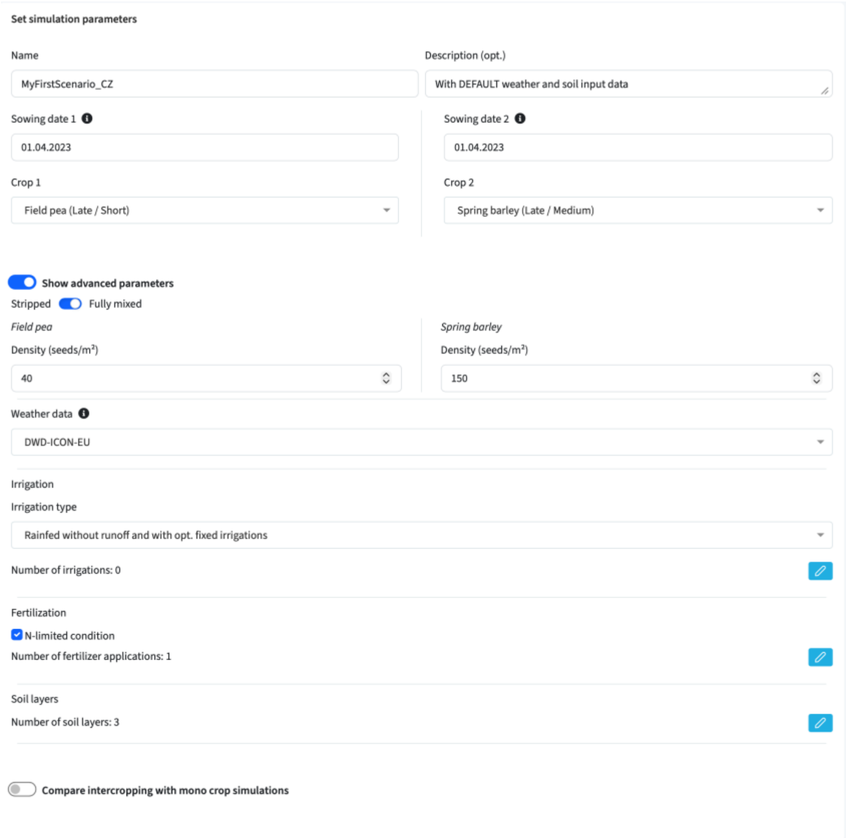

Intercropping design: This switcher determines the mode between stripped and fully mixed intercropping. Either mode requires its own set of parameters. Leave the switch button on the **Fully mixed** for now. You can see the default values for seeding densities which need to be set separately for each crop (in seeds/m^2):

- Field pea: 40
- Spring barley: 150

Weather data: The simulation engine requires daily weather data (min/max temperature, precipitation, solar radiation) for the whole simulation period. The system supports either field-location-based default weather data or custom uploaded datasets. For this example, the weather dataset for running this simulation will be automatically taken from the German Weather Service (DWD) based on the field location. Earliest available weather data from DWD in the system is 2019.

Irrigation: For advanced simulations, the simulation model supports explicitly setting application day-based irrigations. Do not change anything for now (leave as default).

Fertilization: Similar to irrigation, we can also set fertilizations at a day-basis. The default scenario does not include any fertilization applications, so let's create one:

1. Make sure that the N-limited condition box is activated (☑ N-limited condition)
2. Click the edit button ( ), and then a window will pop up on your screen:

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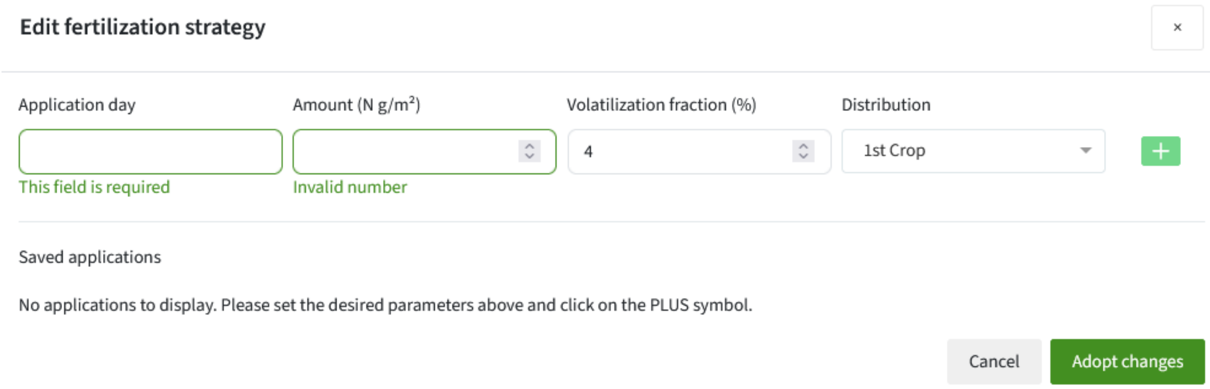

