# Smart Soybean Production
# Work package 1: Results 2022

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Keywords: *Soybean, Green-on-Green, spot spraying, Fourier analysis, sustainable*.



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# Summary

Work package 1 of the PPS Sustainable Soybean Production is about *Green-on-Green* detection; detecting weeds within a soybean crop. In 2022-2023 green-on-green detection experiments were done with the Rometron WEED-IT sensor, which was originally created for green-on-brown detection (a plant vs a non-plant background like soil or concrete)

Distinction between the crop and a weed is not possible by simple sensor detection (as they are all plants), and therefore has to be based on plant location. Shortly and simply stated, the soybean crop is in the row, and anything outside the crop rows is weed. With this method, weeds in the row cannot be recognized.

A soybean trial was sown in Wageningen, Netherlands in May to collect data for creating the algorithms.
Fourier analysis was done on the sensor signal, and we concluded that Fourier does not work when driving parallel to the crop rows. It does work when driving in an angle respectively to the crop row, as is common practice in Brazil. This is because when driving 'through' the crop rows, we see the rows pass in a regular pattern. If this pattern is regular enough, potentially weeds could be found as they break the pattern.

# Introduction

Within the Smart Soybean project, Work package 1, Green-on-Green weed detection, is about detecting weeds within a soybean field using WEED-IT technology by Rometron. The WEED-IT sensor was originally created to distinguish living plant material on another background, like concrete or soil. Therefore detecting weeds in a crop field is a challenge, but could be very interesting if a possibility is discovered. The reason is that the simple and robust technology behind the WEED-IT sensor is attractive to farmers.

Therefore, distinction will have to be based on plant location. That is, plants that are located outside the plant rows are considered weed, and vice versa: plants in the crop rows are considered crop. This means that weeds in the row are not recognized and therefore this study focuses on weeds between the rows.

In the growing season of 2022-2023, an experiment has been conducted to evaluate the possibility to detect weeds with the WEED-IT sensor.

# 1 Activities in 2022

In 2022, a soybean trial was sown in Wageningen, NL, for Work Package 1, to provide a controlled environment with the crop and the weeds on known locations to test first methods and algorithms for distinguishing the soybean crop from the weeds that are growing around it, with the WEED-IT sensor by Rometron.

To this end, a soybean trial was sown in Wageningen on the 16$^{th}$ of May, 2022. The first measurement with the WEED-IT sensor was done just after germination, on the first of June. Four more measurement days followed, with roughly a week interval between them.

The measurement data and the reference data (consisting of reflective bars indicating where the weeds were located, supported by GoPro videos and photos taken on each measurement day) were then used to analyse the data, find patterns and create an algorithm for weed detection.

# 2 Field Experiments

## 2.1 Field layout

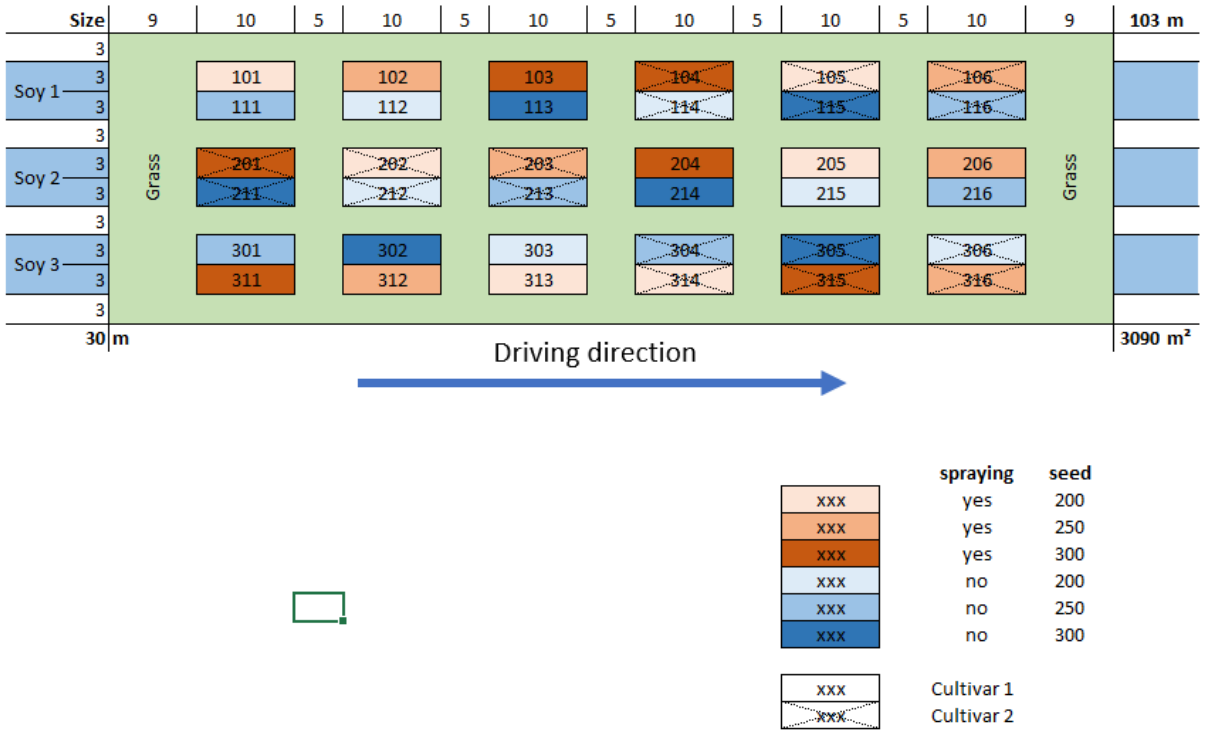


Figure 1: field layout

## 2.2 Crop irregularities

The crop did not emerge very well on all fields. On some plots the soybean crop was very irregular.

The original plan was to spray herbicides before emergence. This was not done due to a mistake by the field team. Therefore spraying happened only after the second measurement day. Especially on the second measurement day there were quite some weeds.

Maize plants were planted in the plots to simulate volunteer maize that is often present in Brazilian soybean fields. There were also lots of volunteer potatoes present in the field.

## 2.3 Measurements

There were five measurement days: 1, 9, 16, 29 June and the 7th of July.

