Automated Soil sampling and solution mixer mechanism

Introduction

Nitrogen in crop management

Nitrogen is an essential element for plant growth, consequently, the fertilization based on it is correlated with crop yields. A lack of knowledge about the current condition of the nitrogen content of the soil may lead farmers to apply large amounts of nitrogen fertilizer with the intention to obtain higher yields of good quality, which seems to be reasonable from an economic point of view as the cost of fertilizer is very small compared to the impact of a low yield; but it does not seem to be a good idea at all from an ecological point of view since this practice brings with it as possible consequence surface- and groundwater pollution, due to nitrate leaching into the soil. Potential health risks for humans and animals are led by high nitrate concentrations in vegetables and in drinking water, as pointed out by Andreas Möller et al. (2003, p. 4).

Efficient nitrogen fertilization

Good knowledge of soil-N availability for a better nitrogen fertilization practice may allow farmers to keep maximizing crop yield but under a moderate rate of N fertilization instead of a high rate of N fertilization (Anbessa and Juskiw 2012, p. 2), which is determined with a nitrate content analysis.

Soil samples are usually carried out by external services or farmers, while soil nitrate content analysis is usually carried out ex-situ in a laboratory. Mineralization of soil samples is a particular problem when they are not properly cooled during storage and shipping, which can lead to erroneous values in the analysis result. On the other hand, if the samples are frozen, thawing can substantially increase the nitrate content, producing incorrect information on the condition of the soil (Esala, 1994). Also, the need to send soil samples to a laboratory means that the farmer may have to wait for several days to receive the results.

Project proposal

The purpose of this project is the development of the prototype of an automated soil sampler and solution mixer machine that prepares the soil for a later soil nitrate content analysis in-situ; consisting of two main mechanisms:

i) A soil sampling mechanism, which is able to: a) take samples from a depth of 1 to 2 feet to suit different crops, and b) collect the sample for the next step.

ii) A solution mixer mechanism, which: a) adds an extractant to the soil sample, b) has a water container c) mixes the solution so that it is prepared for a further nitrate content analysis, and d) disposes of the solution and rinse the container, which is necessary after each analysis so as not to interfere with the measurement of the next one. The most commonly used extractant is water, but

may be different according to the nitrate test applied; then if the extractant is other than water, a container for it is needed.

A completely automated system for nitrate content analysis in-situ can provide the farmer with quicker and more accurate results (based on the avoidance of the problems associated with the traditional ex-situ process). Since the mechanism covers until the mixture of the soil solution, it gives the possibility of using different nitrate tests, such as the widely known strips or ion-selective electrodes. This machine has its own platform on which it is mounted, then it can be carried by any vehicle through the field. A data analysis system would be part of the nitrate test system itself.

Design

Sampling:

- Up and Down system: Rack and pinion
- Sampling tool: Drill
- Sampling tool rotation: DC motor

Soil sampling mechanism

It is made of two parts: (i) a vertical motion sub-mechanism that is going to move the (ii) drilling mechanism which basically consists of a tool to drill down the soil.

- Up and Down system: Leadscrew with a stepper motor - it offers higher controllability and stability than Rack and pinion
- Sampling tool: Drill.
- Sampling tool rotation: DC motor + gearbox