3. An N fertilization rate of 30 kg N ha^{-1} has to be applied one day before the sowing date (i.e., **31.03.2023**).

   ATTENTION! The system requires that the amount of N rate is defined in g N m^{-2}. As farmers usually define their N fertilization rates in kg N ha^{-1}**, it must be converted** (in this case, dividing by 10, i.e. **3 g N m^{-2}**).

4. Do not change the default volatilization fraction (4%).

5. Set the distribution of N to **Both**, since we want to simulate a fully mixed intercropping system.

6. Click the + button to save the N application just entered for the specific date, N rate, volatilization fraction and distribution settings.

7. If any mistake was done here, the unwanted application can be deleted (using the button).

8. Make sure that you **ONLY** have a single application with the correct date and amount shown in the **Saved applications** area. Your N management box should be as follows:

9. Save the changes you have made, by pressing the Adopt changes button.

Soil layers: The simulation model requires detailed soil data to correctly simulate the processes of daily and cumulated water and nitrogen uptake by the plants. Since detailed soil data is often hard to come by, the system automatically creates three soil layers based on the geographic location of the field-of-interest by relying on gridded ESDAC soil data. For this example, keep the default selections as follows:

1. The default soil profile is 90 cm deep and divided into 3 layers of 30 cm each.
2. The default value for initial soil plant available water is 2/3 of the total plant available water in the profile.
3. And the default value of initial soil mineral N is 60 kg N ha^{-1}.

After you have inspected all the information for running an intercrop simulation, simply click the Save and execute simulation button. The system executes the simulation run after which the following charts will be displayed on your screen, displaying a set of key indicators for the simulation run:

Hovering over the points in the line charts or over the bars displays the exact values. Clicking the zoom button in the top-right corner enlarges the chart; clicking it again returns you to the overview view.

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3.2 Exercise 2: An intercropping simulation using measured data

Now, you will create a simulation for the same field already created (**MyFirstField**). In addition to the field location, field measurements of soil properties and weather records from a nearby ground weather station are used.

Create a new scenario by copying the settings from the scenario created above:

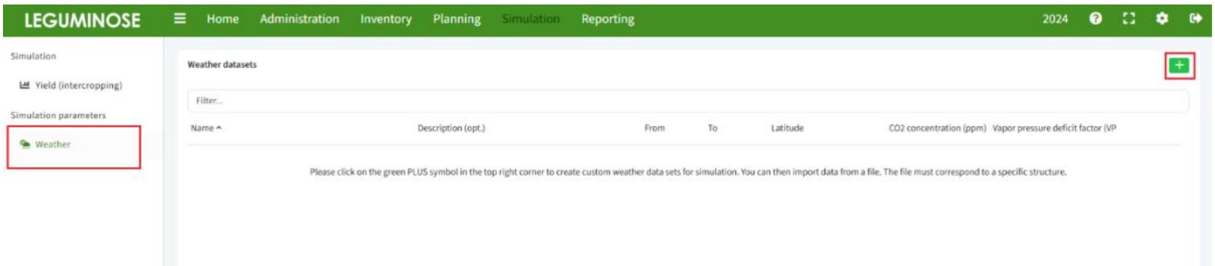
1. Click on **Scenarios** to switch the view to the scenarios list or click on **Simulation** in the top nav bar if you have navigated to somewhere else in the web app.

