Prototypes4soil2data: Modular designed mobile field laboratory for standardized soil nutrient analysis directly on the field

Vadim Riedel[1*], Elena Najdenko[5] ,Andreas Möller[2], Matthias Terhaag[3], Daniel Mentrup[4], Hendrik Kerssen[4], Frank Lorenz[5], Tino Mosler[6], Heinrich Tesch[6], Walter Peters[7], Walter Nietfeld[8], Stefan Hinck[1], Arno Ruckelshausen[1]

[1] University of Applied Sciences Osnabrueck, Postfach 1940, 49009 Osnabrueck, Germany

[2] ADVES GmbH & Co. KG, Eschstraße 23, D-49424 Goldenstedt-Lutten, Germany

[3] ANEDO GmbH, Huelsmeyerstr. 35, 49406 Eydelstedt, Germany

[4] iotec GmbH, Albert-Einstein-Str. 1, 49076 Osnabrueck, Germany

[5] VDLUFA Nord-West, Jaegerstr. 23-27, 26121 Oldenburg, Germany

[6] MMM tech support GmbH & Co. KG, Weigandufer 18, 12059 Berlin, Germany

[7] Bodenprobetechnik Peters GmbH, Bahnhofstraße 36, 49635 Badbergen, Germany

[8] Bodenprobetechnik Nietfeld GmbH, Nietfeldsweg 25, 49635 Badbergen, Germany

* Corresponding author. Email: v.riedel@hs-osnabrueck.de

Abstract

Currently, soil nutrient analysis involves two separate processes for soil sampling and nutrient analysis: 1. field soil sampling and 2. laboratory analysis. These two - separate - main work processes are combined and conceptualised for a mobile field laboratory so that soil sampling and analysis can be carried out simultaneously in the field. The module-based field laboratory "soil2data" can carry out these two main work processes in parallel and consists of 5 different task-specific modules that build on each other: app2field, field2soil, app2liquid, liquid2data and data2app. The individual modules were designed and built for the sub-process steps and adapted to the special features of the mobile field laboratory "soil2data". The biggest advantage is that the analysis results are available immediately, and a fertiliser recommendation can be generated instantly. For further analyses, the results are stored in the data cloud. The soil material remains in the field. In the ongoing project "Prototypes4soil2data", the mobile field laboratory soil2data is being further developed into a prototype with a modular structure.

Keywords: soil nutrient analysis, soil sensor, ion-selective field effect transistors (ISFET), mobile field laboratory, soil preparation for analysis

1. Introduction

For optimised and effective fertiliser management in crop production, information on the - site-specific - soil nutrient status is an important calculation parameter, along with other decision variables such as the site-specific yield potential or the soil texture (Hinck et al. 2022, Hinck et al. 2013, Lorenz & Münchhoff, 2015). Currently, several weeks can elapse between soil sampling and the availability of the analysis result, i.e. the results are not available promptly.

2. Materials and Methods

In order to be able to carry out soil nutrient analysis directly on the field, a concept has been developed (Hinck et al. 2022). The individual process steps of the two main work processes 1. collect soil samples on the field and 2. nutrient analysis in the laboratory have been analysed and divided into sub-process steps. The necessary sub-process steps from both main work processes were adopted and further developed into a new main concept (Tsukor et al. 2019). As a result, a demonstrator of the mobile field laboratory "soil2data" was built (see fig. 1). In the current project "Prototypes4soil2data", the individual necessary sub-process steps are being optimised and designed as a modular structure. This has the advantage that changes or extensions in the sequence of a sub-process only affect the relevant sub-process and not the entire process sequence. All modules together in combination make up the mobile field laboratory. The modular design has the additional advantage that the modules can also be used as independent modules for the specific sub-process.

Figure 1. The mobile field laboratory “soil2data”

3. Results and Discussion

From the 1st main process "Collecting soil samples in the field", the sub-process steps: "Soil sample planning" and "Collecting soil samples" are developed into separate modules for the mobile field laboratory "soil2data". The module "app2field" contains the planning of soil sampling. Soil sampling planning is very important for the use of a mobile field laboratory because the analysis data have to be assigned to the fields or part fields. This is done automatically in the following process sequence when the fertiliser recommendation is generated, so an appropriate database is an important prerequisite. Furthermore, the

planning data helps the driver to navigate to the field and gives an orientation within the field where to sample. In the module "field2soil" the collection of a mixed soil sample is implemented. A representative soil sample is taken to a depth of 30 cm using a commercially available and adapted soil sampling device. The transport of the soil sample material to the laboratory is not necessary and is omitted. From the 2nd main process "nutrient analysis in the laboratory", the sub-process steps: "soil preparation", "analysis" and "documentation and “providing of results" were developed as the modules "soil2liquid" for the preparation of the soil sample, "liquid2data" for the analysis of the soil sample and "data2app" for data management. The soil sample material remains on the field after analysis. The 5 individual modules together form the mobile field laboratory "soil2data" (s. fig. 2). Each module can also be used as a stand-alone application.

