PROXIMAL AND DRONE BASED HYPERSPECTRAL SENSING FOR CROP NITROGEN STATUS DETECTION IN HISTORIC FIELD TRIALS

Video

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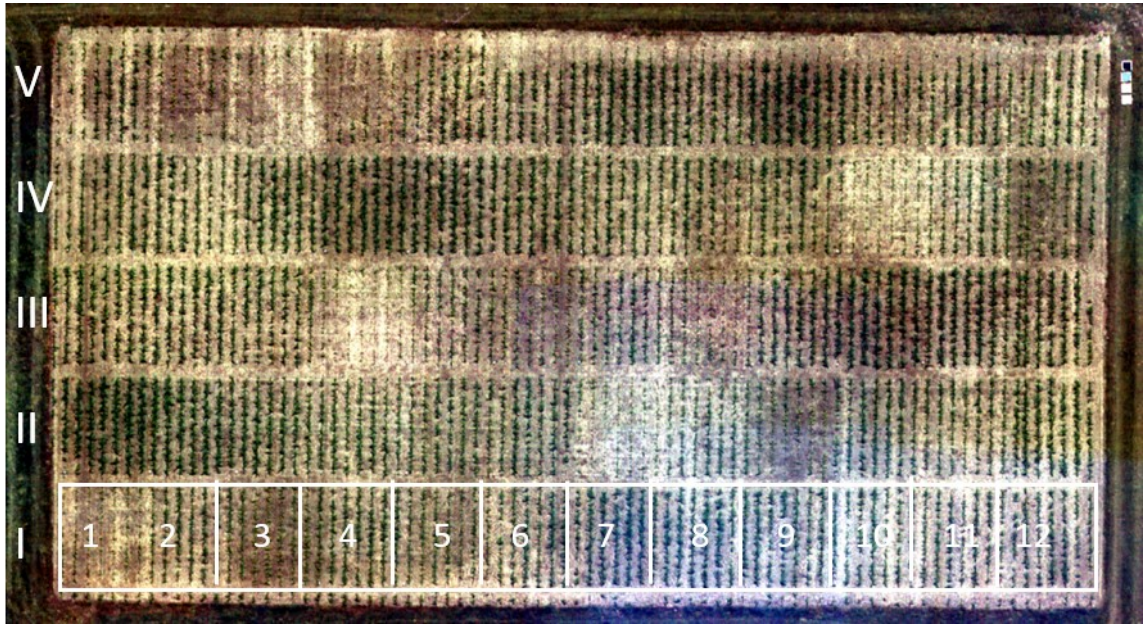
Aim

- Hyperspectral sensing as a tool to evaluate plant biomass and nitrogen (N)
- Long term fertilizer trial to evaluate sustainable management of the soil resources
- Replace laborious and costly manual in-field sampling with fast and non-destructive sensing methods.

The longterm fertilization trial

- Zurich Organic Fertilization experiment' (ZOFE) established in 1949, located at Agroscope in Zürich
- 12 input treatments: zero and mineral control (1 &12), pure and combined organic and mineral fertilization treatments, block design

Nr.	Treatment	Nutrient input (min/org) [kg ha^{-1}]		
		N	P	K
1	Zero control	0/0	0/0	0/0
2	Manure	0/86	0/27	0/117
3	Sewage sludge	0/174	0/163	0/9
4	Compost	0/93	0/21	0/106
5	Manure +PK	0/87	45/27	195/117
6	Sewage sludge +PK	0/174	45/163	195/10
7	Compost +PK	0/93	45/21	195/106
8	Peat +PK	0/0	45/0	195/1
9	N0P2K2	0/0	45/0	195/0
10	N2P1K1	100/0	22/0	98/0
11	N2P2K2	100/0	45/0	195/0
12	N2P2K2Mg / mineral control	100/0	45/0	195/0



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Spectral and ground sampling

- Aerial sensing by a 40 channel camera (based on imex) integrated and calibrated by Gamaya
- In field spectroscopy done with a PSR+ spectrometer (Spectral Evolution)
- Plant sampling, processing and lab analysis according to standards for field experimentation and reference methods