2. Click on the button to copy the scenario already created (**MyFirstScenario_CZ**).

3. Name the new scenario as **MySecondScenario_CZ.**

Now, let's upload a custom weather data set:

1. Press Weather on the left to navigate to the custom weather view.



2. Click the button. A box will pop up in your screen and you need to enter the following information:
   - Name of your weather dataset: **Weather_CZ_Exercise2**
   - Latitude: **49.7906758**

   If you like, you can also add an optional description. Leave CO2 concentration and Vapor pressure deficit factors at their default values.

3. You should now see a screen like this:

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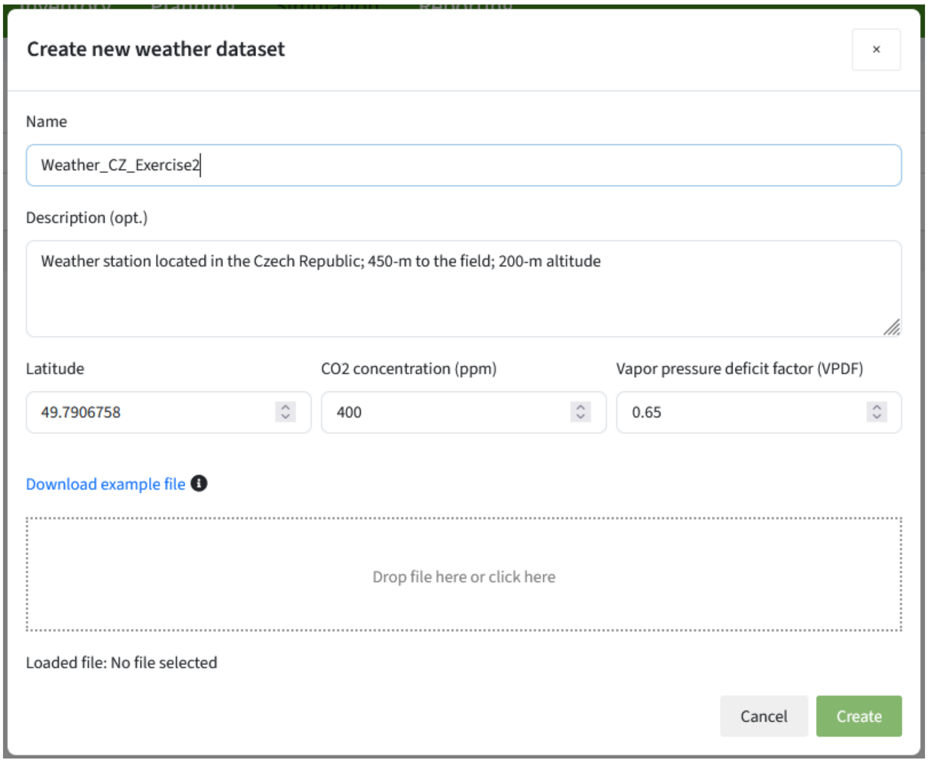

4. You have been provided with an example weather file **MyWeather_CZ_Exercise2.csv** for upload. The file contains the following data points per rows (day):
   - Year
   - Day of Year (1 to 365 or 366, in the leap years)
   - Solar radiation (MJ m^{-2} d^{-1})
   - Maximum air temperature (°C)
   - Minimum air temperature (°C)
   - Daily rainfall (mm)

