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1 Overview

The intermediate report discusses the status of the field studies, provides a description of the collected data sets and suggests amendments to the evaluation protocols.

The details of the experimental protocols are available in deliverable D7.1.

The following section discusses the field studies that were performed at Chatelain. Then comes a description of the studies by Iaac at Valldaura and Chatelain. Finally, we close off with some thoughts about the field studies for next year.

1.1 Partners involved

Leader: Chatelain

Participants: Iaac, Sony CSL

1.2 Relation with other work packages and tasks

- **WP2**: development and testing of the LettuceThink rover
- **WP3**: development and testing of the aerial robot.
- **WP4 and WP5**: algorithms and adaptive techniques for outdoor plant scanning.
- **WP8**: demonstrations

1.3 Dissemination / IPR policy

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2 Studies at Chatelain, by Chatelain & Sony

The main studies that are presented below are 1) the evaluation of the impact of the number of passages of the robot on the weed population, 2) whether or not the weeding stimulates or inhibits the germination of weeds, and 3) the effect of weeds on the productivity.

For all the experiments the following data was extracted from the field:

- pictures taken with the camera on the robot. During the analysis of the pictures, the PLA (plant leaf area) was measured, giving indications on plant growth on the zones for each case scenario.
- number of weeds counted twice a week, indicating the number of germinated weeds on each case scenario.

2.1 Evaluation of the weeding frequency

For a more detailed description of this experiment, please see D7.1, section 2.4.
**Purpose:** Find the more efficient frequency of weeding done by the robot in order to keep crop bed cleans.

**Summary of the information extracted:**
- Sorted pictures
- Graphs that shows the evolution of
  - the plant leaf area (measured out in the pictures)
  - the evolution of the number of weed germination
- With those 2 informations: how many weeds the robot took out and how many weeds remained.
- We can see that weeds are more developed in the tunnels that in open field.
- When comparing the plant leaf area on the pictures, we can say that
  - there is not an important difference of weed development for the frequencies two time a week and one time a week
  - the amount of weeds in the zone weeded one time a week is quite low.
- We can conclude that in the tunnels and in open field, the frequency of one weeding per week is sufficient: the crop bed is clean and with this frequency the robot will be able to cover a larger area in the farm.

**Results**

The images below give an idea of the pictures taken by the LettuceThink robot.

*Picture name: chat_I1-13_f-0x-1_20180416-205724_before*
In addition to these images, we counted the number of weeds manually. The data was processed as follows:

- The number of weeds was averaged between the 3 zones dedicated to a given weeding frequency. This average was plotted against the time for each of the weeding frequencies. The resulting graph can be seen below (F1x means weeding was done once a week, F2x twice a week, F05x once every two weeks, F0x no weeding at all).
For each zone, images of subsequent passages were first aligned manually, then cropped, and finally the projected leaf area (PLA) was estimated using segmentation based on the color index for each of them.

The PLA was averaged between the 3 zones dedicated to a given weeding frequency. This average was plotted against the time for each of the weeding frequencies.

The resulting graph can be seen below.

The images of the zones were also assembled in a matrix-like representation for quick visual inspection. This result is shown below:
All the data here (visuals and graphs) presented come from the experiment done in April inside the greenhouse.

**Conclusion**

From these experiments in the greenhouse, we can conclude that weeding with the robot once every week allows for a clean crop bed.

### 2.2 Evaluating the impact of the weeding on the germination

For a more detailed description of this experiment, please see D7.1, section 2.5.

**Purpose:** find out if the robot activates or inhibits weed germination and if it depends on the soil structure.

**Information collected:**
- Sorted pictures
- Graphs that show the evolution of:
  - the plant leaf area (measured out in the pictures)
  - the evolution of the number of weed germination

Using those two pieces of informations, can we gain insights in how the weeds germinate after the robot worked the soil?

**Results**

The data was processed as followed.
- The number of weeds was averaged between the 3 zones dedicated to a given weeding and soil type case. This average was plotted against the time for each of the weeding and soil type case.
For each zone, images of subsequent passages were first aligned manually, then cropped, and finally the projected leaf area (PLA) was calculated for each of them. The PLA was averaged between the 3 zones dedicated to a given weeding and soil type case. This average was plotted against the time for each of weeding and soil type cases. The resulting graph can be seen below.
The images of the zones were also assembled in a matrix-like representation for quick visual inspection. This result is shown below:

### Inside

<table>
<thead>
<tr>
<th>Date</th>
<th>19/04</th>
<th>23/04</th>
<th>27/04</th>
<th>30/04</th>
<th>03/05</th>
<th>07/05</th>
<th>10/05</th>
<th>14/05</th>
<th>17/05</th>
</tr>
</thead>
</table>

Calendar presenting pictures of the germination test zones

### Outside

<table>
<thead>
<tr>
<th>Date</th>
<th>19/04</th>
<th>23/04</th>
<th>27/04</th>
<th>30/04</th>
<th>03/05</th>
<th>07/05</th>
<th>10/05</th>
<th>14/05</th>
<th>17/05</th>
</tr>
</thead>
</table>

Calendar presenting pictures of the germination test zones

**Conclusion**

We can see that weeds are more developed in the tunnels than in open field. The number of weeds and the PLA are correlated.