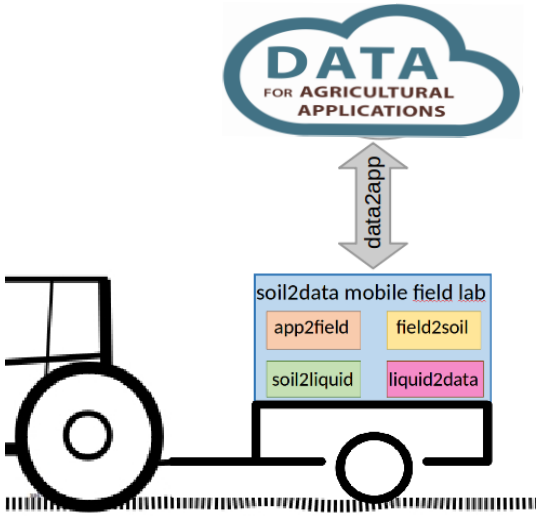

Figure 2. soil2data app concept: The mobile field laboratory "soil2data" includes 5 combined modules

In particular, the soil preparation needed to be adapted, so the preparation time in the field is much shorter compared to the laboratory and the preparation can be done in two stages (see fig. 3). For this purpose, spatially developed extraction conditions (short time, little liquid, ideally all target nutrients in one soil sample) are adapted to the in-field method for express wet chemical extraction of plant-available nutrients (NO_3^-, $H_2PO_4^-$ and K^+) and pH for subsequent direct measurement using ISFET measuring technology (Najdenko et al. 2023). The two-stage preparation makes the soil preparation process very flexible. If necessary, changes can be made in the sub-process flow or in the choice of extraction agents. The soil2liquid module provides mechanical and chemical processing of the collected soil sample material.

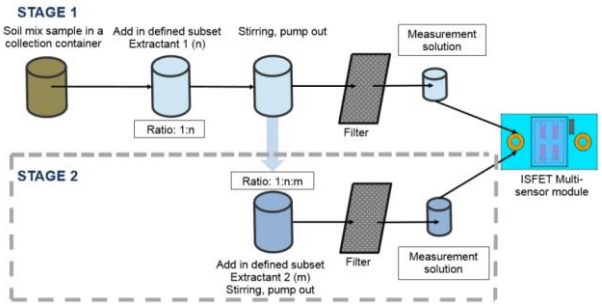

Figure 3. "soil2data" 2 stages soil nutrient extraction procedure (Source: Tsukor et al. 2019)

The soil preparation is based on the standard of VDLUFA (German Association of Agricultural Analysis and Research Institutes) valid in Germany. If the soil has been prepared in accordance with this standard, then the appropriate regional LUFA fertiliser recommendation can be used. Once soil sampling has been completed in a field, the analysis results are sent to the cloud via data2app, fused with other external data (e.g. cultivated crop, soil texture) and a fertiliser recommendation is automatically generated.

An innovative key component for direct analysis on the field is the NUTRISTAT analysis module with ISFET measuring technology (lab-on-chip) (see fig. 4). The pH value and the nutrients NO_3^-, $H_2PO_4^-$, K^+ as well as the electrical conductivity are measured. Good measurement dynamics and reproducibility have been demonstrated in numerous laboratory tests (Tsukor et al. 2019) (see fig. 5).

