QUANTIFICATION OF ROOTS BY THE USE OF NIR HYPERSPECTRAL IMAGING AND CHEMOMETRICS

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Context

Roots, the belowground part of plants, **play a major role in plant development**. Their study in field conditions is important to identify suitable soil management practices for suitable crop productions but roots are hidden by soil and their study is therefore difficult. Estimation of root system development is often based on the **soil coring method** which allows repeated measurements during the growing season in the field as well as in different soil horizons. However, this method is **limited due to the time needed to extract roots from soil cores and to manually sort them from crop residues before quantification**. To avoid this tedious sorting step and remove operator subjectivity, **a faster sorting method was developed**. **Near infrared hyperspectral imaging** (NIR-HIS) was tested as a rapid method to quantify the amount of roots in soil samples.

Methodology and calibration results

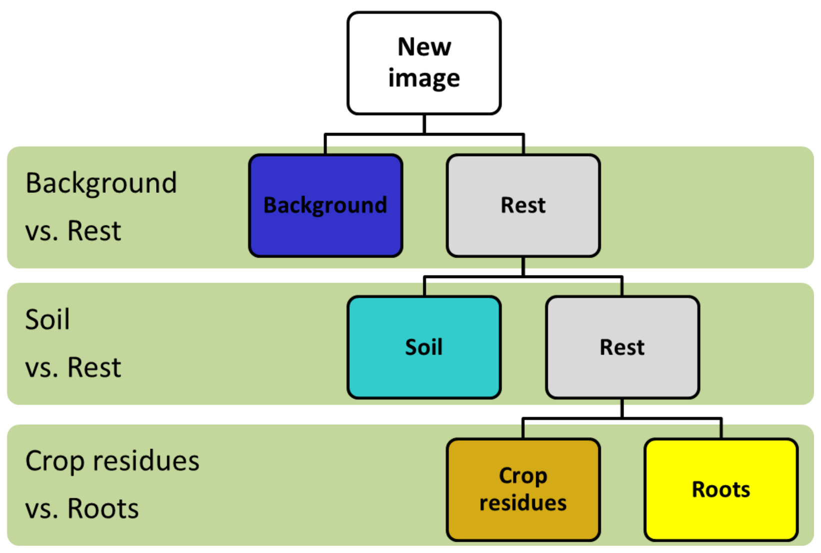
Sample extraction and preparation

1) **Field sampling** of soil cores;
2) **Washing** with tap water to extract roots. Crop residues are also extracted;
3) **Drying** of washed samples.

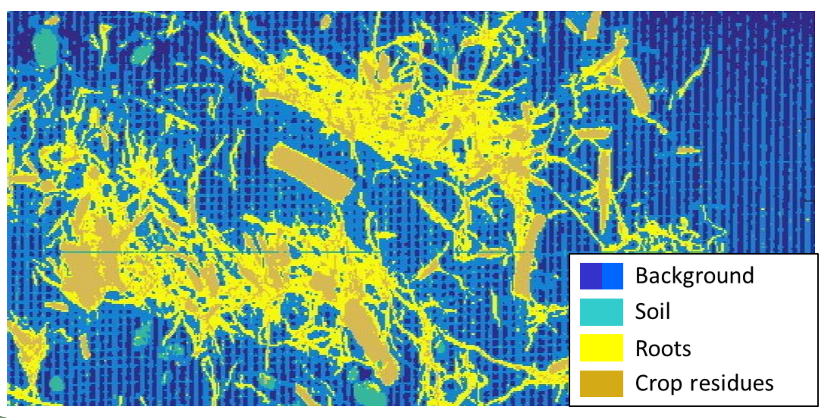
Image acquisition

NIR images are acquired with a **NIR hyperspectral line scan** (= push-broom) [1]. Samples are laid on a conveyor belt placed under the NIR camera. For each pixel of the NIR image, a complete spectrum including 209 wavelengths (1118-2424 nm) is saved.

Discrimination of root spectra



A **dichotomous classification tree** based on **3 successive SVM discriminant models** is used to separate root spectra from spectra of background, soil and crop residues on NIR images [2;3].