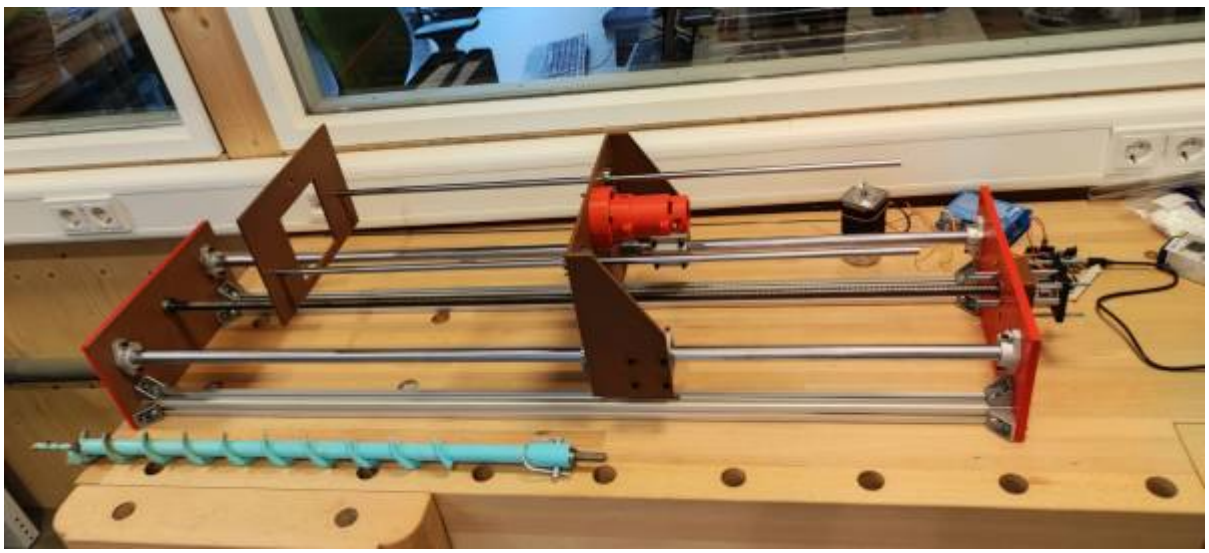
Drilling mechanism draft

By checking *other projects* I had the idea of not doing it on a specific rover (the FarmRobot as it was exposed the last time), but doing it on a separated frame exclusive for it, that way it can be carried by any vehicle, whether the FarmRobot, the Summit (the one at the GreenFabLab), also a tractor; I think it will also be better in terms of the stability of the needed water container.

I also add this draft describing the parts that will be part of the Up-Down sub-mechanism for the soil sampling mechanism.

Animation of idea

Prototype in development



Taking advantage of the Digital fabrication technologies, 3D printed pieces are being used to evaluate aspects to improve regarding sizes, stability, and performance

Solution mixer mechanism

- It needs a water container.

- If a rotating plate is needed, it can be based on the Lazy Susan mechanism.
- I consider using the sampling tool also to mix the solution, which will be cleared through future tests and continuous research.
- It could be partly merged with the Soil sampling part using the container for the sample as a container for mixing the solution using the same sampling tool.

Rovers

Rovers available at the Hochschule Rhein-wall to develop or test the mechanism:

Summit-XL

The Summit-XL, is a commercial Autonomous Mobile Robot (AMR) designed to operate indoor and outdoor.

Dimensions: 720 x 614 x 416 mm
Weight: 65 Kg
Payload: 65 Kg
Speed: 3 m/s
Environment: Indoor / Outdoor
Autonomy: 10 h

Farm robot

Developed in the FabLab_HSRW-KaLi, the Farm Robot is an open-source robot for weed control in arable and vegetable growing, as well as for use on meadows in nature reserves.

References

Anbessa, Yadeta & Juskiw, Patricia (2012). Review: Strategies to increase nitrogen use efficiency of spring barley. Canadian Journal of Plant Sciences. 92(2):617-625.

Andreas Möller, Sven Altfelder, Hans Werner Müller, Talal Darwish & Gilani Abdelgawad. (2003) A Guide to Sustainable Nitrogen Management in Agricultural Practice.

Esala, Martti. (1994). Deep-freezing pretreatment and time of extraction of soil samples for inorganic nitrogen determination. Communications in Soil Science and Plant Analysis 25(5-6):651-662.

Notes

Tests

Tests

Bill of Materials

BOM - Nitrate Robot

Rolf's notes

Soil sampler

- Soil sampler tubular soil sampler stainless steel T-style bulldozer design
- Grooving cylinder
- Bürkle soil sampler Pürckhauer

A foundation idea for a possible future project:

- Analysis of Vegetation Indices to Determine Nitrogen Application and Yield Prediction in Maize (Zea mays L.) from a Standard UAV Service

Nitrate test

- Nitrate Ion Selective Electrode
- Test strips

Other projects

- Development of an Automatic Soil Sampling Machine
- BoniRob
- Autonomous robots and the Internet of Things in underground mining
- https://www.rogoag.com/farmers
- Development and use of an automated on-the-go soil nitrate mapping system
- Soil Sampling automobile

Support documentation

- Development of a quick on-farm test to determine nitrate levels in soil
- Soil Sampling and Nitrate Quick Test - Scheme
- How to use the nitrate quick test
- Testing Your Soil: How to Collect and Send Samples
- Soil Sampling Guidelines
- Field collection of soil and sediment samples
- Soil Sampling and Methods of Analysis - Book
- Nitrate Concentrations in the Root Zone Estimated Using Time Domain Reflectometry
- Digging Deeper for Agricultural Resources, the Value of Deep Rooting
- A Guide to Sustainable Nitrogen Management in Agricultural Practice
- Soil Sampling to Assess Current Soil N Availability
- Nitrogen efficiency of spring barley in long-term experiment
- Strategies to increase nitrogen use efficiency of spring barley
- Deep-freezing pretreatment and time of extraction of soil samples for inorganic nitrogen determination