On top of the WEED-IT sensor a GoPro camera was placed, such that we could determine where/ in which channel the weeds were located. The first day the camera was only switched on halfway the measurements, and the third measurement day the camera broke down during the measurements.

Measurements were taken driving parallel with the rows. On the last two measurement days, two fields were measured with a 30-degree angle with respect to the seeding direction of the rows to simulate the situation in Brazil where spraying is usually performed under an angle, and not parallel with the rows.

On July 7th, some tests were done having a run on the same field driving 5 cm aside from the first time. Moreover two heights of the sensor were tested because the height of the canopy was at a transition point between two sensor heights.

# 3 Data analysis

## 3.1 Selection of plots

Based on several requirements, plots were selected for data analysis. The availability of GoPro data was an important one to double-check the presence and location of weeds (as the GoPro videos provided important reference data for algorithm development with the sensor data).
Other requirements for selection were the presence of transplanted 'volunteer' maize in the plot and uniform emergence of the soybean were other requirements.

### 3.1.1 First measurement day

On the first measurement day, the crop had not just emerged and was not well detectible for the WEED-IT sensor. There were also several natural weeds present besides the maize. Mostly volunteer potato plants and couch-grass. Herbicide spraying had not taken place yet due to the communication issue mentioned above.

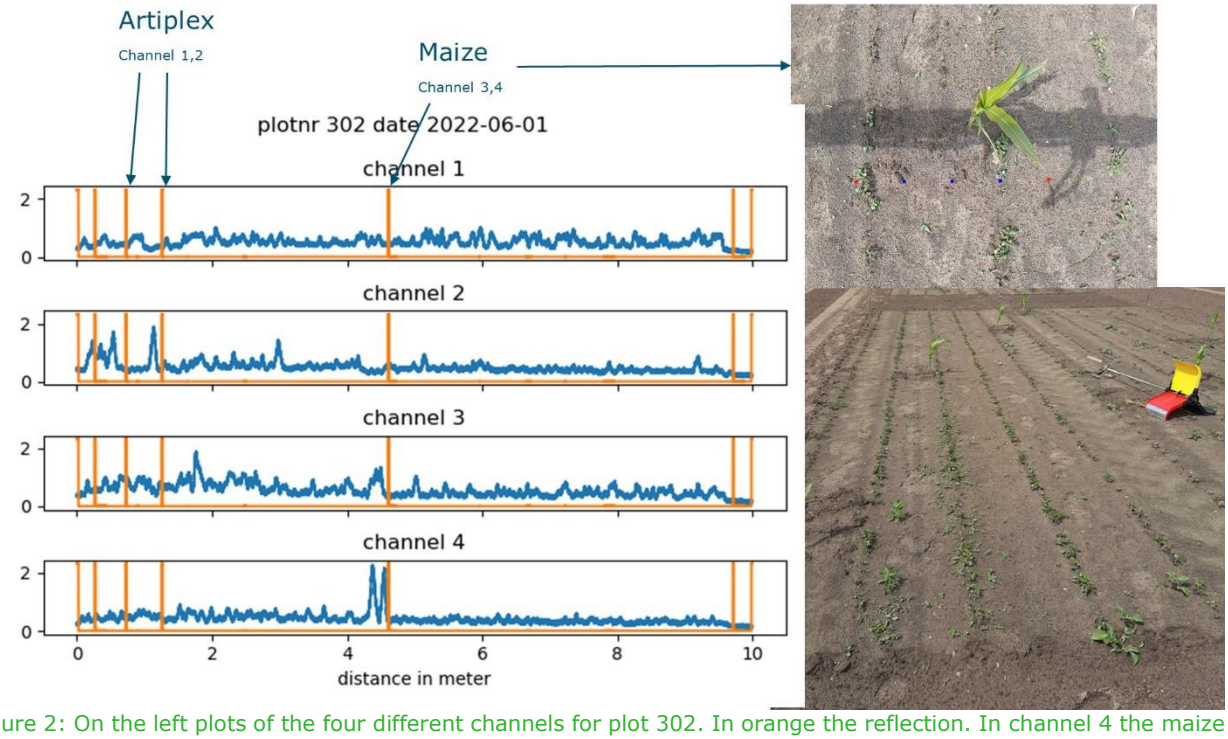


Figure 2: On the left plots of the four different channels for plot 302. In orange the reflection. In channel 4 the maize is clearly visible. On the top right the maize seen from the GoPro. The red dots in the image are the extremes of where the WEED-IT measured. The blue dots partition the measurement area in four equal parts. On the right bottom an overview of the plot. The cop did not emerge fully yet.