Figure 4. NUTRISTAT analysis module with ISFET measuring technology (lab-on-chip) to measure NO_3^-, K^+ and $H_2PO_4^-$ as well as pH and electrical conductivity

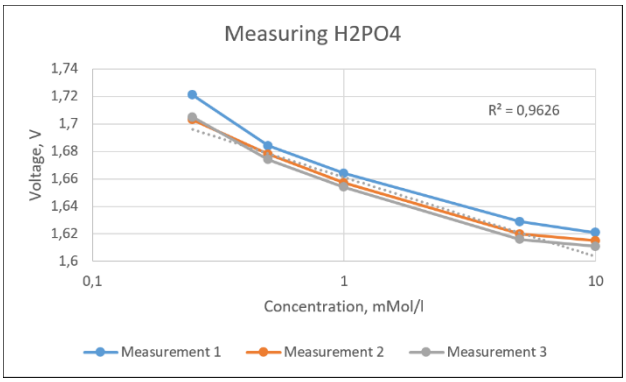

Figure 5. Measurement results (V) at different solution concentrations (log[mMol/l]) measured with NUTRISTAT analysis module with ISFET measuring technology, exemplarily shown for $H_2PO_4^-$, the coloured lines indicate the measurement repetitions

For reliable operation of the NUTRISTAT analysis module, specified control and readout electronics have been developed as part of the project. The control and readout electronics are designed for rugged field use on vehicles or carrier platforms. The NUTRISTAT analysis module with ISFET measurement technology has 4 ISFET modules and 1 reference electrode which has been taken into account in the circuit design.

4. Conclusions

The two main processes "soil sampling" and "soil analysis" are combined and carried out directly on the field. The individual process steps run in parallel and automatically. The main advantage is that the fertiliser recommendation can be generated automatically. Once the soil sampling has been completed, the result with a fertilizer recommendation for each field is available to the farmer in less than a minute. The mobile field laboratory "soil2data" digitalises the soil sampling.

Further advantages are immediate availability of results, in case of unclear results, the sampling and analysis can be repeated immediately, or a dynamic adjustment of the sampling density can be made.

Acknowledgements

The project is supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the innovation support program.

With support from
Federal Ministry of Food and Agriculture
by decision of the German Bundestag
Federal Office for Agriculture and Food
ptble

Note

This publication was presented as a presentation entitled “Prototypes4soil2data: Modular designed mobile field laboratory for standardized soil nutrient analysis directly on the field” at the 20th CIGR World Congress in Kyoto, Japan on 08.December 2022.

References

Hinck, S., Möller, A., Terhaag, M., Meyer, T., Mentrup, D., Kerssen, H., Najdenko, E., Lorenz, F., Mosler, T., Tesch, H., Peters, W., Nietfeld, W., Riedel, V. & Ruckelshausen, A. (2022): Analyse-to-go on the field: prototypes4soil2data. Presentation at the 22ndWorld Congress of Soil Science in Glasgow/Scotland. https://doi.org/10.48769/opus-3913

Hinck, S., Möller, A., Mentrup, D., Najdenko, E., Lorenz, F., Mosler, T., Tesch, H., Nietfeld, W., Scholz, C., Tsukor, V. & Ruckelshausen, A. (2018). soil2data: Concept for a mobile field laboratory for nutrient analysis. Proceedings of the 14th ICPA (unpaginated cd-rom). Montreal, Canada. https://www.researchgate.net/publication/326773973_soil2data_Concept_for_a_mobile_field_laboratory_for_nutrient_analysis

Hinck, S. Emeis, N., Mueller, K. (2013): Part Field Management: Comparison of EC-value, soil texture, nutrient content and biomass in two selected fields. Proceedings 3rd Global Workshop on Proximal Soil Sensing, Potsdam. https://www.researchgate.net/publication/260502756_Part_Field_Management_Comparison_of_EC-value_soil_texture_nutrient_content_and_biomass_in_two_selected_fields

Lorenz, F. und Münchhoff, K. (2015): Teilflächen bewirtschaften – Schritt für Schritt (Managung sub-fields – step by step). AgrarPraxis kompakt, DLG-Verlag, Frankfurt am Main.

Najdenko, E., Lorenz, F., Olfs, H.-W., Dittert, K. (2023). Development of an in-field express method for NO_3^-, $H_2PO_4^-$ and K+ wet-chemical extraction and pH value for the measurement with ISFET. Journal of Plant Nutrition and Soil Science, in print.

Tsukor, V., Hinck, S., Nietfeld, W., Lorenz, F., Najdenko, E., Möller, A., Mentrup, D., Mosler, T., Ruckelshausen, A. (2019): Automated mobile field laboratory for on-the-go soil-nutrient analysis with the ISFET multi-sensor module. Proceedings 77th International Conference on Agricultural Engineering (AgEng 2019), p. 377 - 382. VDI-Reports 2361, Düsseldorf, Germany. https://elibrary.vdi-verlag.de/10.51202/9783181023617-377/automated-mobile-field-laboratory-for-on-the-go-soilnutrient-analysis-with-the-isfet-multi-sensor-module?page=1