When comparing the evolution of weeds in the different soil structure and weeding status we can say that

- in a sandy soil (Sx and Sp) the robot inhibits the weed germination (outside and inside)
- in a clay soil (Lx and Lp) the robot activates the weed germination. But even if the results are quite conclusive in the greenhouse scenario, in open field, the difference is not significant.

We will probably have to do those experiments again next year.
After the experiments of last year, we supposed that weather had an impact on weed germination, more specifically, we thought that water availability had an impact. Unfortunately, the fields conditions did not allow us to control that parameter and to draw conclusions about this.

2.3 Weed test: impact of the weeds on plants (carrots) germination and development

For a more detailed description of this experiment, please see D7.1, section 2.7.

**Purpose:** Evaluate the impact of weeds on the productivity: to what extend the weeds affect the growth and the harvest of the crop.

**Results**

The summary of the results is shown in the table below:

<table>
<thead>
<tr>
<th></th>
<th>Non-weeded areas</th>
<th>Weeded areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of carrots</td>
<td>88</td>
<td>86</td>
</tr>
<tr>
<td>Average weight (in kg)</td>
<td>0,96</td>
<td>3,68</td>
</tr>
</tbody>
</table>

The details for each zone can be found in the tables below:

<table>
<thead>
<tr>
<th>Areas that were weeded</th>
<th>Number of area</th>
<th>Number of carrots</th>
<th>Total weight (in kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>73</td>
<td>2,15</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>67</td>
<td>2,7</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>106</td>
<td>5,1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>80</td>
<td>3,95</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>92</td>
<td>3,95</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>95</td>
<td>4,8</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>87</td>
<td>4,30</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>77</td>
<td>4,20</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>80</td>
<td>4,40</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>90</td>
<td>3,05</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>100</td>
<td>1,9</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>86</strong></td>
<td></td>
<td><strong>3,68</strong></td>
</tr>
</tbody>
</table>
### Areas that were not weeded

<table>
<thead>
<tr>
<th>Number of area</th>
<th>Number of carrots</th>
<th>Total weight (in kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>96</td>
<td>1.1</td>
</tr>
<tr>
<td>13</td>
<td>89</td>
<td>1.2</td>
</tr>
<tr>
<td>14</td>
<td>74</td>
<td>1.20</td>
</tr>
<tr>
<td>15</td>
<td>68</td>
<td>1.05</td>
</tr>
<tr>
<td>16</td>
<td>98</td>
<td>1.05</td>
</tr>
<tr>
<td>17</td>
<td>105</td>
<td>1.3</td>
</tr>
<tr>
<td>18</td>
<td>76</td>
<td>0.65</td>
</tr>
<tr>
<td>19</td>
<td>89</td>
<td>0.65</td>
</tr>
<tr>
<td>20</td>
<td>64</td>
<td>0.4</td>
</tr>
<tr>
<td>21</td>
<td>96</td>
<td>0.8</td>
</tr>
<tr>
<td>22</td>
<td>96</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>105</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>86</strong></td>
<td><strong>0.94</strong></td>
</tr>
</tbody>
</table>

### Observations

When harvested, the carrots that grew in the areas without weeding were really smaller. A video showing the difference between the two zones is available [here](#).
**Conclusions**

When we compare the weight of the carrots in both areas, we can clearly see that weeds decrease the yield: carrots are smaller in the second area (without weeding): the roots and the vegetative parts are not as developed as the carrots where weeding was done. The weeds have a negative impact on the crop yield: on average 3.68 kg in the weeded areas versus 0.94 kg in the non-weeded areas (a factor of 3.9).

We can see that the number of carrots in every small area was nearly the same with and without weeding. The weeds didn’t seem to disturb the germination.

**2.4 Conclusion and next steps**

The experimental layout will be extended to cover more crop types and more planting configurations, to match usual conditions in market farms.

It is necessary to repeat some of the tests during the second year with other species (radishes do not need weeding) and less ideal conditions (radishes are normally grown densely packed).

For example:

- Instead of radishes, perform the test on cabbages
- No more “no-weeding” scenario because it is difficult to manage and because the experiments of the first year are quite conclusive.
- Combination of the robot with a cablebot to facilitate observations at regular time intervals.

It would also be interesting to perform the same tests on a real sandy soil: clay soil amended with sand cannot give results comparable to those of sandy soil.

**Limits and issues:**

- Problems with pictures: dates were wrong, pictures upside down, some are missing, apriltags are sometimes difficult to read (the software was not able to pick them out in pictures: leaves covering, to much sun and reflective tape)
  
  Because of these shortcomings a lot of work has been done before the analysis:
  - find, sort and order pictures by dates
  - find a way to crop efficiently the pictures (always the same area or move with the robot)

**What’s left to do:**

- Find a more efficient way to extract and to crop the images.
- Set up new experiments to show farmers that the robot is improving their productivity.