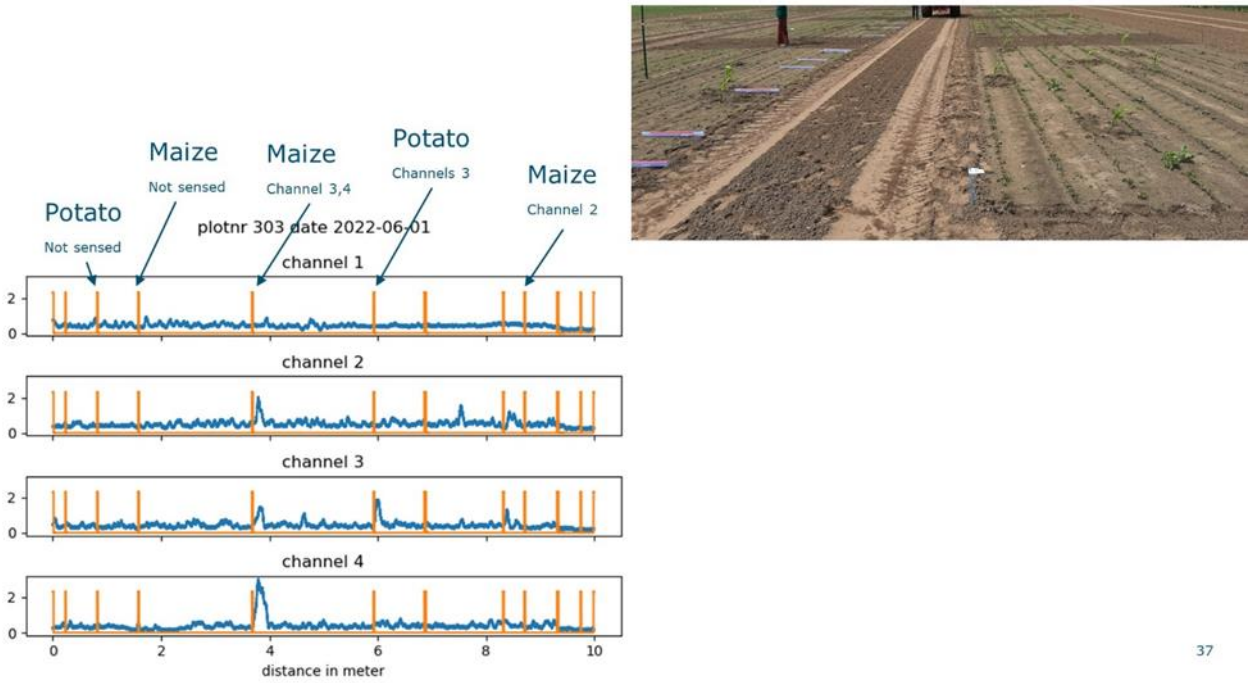


Figure 3: Plot and picture of plot 303. The weeds are well visible.

### 3.1.2 Second measurement day

On the second measurement day quite some weeds had appeared.

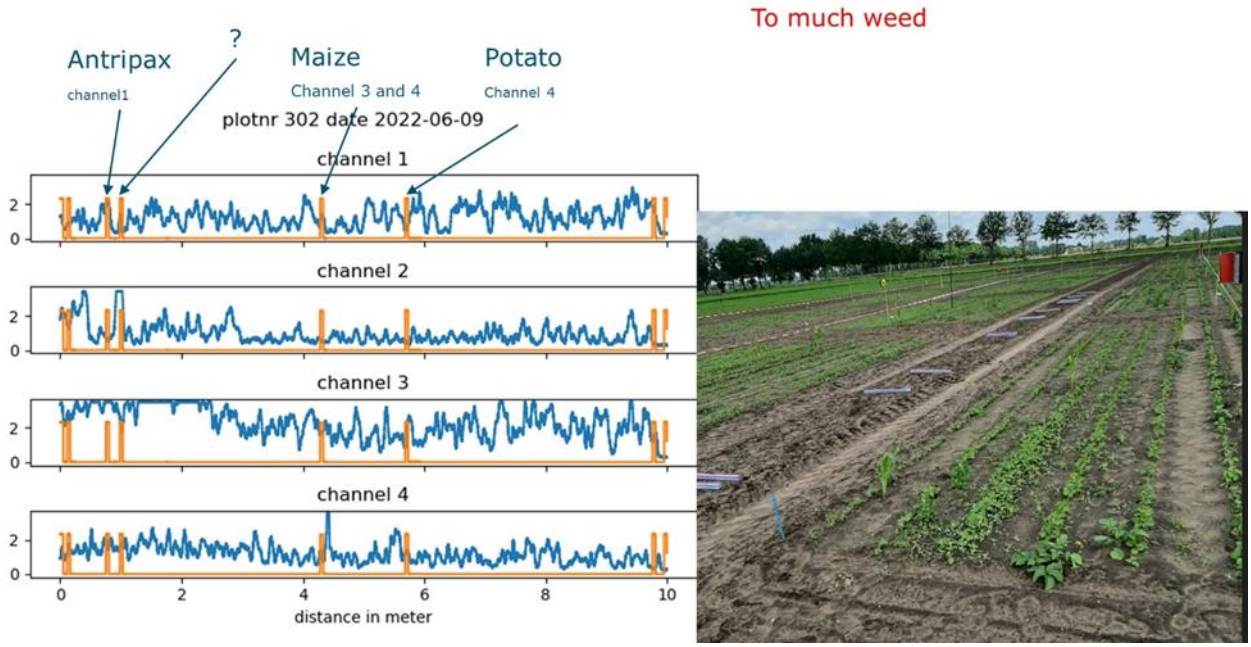


Figure 4: Plot and overview picture of plot 302, there is a lot of weed but the maize, which is much taller could maybe be detected.