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ABSTRACT

Remote sensing holds vast potential for precision and smart farming and for field phenotyping applications. We present a small, but high-quality dataset consisting of ground truth, handheld spectrometer (proximal) and drone (remote sensing) data gathered in one of the world's oldest long-term field experiments (>70 yrs). The proximal and the remote sensing approaches showed comparable performance. Medium to strong correlations with the ground truth parameters were shown. Long-term field experiments are a valuable source for sensor calibration, calibration and validation of remote sensing products and applications. Vice versa, remote sensing methods and technology can support, improve and enhance data acquisition in field trials, particularly in long-term experiments.

Index Terms— Proximal sensing, remote sensing, high throughput phenotyping, drones, field experimental trials

1. INTRODUCTION

Remote sensing techniques are increasingly used in the framework of precision agriculture [1] and for agricultural research [2,3]. The research work can be divided in two domains focusing on 1) spatial and environmental monitoring and on 2) plot-based experimentation through high throughput phenotyping (HTP). Although the presented paper will focus on the latter, the underlying principles and obtained results are also relevant and applicable to the first.

The concept of HTP was mainly initiated by the breeding community [4], became of their demand to efficiently assess large field trials with hundreds to thousands of different plots [5]. Today, phenotyping of field trials is increasingly applied to other research purposes in agriculture including plant protection and fertilization trials [1]. The large variety of applications implies the high value of the methodology.

In this work we present the use of ground-based (proximal) and drone-based (remote) hyperspectral sensing as a tool to evaluate plant biomass and nitrogen (N) status in a long term fertilizer trial comparing mineral and organic nutrient sources with respect to sustainable management of the soil resources and agronomic productivity. The idea is to partly replace laborious and costly manual in-field sampling with fast and non-destructive sensing methods. The feasibility of both investigated sensing approaches and instruments for this purpose will be discussed.

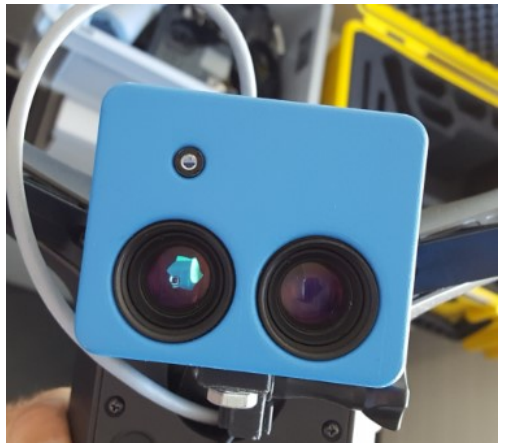
2. METHODS

2.1. Experiment and crop cultivation

For this study we used the historic (long-term) field trial 'Zürich Organic Fertilization experiment' (ZOFE), which was established in 1949 and is located at Agroscope in Zürich (47°25'36" N, 8°31'08" E, 420 masl).

The soil has an average density of 1.6 g cm^{-3} and is a carbonate-free Luvisol. Soil properties in the 0–20 cm layer at the start of the trial were 14% clay, 27% silt, and 57% sand; organic C content was 1.3% and soil pH 6.5. Mean annual temperature and precipitation of the location is 9°C and 1040 mm, respectively [6]. The experiment was established in the beginning of July to August 2020 in grain maize (Corn). Crop management was performed according to local practice with a seeding date in late April.

Figure 1: Aerial image of the experiment with indicated plot (x-axis) and block arrangement (y-axis).