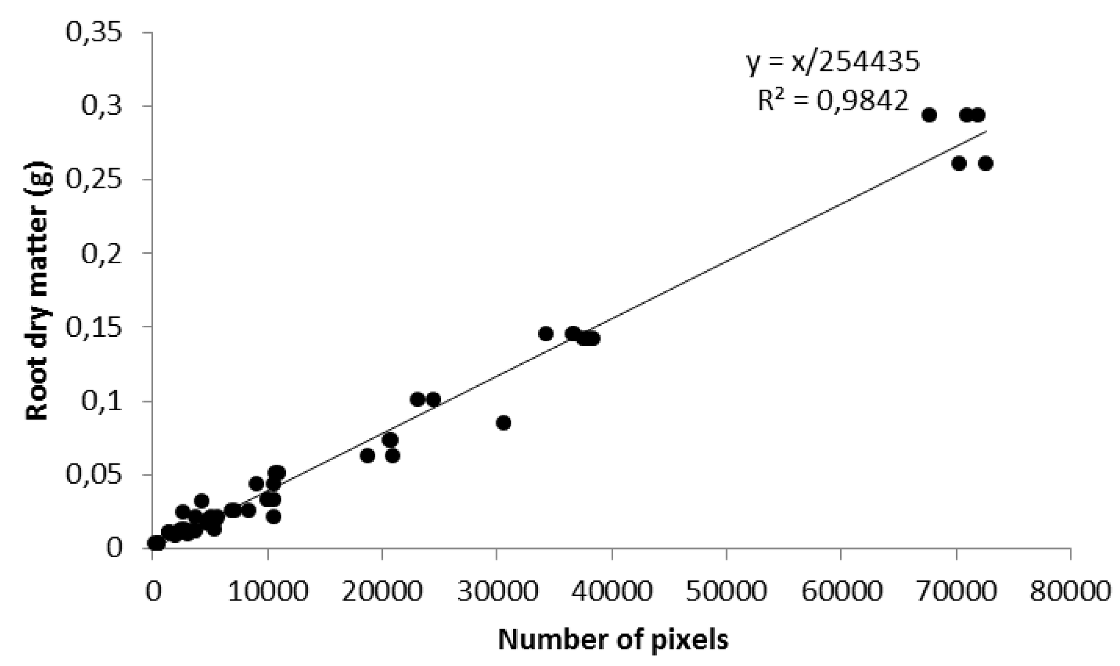
Each pixel is assigned to one spectral class.

91% of root spectra were correctly predicted.

Root quantification

The number of pixels classified as root on NIR image **is linked to a root dry matter** :

Root dry matter (g) = Number of root pixels / 254435 (R^2 = 0.98)



Application on winter wheat roots in a field trial

Field experiment

Soil samples were collected from a depth of 30 cm in a winter wheat crop in a long term field trial comparing conventional tillage and reduced tillage. Soil cores were divided into 3 soil horizons (0-10, 10-20 and 20-30 cm deep).