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```
Year;Day of Year;Solar radiation (MJ/m²/d);Maximum temperature (°C);Minimum temperature (°C);Daily rainfall (mm)
2023;1;3.45;9.5;1.4;0
2023;2;1.15;8.3;5;0
2023;3;3.73;8.4;-1;0
2023;4;2.93;7.1;-2.8;3.3
2023;5;3.9;10;4.4;0.1
2023;6;0.8;8;3.5;1.8
2023;7;3.65;7.1;2.2;0
2023;8;1.34;6.3;4;0.2
2023;9;1.05;7;3.5;4.6
2023;10;1.97;5.9;-0.4;1.4
2023;11;3.86;5.1;-3.4;3.4
2023;12;4.29;8.6;1.4;2.4
2023;13;0.6;7.2;4.3;5.8
2023;14;4.17;8;1.2;0.1
2023;15;0.68;5.5;2.2;10.5
2023;16;4.25;5.1;-0.6;0.1
2023;17;5.22;5.1;0.6;0.5
2023;18;1.7;3.8;-1;3.2
2023;19;3.18;1.8;-2.4;0
2023;20;4.5;1.8;-5.2;0.5
2023;21;4.17;0.7;-2;2.8
2023;22;1.7;1.4;-1.4;1.3
2023;23;2.74;3.7;-3.9;0
2023;24;2.1;3;0.9;0
2023;25;2.5;2;0.3;0.1
2023;26;2.48;-0.2;-1.6;0.3
```

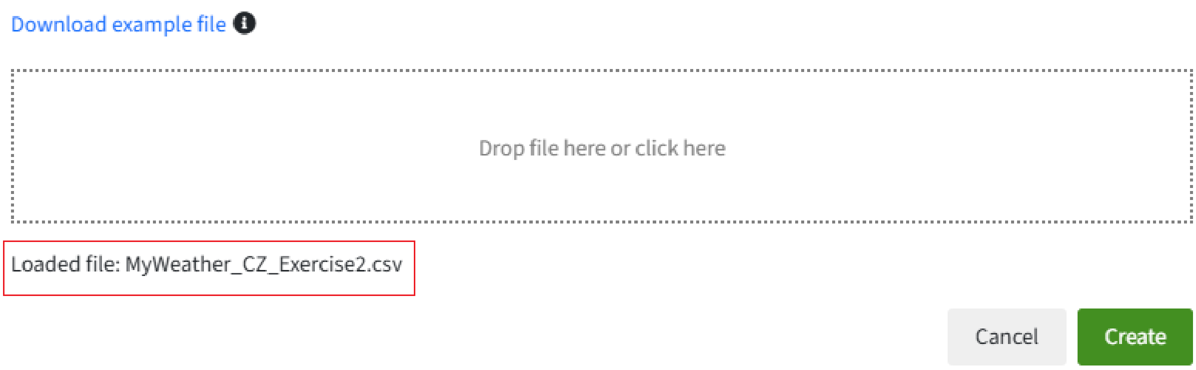
The file covers the whole 2023 year. If you want to use your own custom data, make sure that:

- the file covers the whole simulation range, i.e. starts a few days before the first sowing date or the first irrigation/fertilization date (whichever is earlier) and allows for a reasonably long simulation duration (around 360 days after the simulation start date).
- the data points per line are separated by a **semicolon.**
- Either **coma** or **point** is used as decimal separator.
- No gaps in the provided daily data are existing.

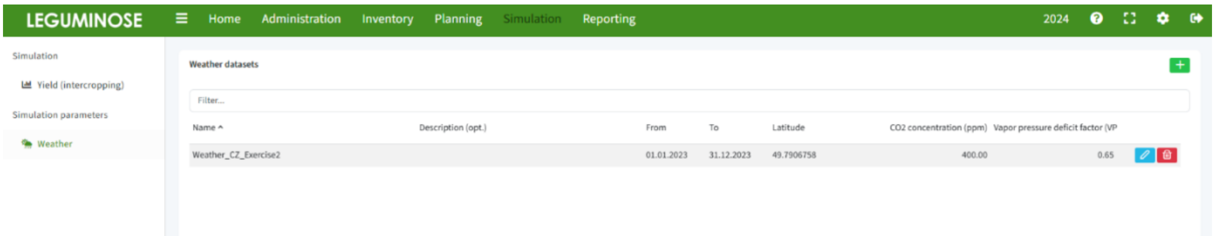
You can also download an example file by clicking on **Download example file**.

5. Now, click on **Drop file here or click here** to open the file explorer, navigate to the file, and open the file. Alternatively, you can also **drag and drop** the file to the drop zone.