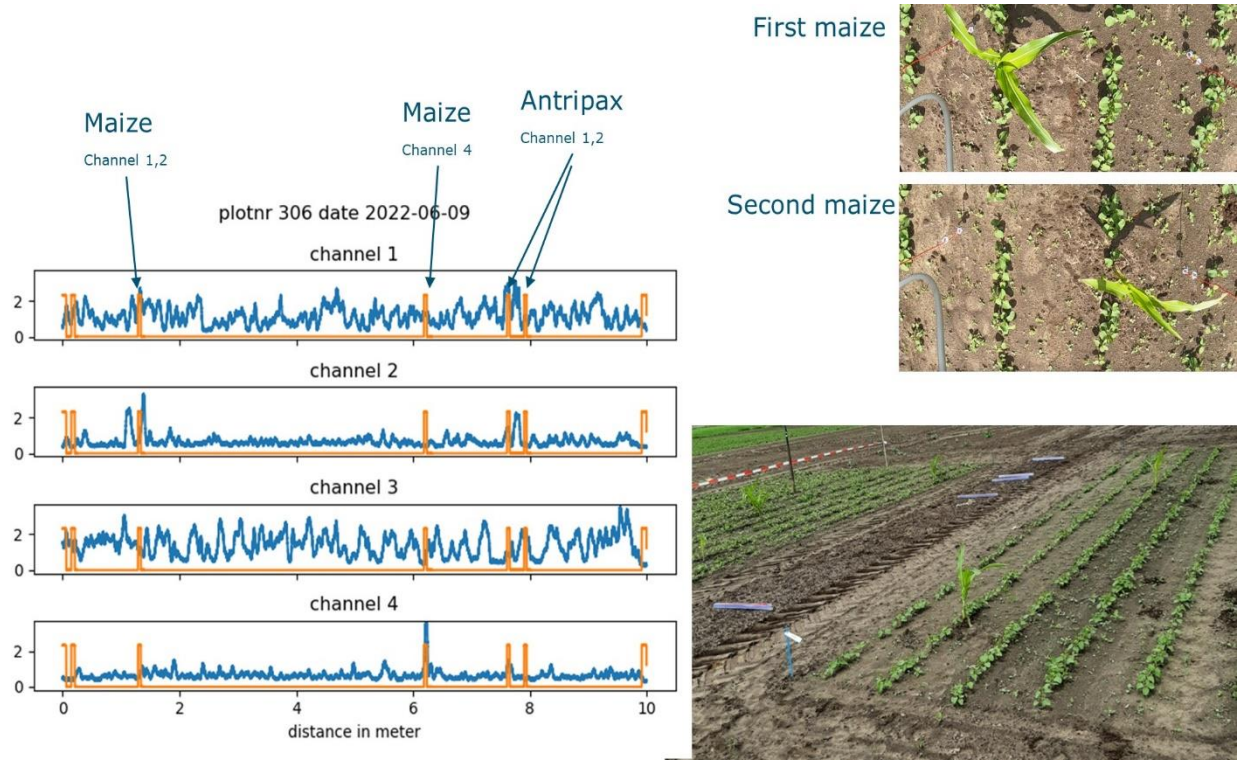


Figure 5: Plot and images of plot 306 on the second measurement day. Maize is visible in contrast to the soil in channel 2 and 4.

### 3.1.3 Third measurement day

On day three herbicide has been applied, so between the crop bare soil became visible.

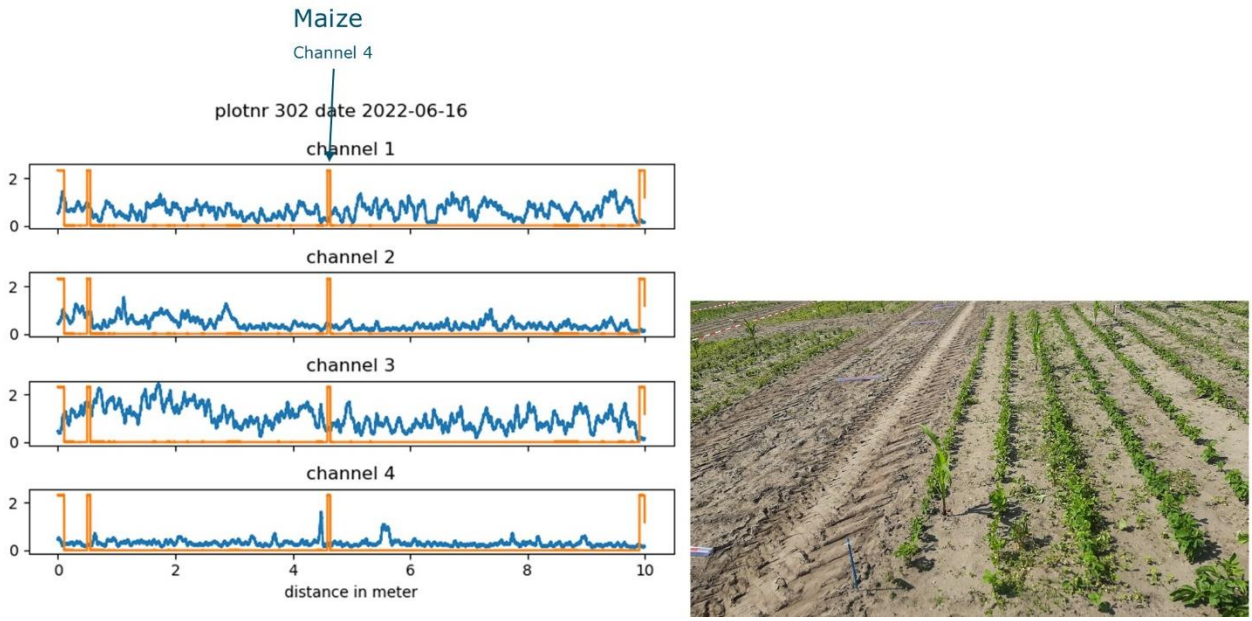


Figure 6: Plot 302 with the maize visible against the bare soil in channel 4.

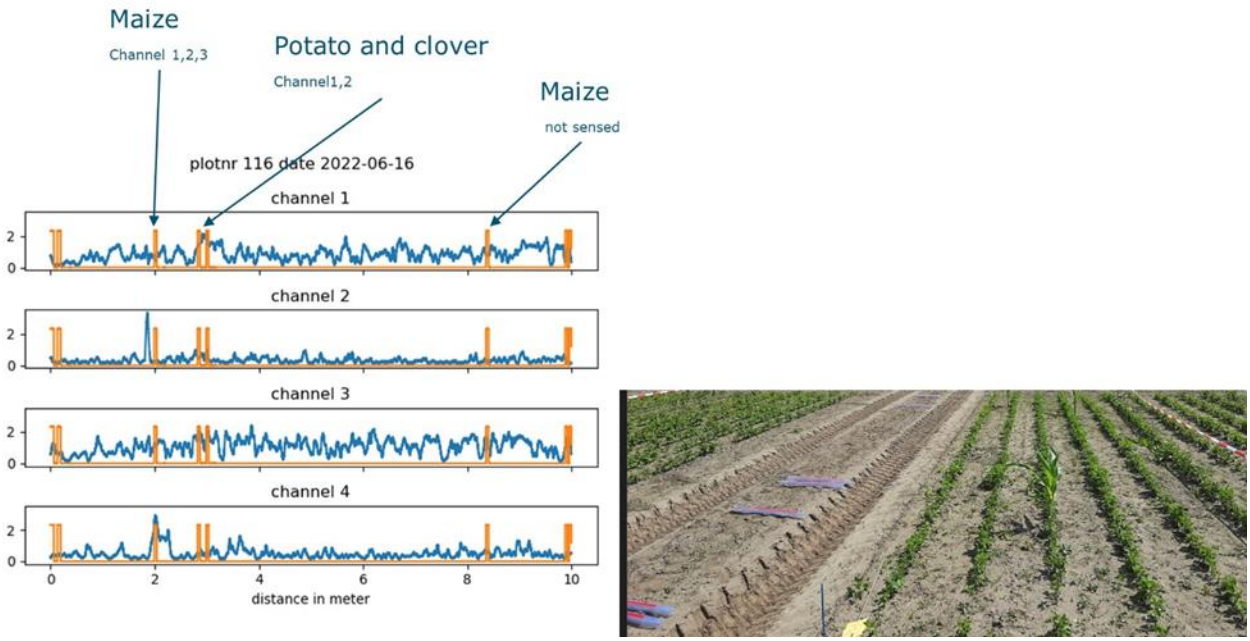


Figure 7: Plot 116, with again the maize visible against the soil.