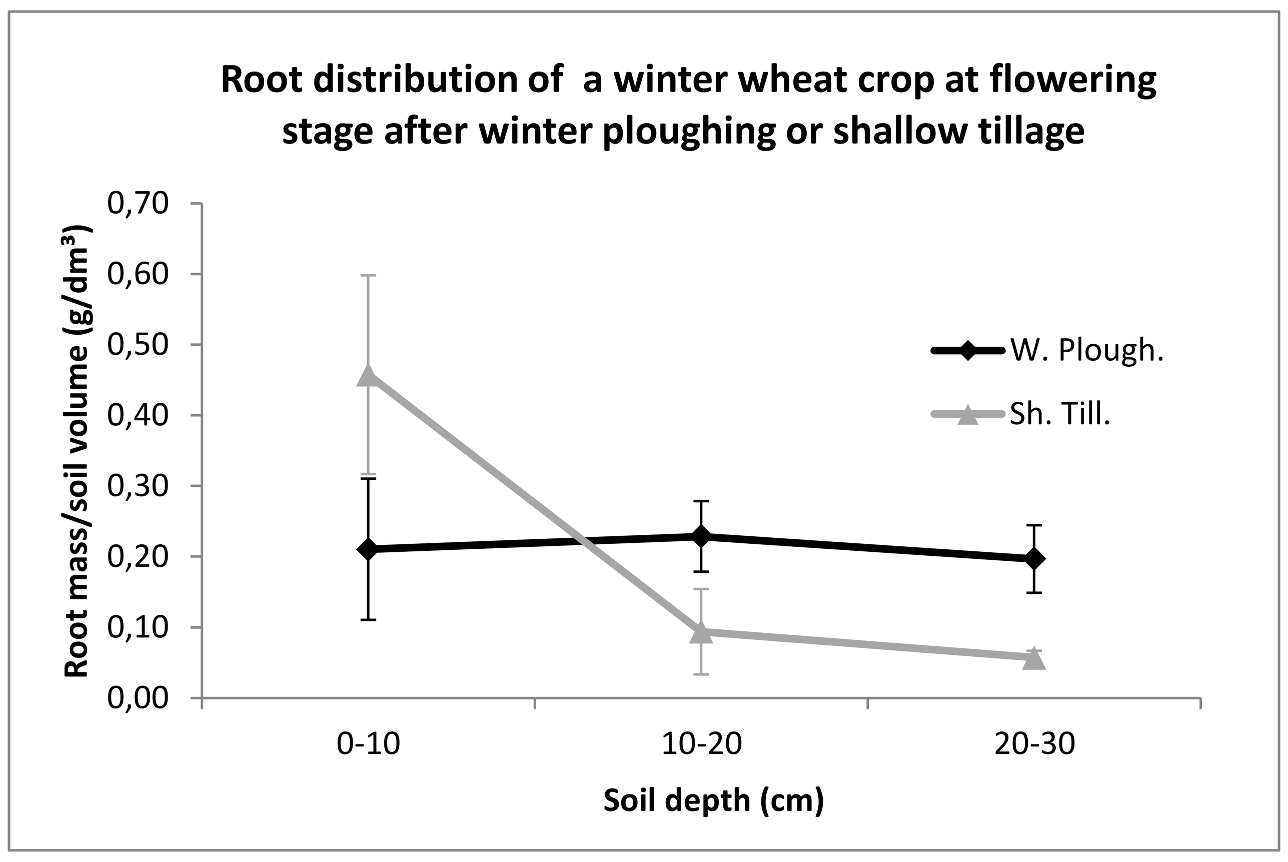
Winter ploughing
25 cm depth tillage

Shallow tillage
10 cm depth tillage

Root quantification

One NIR image was acquired for each soil sample and predicted with the classification tree. The number of pixels classified as roots was converted in terms of root dry mass by soil volume (g/dm³). Results showed a **homogeneous distribution of roots in the soil profile (0-30 cm) with winter ploughing** and a **concentration of roots in the top soil (0-10 cm) with shallow tillage.**

These results are helpful to understand **how crops adapt their root system after different tillage types.**



Conclusion and perspectives

The method based on **NIR-HSI and chemometrics** allows **faster quantification of roots than current manual sorting method** and is **not affected by operator subjectivity**. In this case of study, it allowed a rapid comparison of quantities of winter wheat roots after different tillage types. However, predicted quantities of roots must be used carefully when crop residues are present on NIR images because of spectral confusion between roots and the border of crop residues.

Based on spectral data, **this method could easily be used with other crops.** Preliminary studies have already been done with faba bean and associated crops of winter wheat and peas.

References:

[1] Vermeulen, P., Fernández Pierna, J. A., van Egmond, H. P., et al., 2012. Online detection and quantification of ergot bodies in cereals using near infrared hyperspectral imaging. *Food Addit Contam A*, 29(2), pp. 232–240.

[2] D. Eylenbosch et al.: 2014. Detection of wheat root and straw in soil by use of NIR hyperspectral imaging spectroscopy and Partial Least Square discriminant analysis In *Proceedings of the ESA 13th Congress*, pp. 237–238. Eds P. Pepó and J. Csajbók.

[3] J. A. Fernández Pierna et al.: 2012. NIR Hyperspectral imaging spectroscopy and chemometrics for the detection on undesirable substances in food and feed. *Chemometrics and Intelligent Laboratory Systems*, 117:233–239.