6. If you have successfully loaded the file, the file name should be shown as follows:



7. Click on the Create button and you will see your weather station in the list of weather datasets:



Let's navigate back to the simulation scenario and select the weather data:

1. Select the **Yield (intercropping)** view

2. Select the scenario that you created (**MySecondScenario_CZ**) by clicking the button.

3. Select the plot **MyFirstField** if it is not already preselected. The sowing dates, crops and sowing depths should be the same as in the Exercise 1.

4. Activate **Show advanced parameters**.

5. Change the source of weather data by clicking on the drop-down bar of the **Weather data** source and selecting the weather dat that you've uploaded (**Weather_CZ_Exercise2**).

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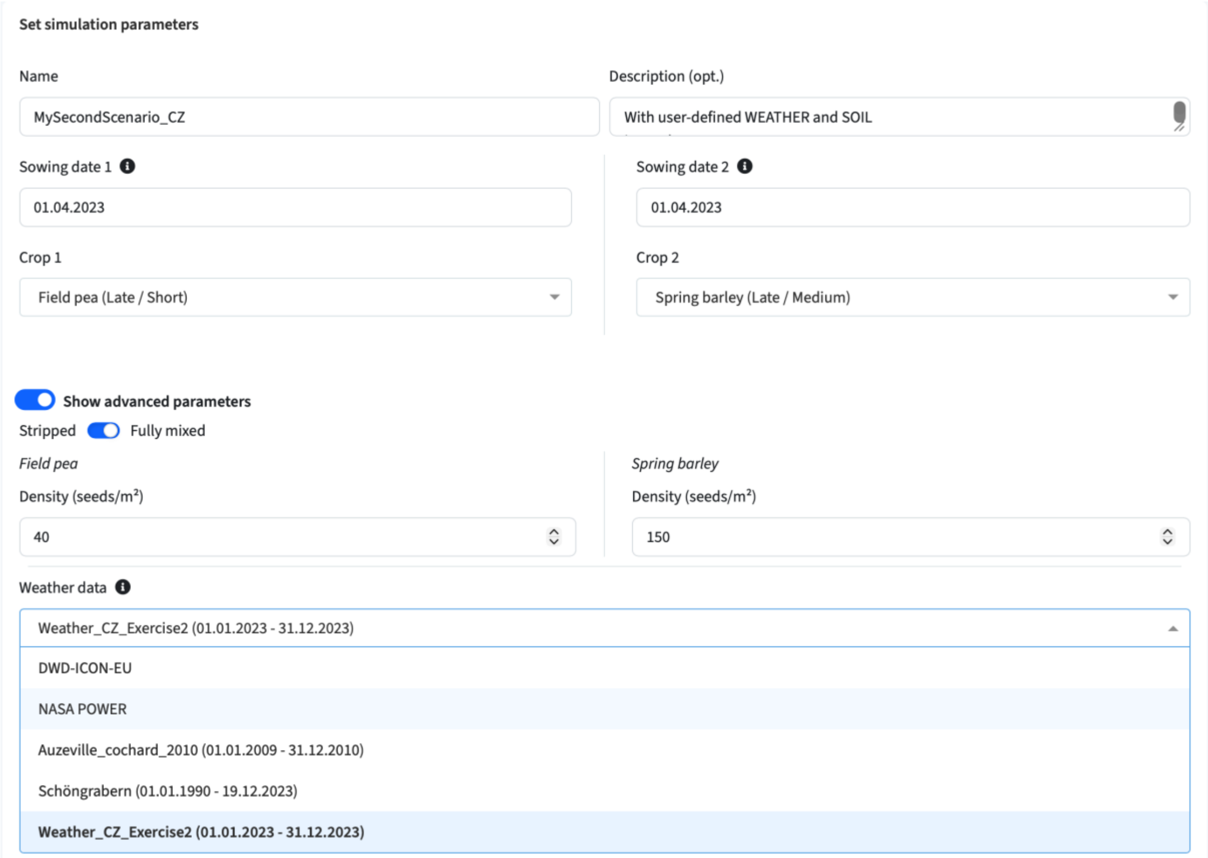
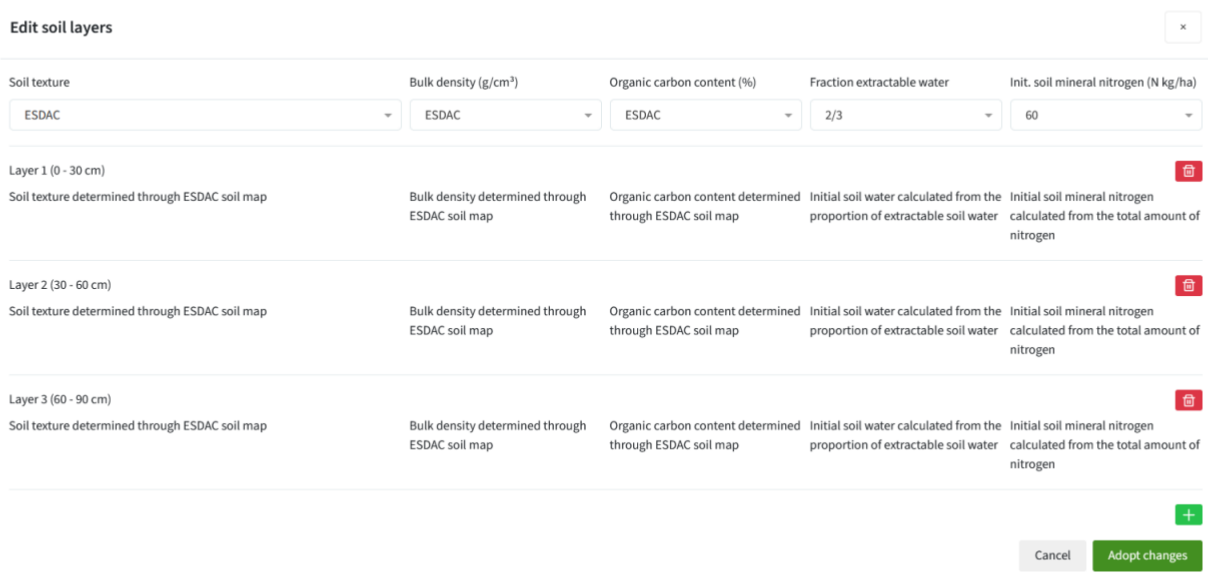


In the next step, let's change the default soil data:

1. Click on the button in the **Soil layers** section. Currently three soil layers are pre-defined with default settings:



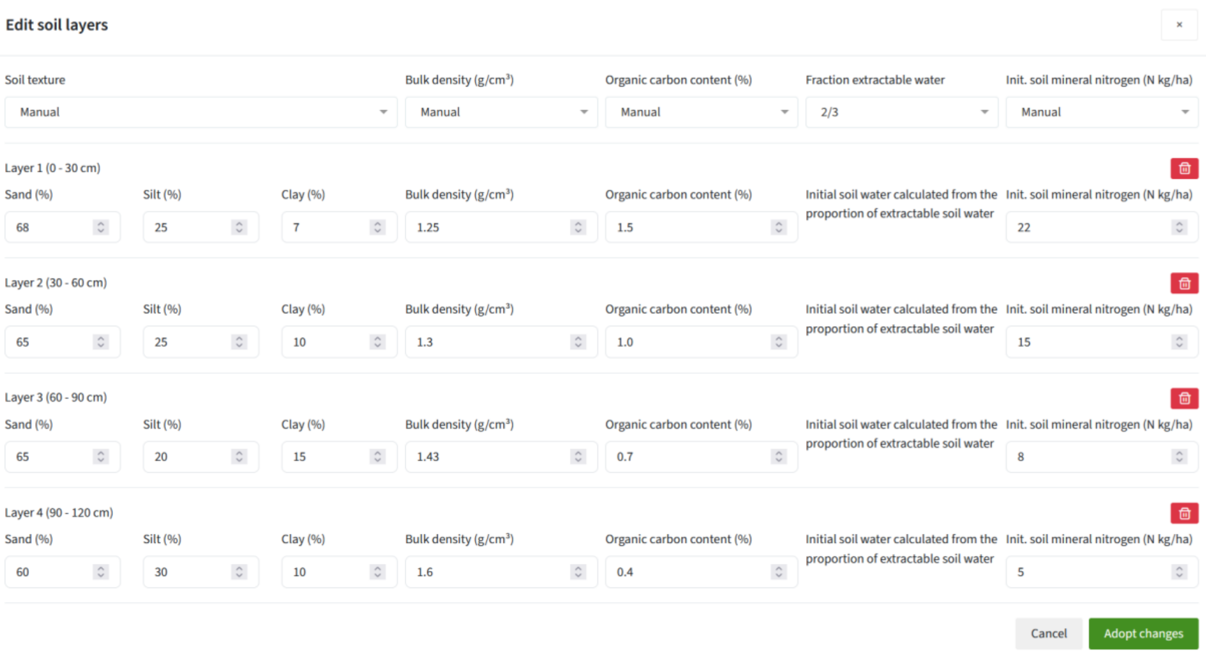
We'll enter the following measured soil data example regarding texture (Sand, Silt and Clay), bulk density (BLD), soil organic carbon (OrgC) and initial mineral nitrogen (Nmin). Note that the system requires organic carbon, if you only have soil organic matter (SOM) available, it needs to be converted to organic carbon first: OrgC = SOM / 2.

Depth (cm)	Sand	Silt	Clay	BLD	OrgC	Nmin
	%			g cm^{-3}	%	(kg N ha^{-1})
0 - 30	**68**	**25**	**7**	**1.25**	**1.5**	**22**
30 - 60	**65**	**25**	**10**	**1.30**	**1.0**	**15**
60 - 90	**65**	**20**	**15**	**1.43**	**0.7**	**8**
90 - 120	**60**	**30**	**10**	**1.60**	**0.4**	**5**