## 3.2 Angled measurements

On the fourth measurement day, some measurements were done while driving at a 30 degree angle, because this is common practice in parts of Brazil. This turned out to be very interesting for data processing, as driving with an angle reveals a clear periodicity in the signal that cannot be seen if the signal follows a single row of crop. Therefore, the Fourier analysis method that we tested last year, may be applicable for plots sprayed at an angle. More research has to be done on this next year.

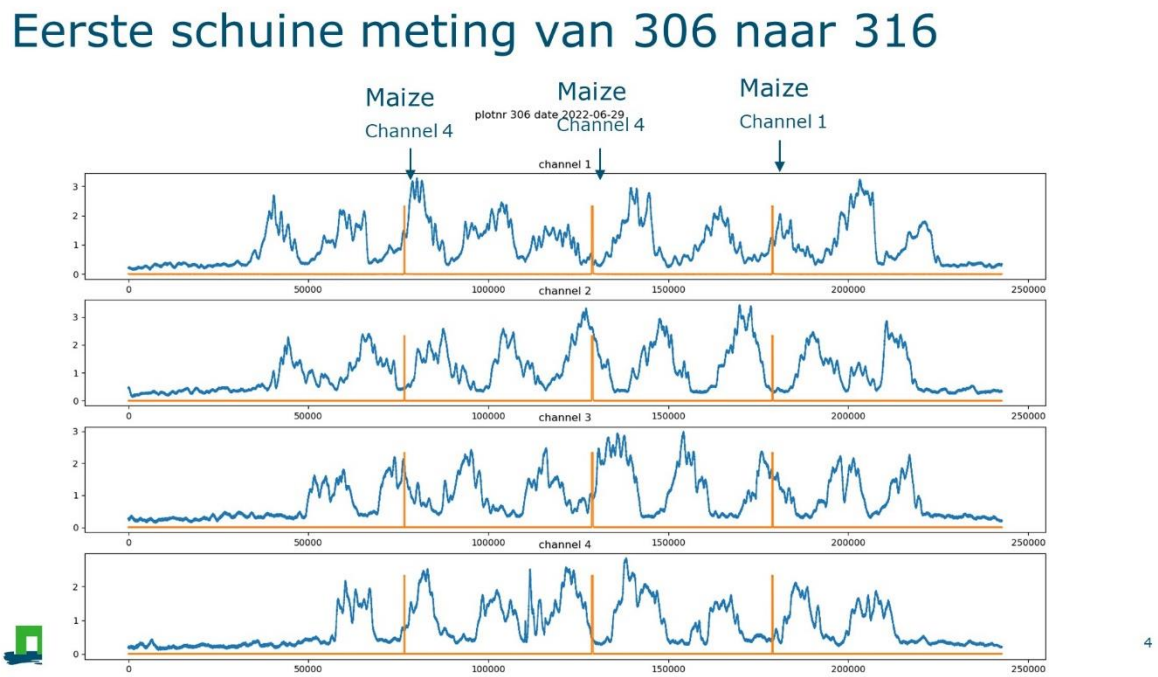


Figure 8: The signal clearly has a periodicity when driving askew.

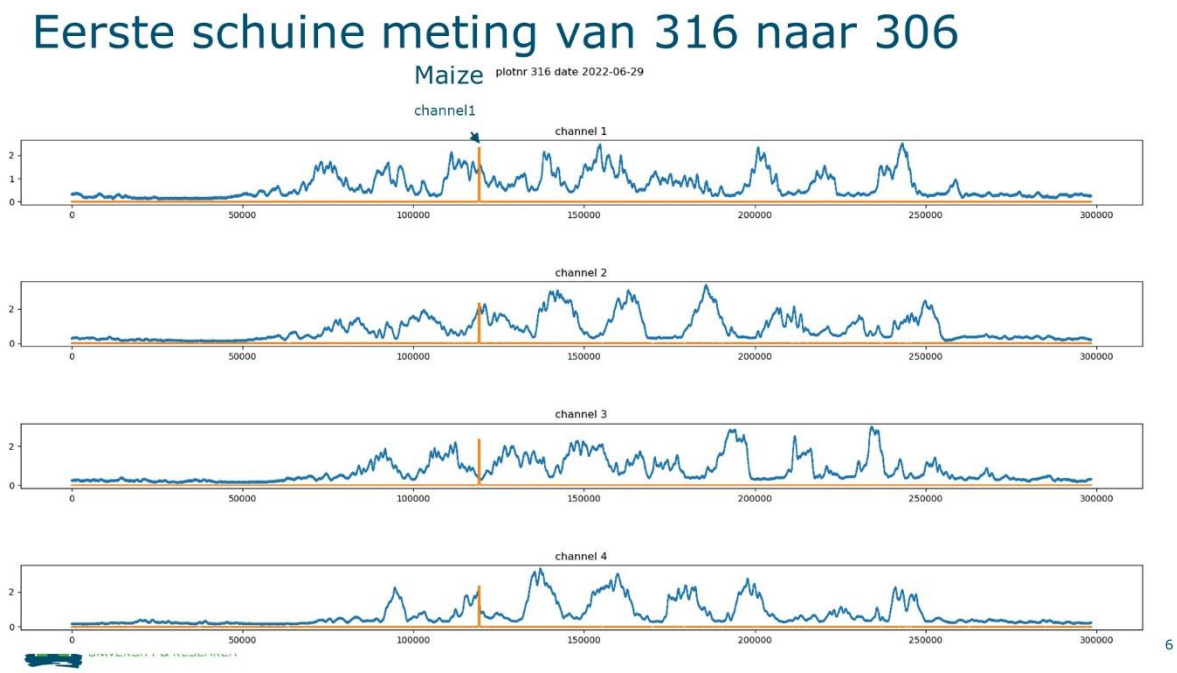


Figure 9: The signal from the same plot, but entering at an angle from the other far end. In channel one the periodicity seems to be broken.

## 3.3 Fifth measurement day

On the fifth measurement day, the canopy was almost closed, which makes it more difficult to find weeds as there is not much empty space between the signals of one row and another.