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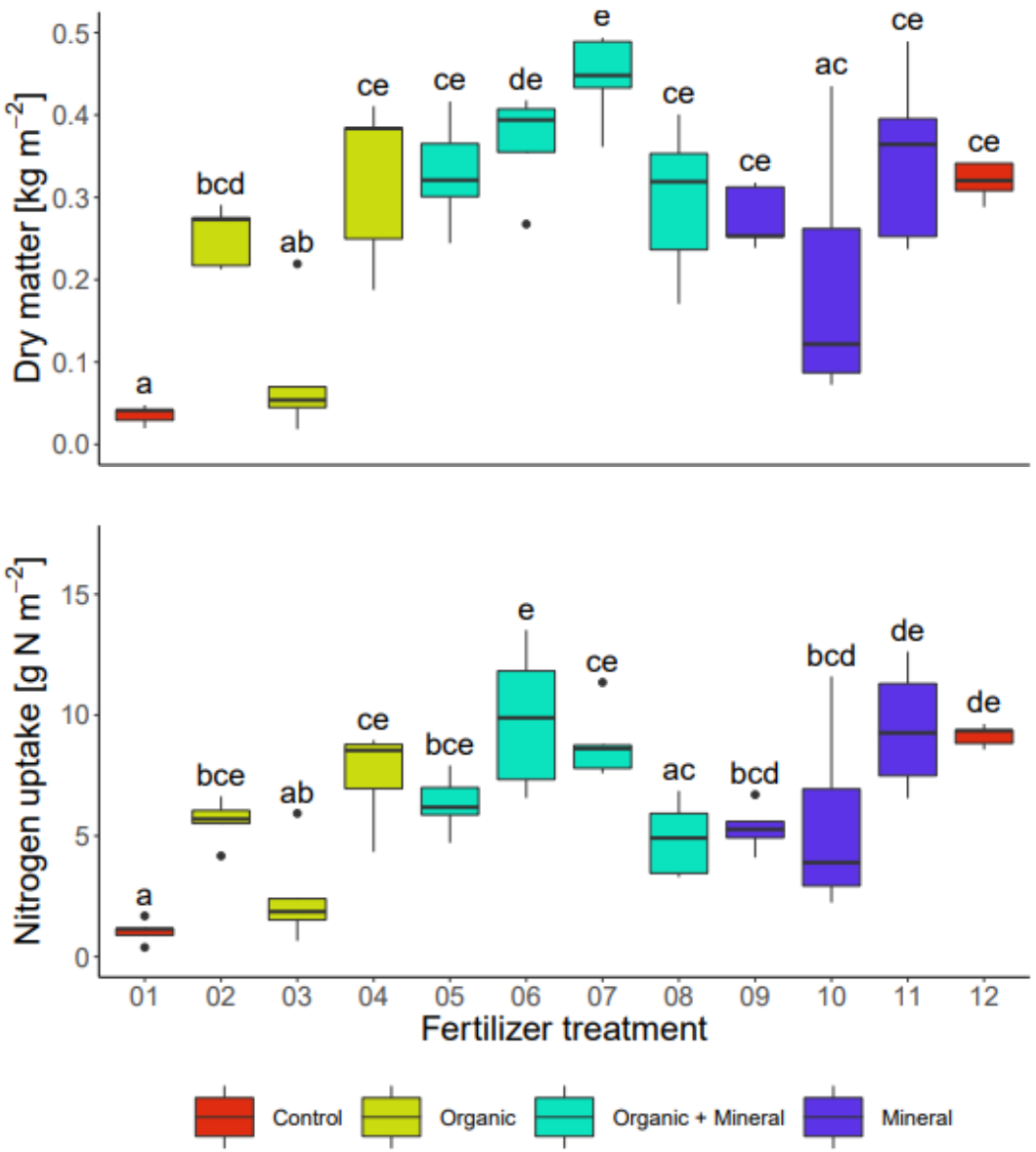
Results: the field trial

- Significant effects of treatment on biomass and N uptake
- No effect by block or plant density

Crop trait	Treatment	Replicate
Plant count (# m^{-2})	0.511	0.425
DM (kg m^{-2})	3.43e-09 ***	0.609
N_{up} (g m^{-2})	2.3e-08 ***	0.924

- Highest biomass and Nuptake in the combined (organic and mineral) fertilization