2. Click on the + button to add another soil layer.

3. Click the drop-down bars (on top) for all parameters (except Fraction extractable water) and select **Manual**.

4. Enter the soil information for **Soil texture**, **Bulk density**, **Organic carbon content** and **Init. soil mineral nitrogen** in their respective boxes and layers. Leave **Fraction extractable water** at their initial settings. You should now see a screen like this:



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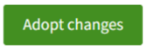
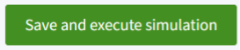
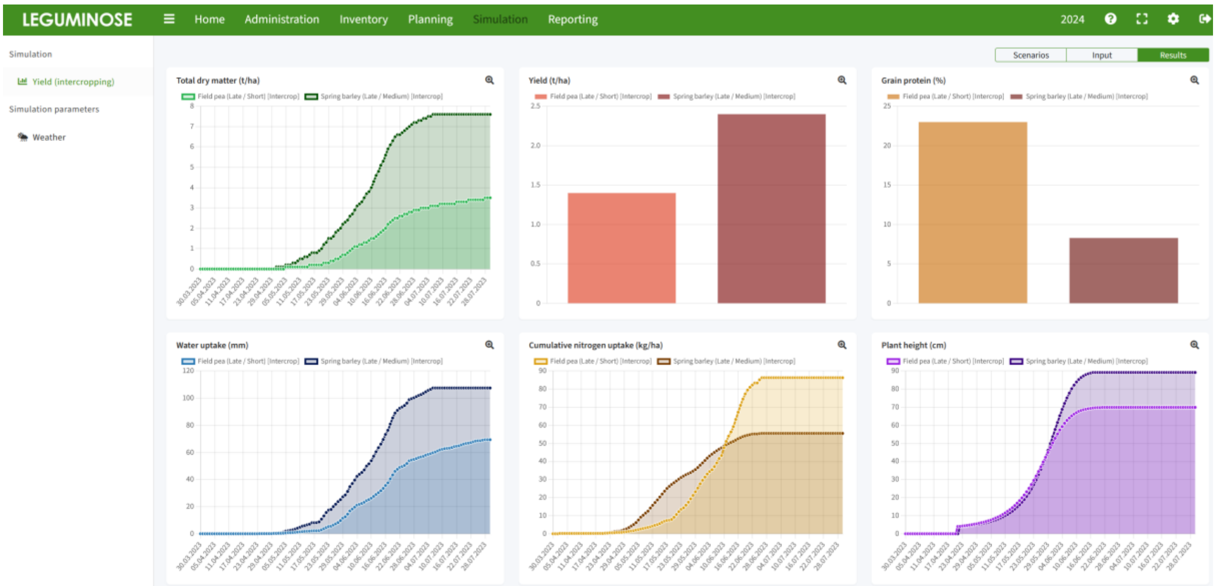
5. Click 

to save your entered soil information.

6. After you have entered all the information for running a simulation, simply click the 

button to execute the simulation with the custom weather and soil data:



7. As in the Exercise 1, the you can examine the data of a specific chart more closely by using the zoom button (🔍).

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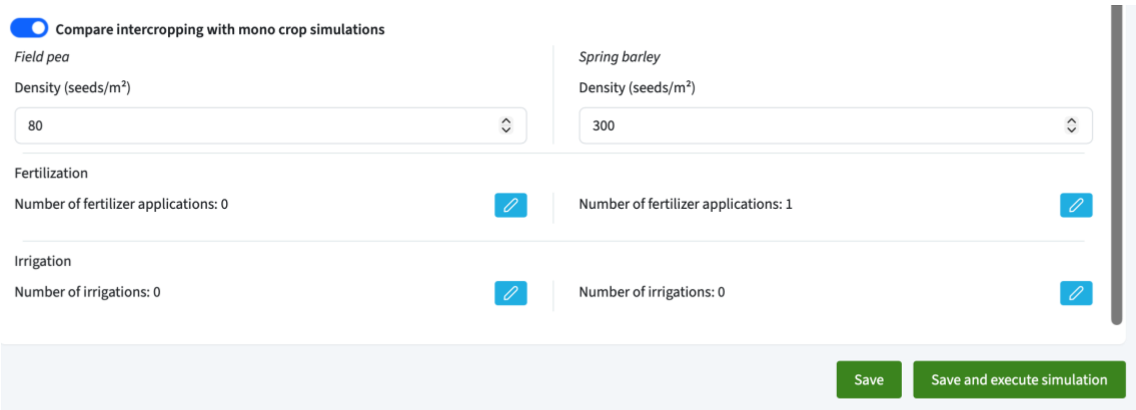
3.3 Exercise 3: Comparing the performance of monocrop versus intercrop

In this exercise, you will be guided on how to compare the results of intercropping simulation with a similar monocrop simulation. The monocrop simulation is conducted with the same crop and sowing selection, but requires some additional monocrop-specific parameters. Let's use the first scenario we have created as example:

1. Switch to the **Input** view if you are in the **Results** view or select **Simulation** in the top nav bar and load the **MyFirstScenario_CZ** scenario by clicking on the corresponding scenario-loading button.