Figure 10: The crop in plot 216 on the fifth measurement day

Measurements were done with different heights of the sensor and next to each other.

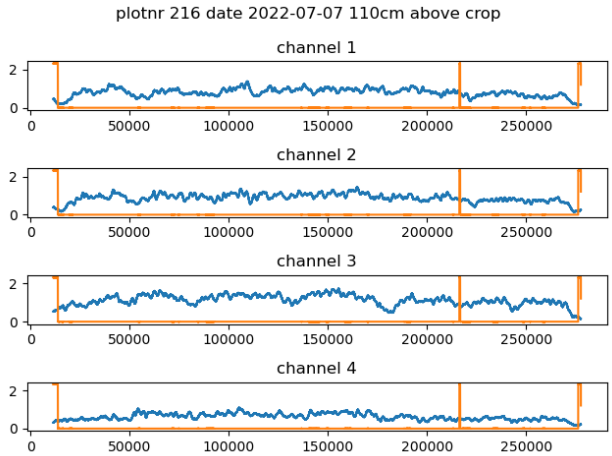


Figure 11: measurements of the plot in figure above when the sensor is put 110 cm above the canopy

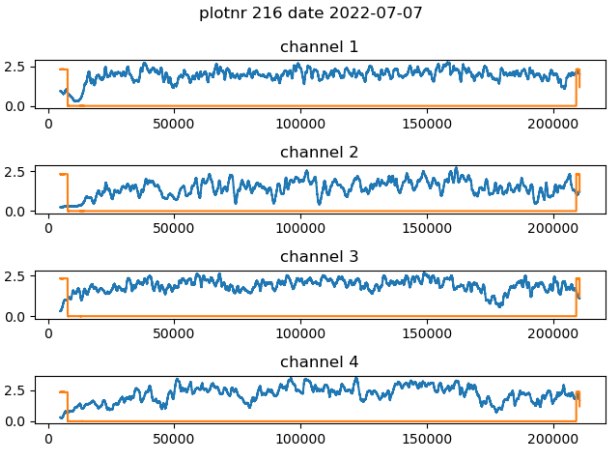


Figure 12: Measurements of the plot in the photo above when the signal is 110 cm above the ground.

Figure 13: Plot 215 on the fifth measurement day.

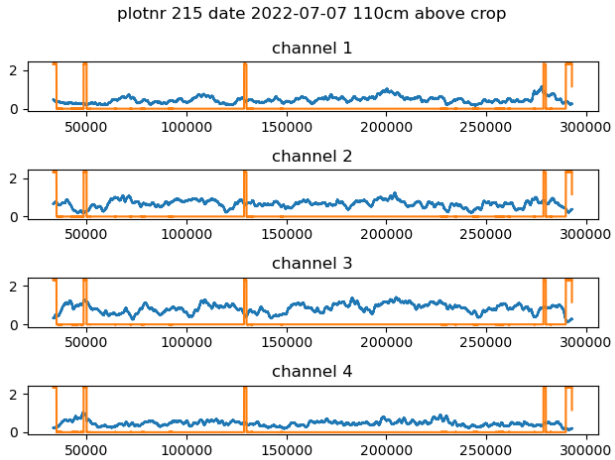


Figure 14:measurements of the plot in figure above when the sensor is put 110 cm above the canopy

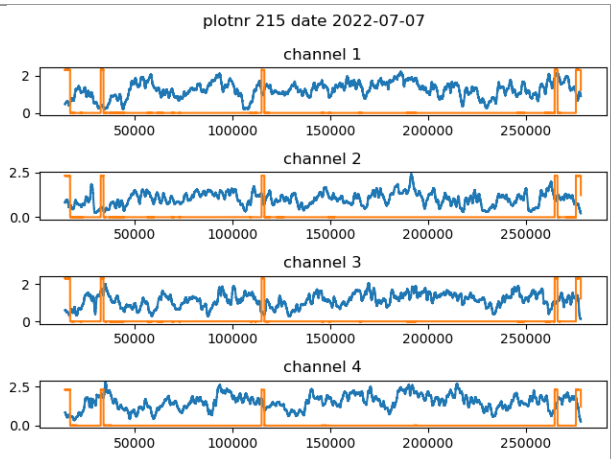


Figure 15:: Measurements of the plot in the photo above with the sensor 110 cm above the ground

Although the maize plants were much higher than the soybean canopy, there was no visible peak in the signal. When the canopy is closed this far, it is too late to distinguish weeds from the crop with the WEED-IT sensor.

## 3.4 Algorithm design for 30 degrees

Based on these results, a proposal was made for creating an algorithm for driving at a 30-degree angle. The proposal suggests creating two algorithms; algorithm one will distinguish between soil and crop based on a *time series classification*[1] algorithm. Algorithm two will distinguish between crop and soil based on Fourier analysis[2]. When in conflict this means that there is a weed between the rows.

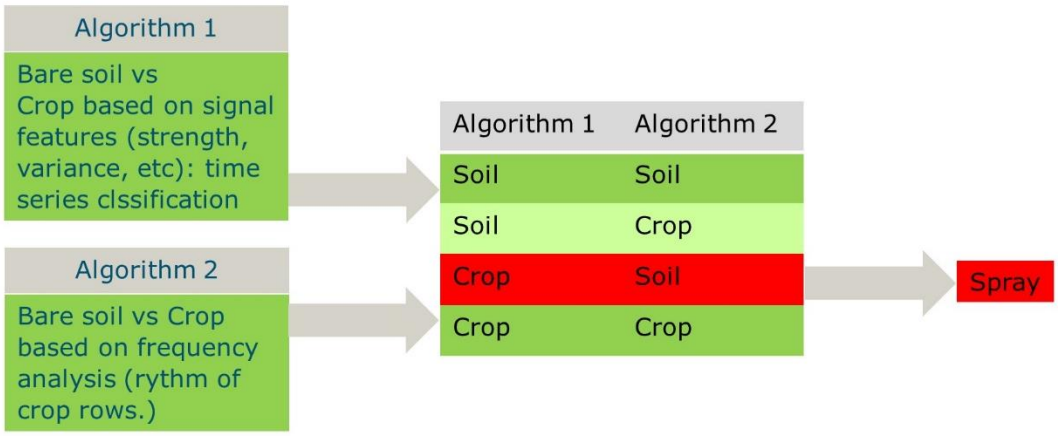


Figure 16: A visualisation of the proposed algorithm.