3 Studies at Valldaura and Chatelain, by Iaac

3.1 Overview of the experimental protocols

This section outlines how data acquisition setups are have been so far applied to the research gardens described in document **D7.1** and provides an overview of the potentials and methods for meaningful interpretation and further analysis of the data. At this stage several drone flights and scans have been made over the gardens and a number of images, 3D point clouds have been produced. The details relating to these scans are detailed in section **D3.1**. Records and templates have been setup to reference the data alongside existing field studies. In this way indicators from a farming perspective outlined in **D7.1** may be matched to data recorded in the scans. A list of flights and data types are recorded here: **Annex: Scans and Data Types**.

![Image 1: Scans and Data Types](image1.png)
Some test flights for image data collection (2D and 3D) have been performed using the drones at varied heights over research gardens. The links below allow you to visualise some of the data online and use tools to make some area and terrain calculations.

<table>
<thead>
<tr>
<th>Session 1</th>
<th>S1 - RGB data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S1 - Normalized Difference Vegetation Index (NDVI)</td>
</tr>
<tr>
<td></td>
<td>S1 - Near infrared (NIR)</td>
</tr>
<tr>
<td>Session 2</td>
<td>S2 - RGB Data</td>
</tr>
<tr>
<td></td>
<td>S2 - Normalised Difference Vegetation Index (NDVI)</td>
</tr>
<tr>
<td></td>
<td>S2 - Near infrared (NIR)</td>
</tr>
</tbody>
</table>

**Image 2: Example of the drone scan with NDVI data of the horticulture garden.**

Although still being compiled, two datasets types have been created to record crop and field cultivars, make observations and extrapolate relations with new information derived from scanning data. A Geographic Information System had been setup to overlay, map and visualize that data with reference to geolocations. Data acquisition in this first year primarily relates to the integration of current methods and common practices used by farming professionals in the Micro Farm market to understand and gauge their efficiency.
3.2 : General Observations Records and Identifiers

A general database that compiles and relates field observations with scan and image data has been started. As well as providing a record of test results, comparative analyses can be made between relevant datasets. Although at an early stage this document will become a resource also for gathering other sensor data. Some sensor kits that are already deployed at Valldaura are listed below.

**Soil Testing:**
A recent soil test was conducted by EuroFins\(^1\) which contained varied data analysis. And also by the Parrot sensor supplied by the Grow Observatory. A deep soil analysis kit is provided by Open Vino.

**Microclimate Analysis:**
Smart Citizen Kit \(^2\) produces calibrated air quality data. Weather station offered by Open Vino \(^3\) Barometric Pressure offered by GNSS / GPS Bad Elf \(^4\) AgriWeather Micro-Climat analysis \(^5\)

---

### Flight Name | Zone | Month | Week | Scan Image | Test Number | Analytical Aspect | Existing Factor Needs | Observation / Result | Analytical Aspect | Records and Notation | Observation / Result
---|---|---|---|---|---|---|---|---|---|---|---

**Image 3 : Research Gardens and records**

---

**Annex : WP7 Research Gardens and Records**

3.3 : Cultivars and Species Identifiers:

Each Research garden has an associated list of cultivars that are either planted or are found as native species. These species have particular features and attributes and development stages that may be referenced or become useful at any stage of future research.

**R1 Cultivars and Study Attributes**
**R3 : Cultivars and Study Attributes**
**R4 : Cultivars and Study Attributes**
**R6 Species and attributes**

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\(^1\) Soil sample testing by EuroFins
\(^2\) www.smartcitizen.me
\(^3\) www.openvino.org
\(^4\) Costaflores / Robotics
\(^5\) Agri Weather Microclimate Analysis

ROMI - D7.2 - Intermediate report on the field studies
The rotation of the crops between plant beds are diagramatised and plotted using a simplified grid system shown below. A possible future iteration of this notation graphic plot may become the basis of an interactive smart phone app or similar interface for simple observations or in field note taking. At this stage the ‘crop plotter’ acts as a simplified reference tool.
3.4 : Mapping and Visualisations

The entire research and all site data can be managed and initially based on a Geographic Information System (GIS). Mapping data can integrate with the information data recorded by the drone, cablebot, rover and from farmers reports, weather reports and other digital markers. Compiling data integrated through QGIS® or another GIS software.

A final step for visualisation of the 3D data scan data with relation geolocation and note overlays has been created by WP2 and WP3 and using Potree, an online WebGL render engine for large point clouds and provides measurement tools for areas, distance and angles. Geolocations are also referenced and elevated profiles can be drawn.
4 Conclusions and next steps

The experimental farming zones have been put to good usage during the first year and allowed the consortium to gather the first datasets and to evaluate the robotics platform.

For the next season, a number of improvements are planned:

1. Both Valldaura and Chatelain will work on the same integrated scenario that combines both the aerial and land-based robot. This will provide datasets that can be compared and duplicates the tests with the robotics platform.
2. We will define more detailed protocols before hand to determine what data will be collected and at what resolution and for what purpose.
3. We will improve the processing pipeline so that the data collection, analysis and visualization can be done more systematically and reliably, and that the data can be made more easily accessible.
4. Further efforts are needed to co-design the tools in collaboration with professional farmers.