2. In the **Input** view, make sure on the right side that the **Show advanced parameters** switcher is active.

3. Now scroll down and you should see another switch button **Compare intercropping with mono crop simulations**. Click to display the monocrop-specific parameters:



4. Since monocrop seed densities are usually different to intercropping densities, we can specifically set the monocrop values here. Let's leave the values at their default values.

5. In addition to monocrop-specific seed densities, we can also define separate crop-specific fertilizer applications and irrigations for monocrop. The method is the same with intercropping, click on the blue edit button, set the desired application date and amount, add to the list, and adopt the changes. Let's add a **3 g/m2** applied at **31.3.2023 only for spring barley**, by clicking on the button in the right section for spring barley next to **Number of fertilizer applications:**

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6. All other parameters like selected weather data and soil parameters are used for both intercropping and monocrop simulations.

7. Now click on **Save and execute simulation** to run the simulations for monocrop and intercropping. The system now takes both intercropping and monocrop parameters into account and executes multiple simulation runs. When the simulations are finished, the results of both intercropping and monocrop simulations are shown in the charts. You can see two additional lines and bars for the corresponding key indicators. If you want to declutter the view (e.g. if you want to specifically compare the first crop in intercropping and monocrop operation), click on the colored boxes (or the crop names) in the legend above the lines/bars to activate or deactivate individual lines/bars. Note that the yield bars for monocrops are naturally higher than the intercropping bars because the available field space is shared between the crops in the intercropping scenario and thus cannot achieve the high yields of monocrops.

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This concludes the demo of intercropping simulation using the LEGUMINOSE web-based platform. Feel free to experiment with different parameters in the **Input** view to check out their influence. Should you enter invalid parameter combinations, the system will provide you with feedback on how to fix the issues. Also, you can hover with the mouse cursor over the info symbols to display additional information if required.

In general, simulation runs are highly sensitive to available weather data and soil properties and might be inaccurate if weather and soil data is inaccurate. For example, if the expected simulation period is exceeding the available weather data, DWD weather data includes short-term forecasts (6 days). Since accurate longer-term forecasts are unavailable, the system extends the required weather data with averaged data from the past years, i.e. if the expected harvest date is far into the future, the results are expected to be quite inaccurate. When the current day reaches the expected harvest day, the results gradually will become more accurate due to the availability of historical data. The most accurate results will be achieved with a full set of custom weather data from a weather station and a complete set of soil data measurements entered into the system.

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