## 3.5 Time series classification

The data collected in Wageningen is very suitable for the time series classification approach. A time series classification is a data analysis approach that helps, in this case, determine whether the signal comes from plant material or soil material, based on the features of the signal.

[1] Eirola, Emil & Lendasse, Amaury. (2013). Gaussian Mixture Models for Time Series Modelling, Forecasting, and Interpolation. 8207. 162-173. 10.1007/978-3-642-41398-8_15.

[2] https://www.collimator.ai/reference-guides/what-is-fourier-analysis#:~:text=Fourier%20analysis%20is%20a%20mathematical,as%20sine%20and%20cosine%20waves.

First a search was done into the state of the art of time series classification, keeping in mind that the method should not be too computationally extensive as it should operate on the field. It came out that *mini-rocket*[3] is the best method. It treats the signal as a one-dimensional image. Image classification is done with the use of convolutional neural networks nowadays. Mini-rocket is a *convolutional neural network*, where the convolutions are predefined, reducing the computational costs.

All the plots have been split in testing- and training plots. Within those plots, 1000-pixel chunks of soil and crop images have been sampled, that equal to approximately 5 cm distance in the field at ground level. On these samples the mini-rocket method, followed by a *ridge classifier* (a frequently used statistical classifier) has been trained on the training dataset and tested on the testing dataset. For comparison also a stand-alone ridge classifier has been tested, not using the mini-rocket time series approach as first step.

On the first measurement day the crop had just emerged and was very small, difficult to detect.

Figure 17: Soybean crop with transplanted 'volunteer corn' on the first measurement day.

To get a look and feel with the data that was gathered in the field experiments, some random representative subsets from the data set have been plotted in Figure 18.

[3] https://dl.acm.org/doi/10.1145/3447548.3467231

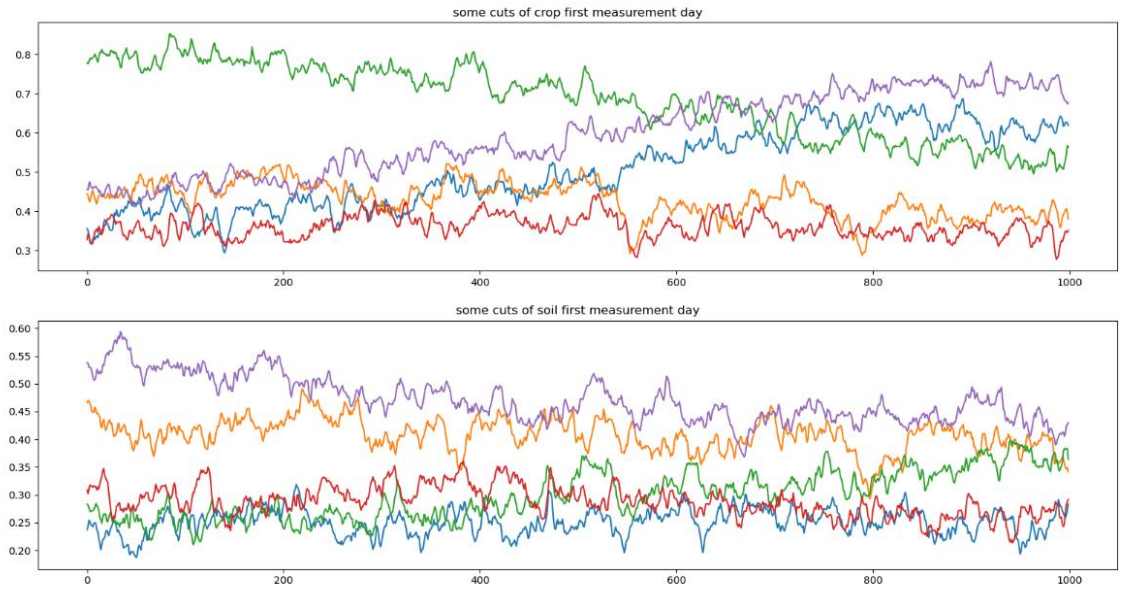


Figure 18: Some plots of soils and of crop on the first measurement day.