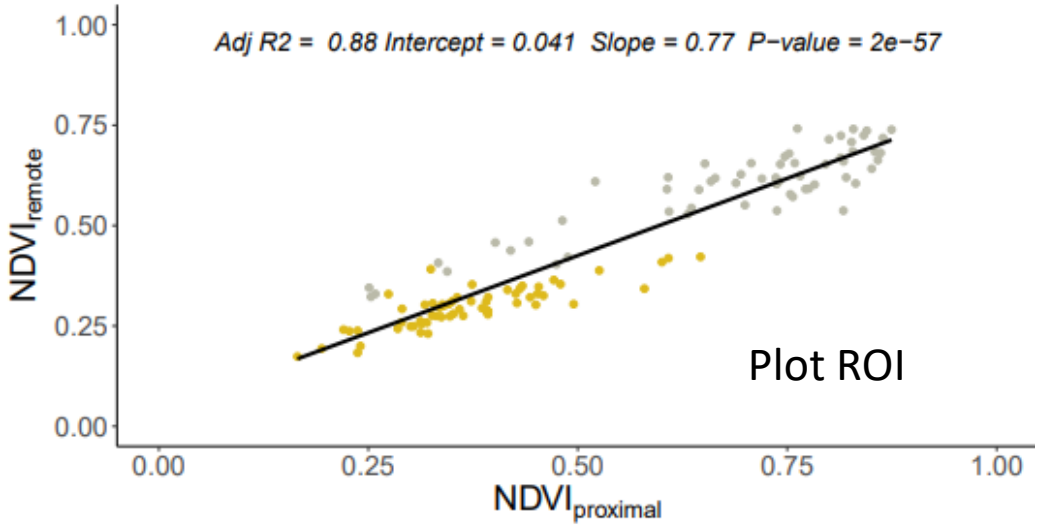


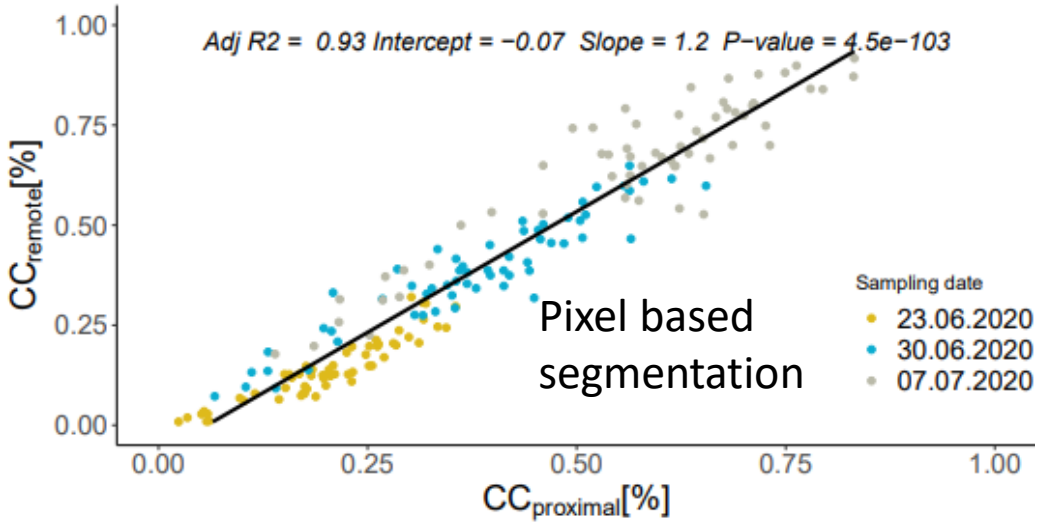
Proximal and remote sensing results

- Reasonable coefficients of determination between spectral indices, canopy cover, biomass and plant N uptake

Method	Trait	DM [kg m^{-2}]	N_{UP} [g N m^{-2}]
Remote	NDVI	0.73	0.54
	NDRE	0.78	0.60
	CC	0.73	0.55
Proximal	NDVI	0.62	0.44
	NDRE	0.69	0.56
	CC	0.61	0.37

- Good representation of ground signal by drone based imaging spectroscopy





Take home message

- Power of proximal and remote sensing methods for high throughput Field phenotyping with respect to nutrient input treatments
- high value of historical field trials to calibrate and validate sensor technology and algorithms

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