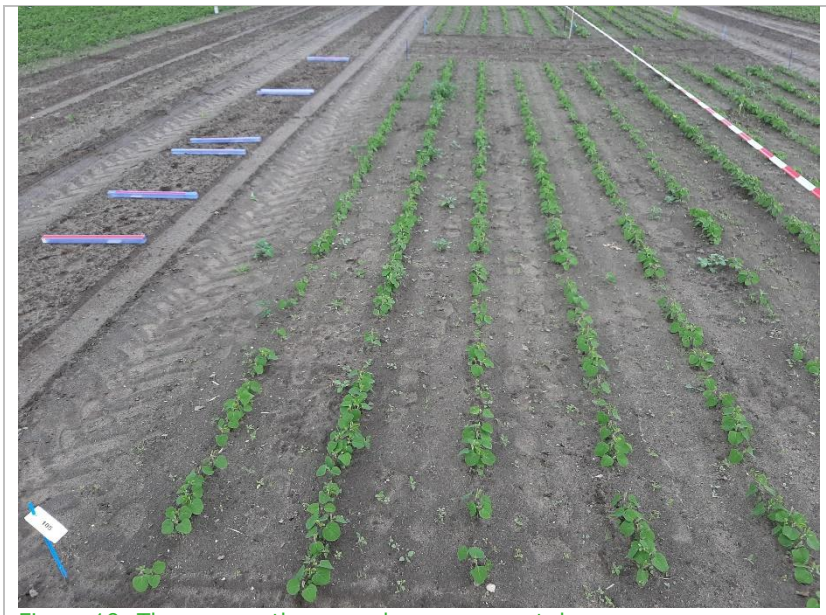

Figure 19: The crop on the second measurement day

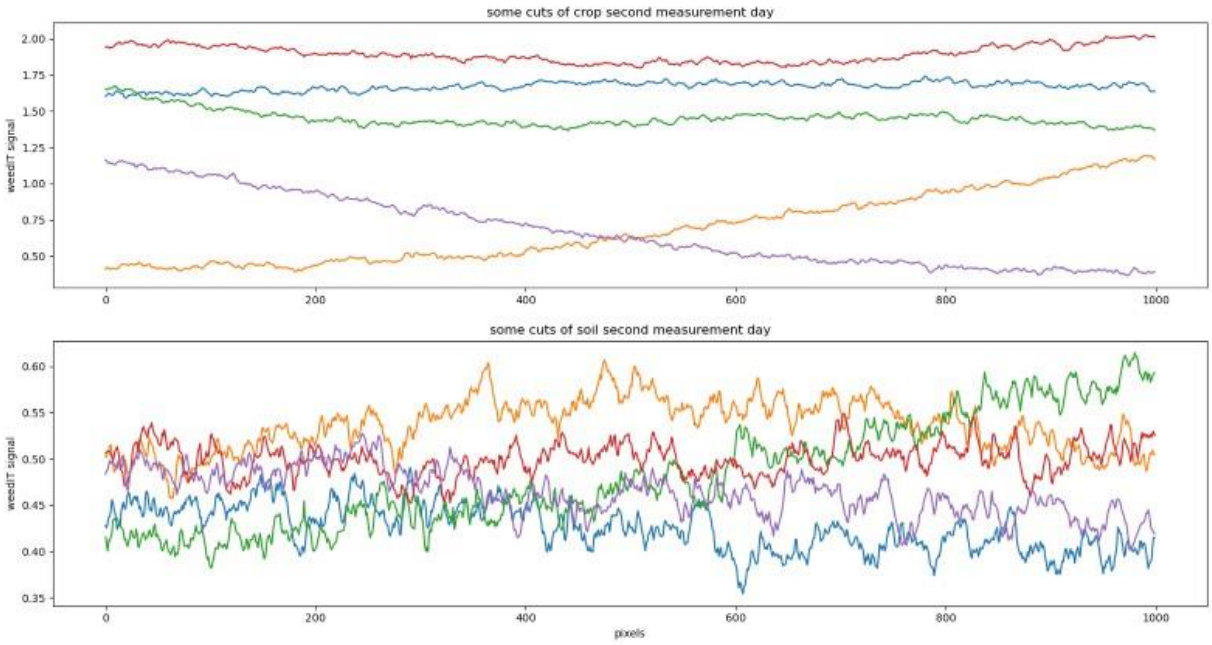


Figure 20: Some plots of soils and of crop on the second measurement day.

Figure 21: The crop on the third measurement day.

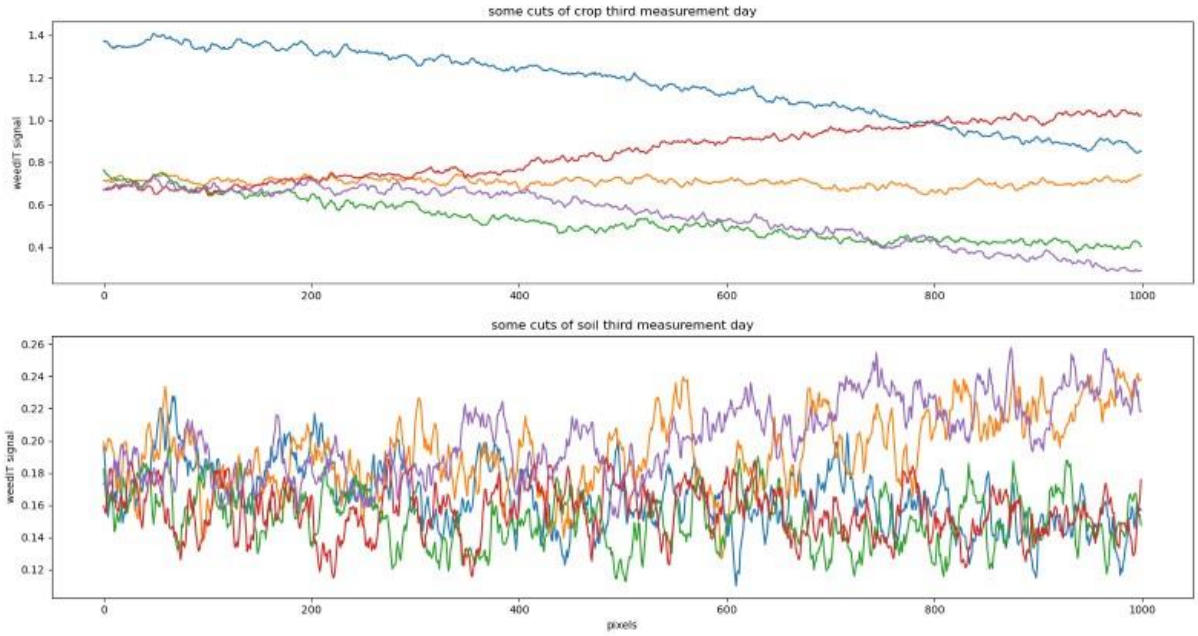


Figure 22: Some plots of soils and of crop on the third measurement day.

Figure 23: The crop on the fourth measurement day.

On the fourth and the fifth measurement day it was not possible anymore to find bare soil. On the data sets, classifiers have been trained separately for each day.

Table 1: Classification accuracy results for crop and soil classification in the datasets used.

| Measurement Day | Ridge classifier after Mini rocket | Ridge classifier |
|---|---|---|
| 1 | 58% | 63% |
| 2 | 91% | 91% |
| 3 | 90% | 88% |

Using the classifiers on the other days did not give satisfactory results.

# 4 Conclusions

Driving and measuring the field in an angle (so not parallel to the crop rows) results in a periodicity in the signal. With Fourier analysis on the WEED-IT signal, it should be possible to predict where a crop row should be, because of regularity in row distance (which provides a frequency). If a plant is found outside the predicted area, one could assume it is a weed.

It is possible to observe weeds between the rows, as they appear against the bare soil. So if the distance between crop plants is too small (i.e. within the row, or between the rows at the end of the season when the canopy covers the bare soil), it is not possible to distinguish the weeds from the crop with the WEED-IT sensor.

Increasing the height of the sensor on the fully-grown soybean crop did not increase the traceability of the weeds.

Time series classification of 1000-pixel time series makes a clear distinction between the soybean crop and the soil.

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