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 production 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

1

Sampling

Field sampling of soil cores

Extraction of roots and crop residues from soil with tap water

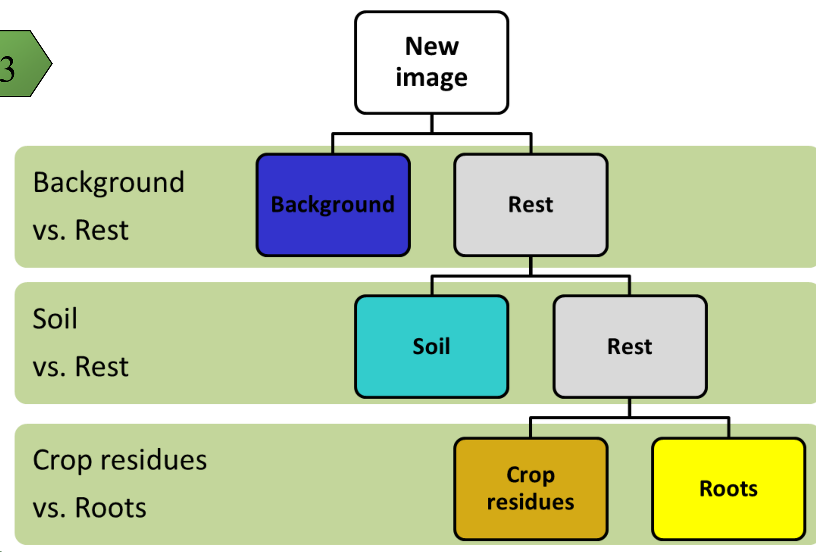
Drying of washed samples

2

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 (1100-2498 nm) is saved.

3



Spectra discrimination

A **dichotomist classification tree** based on **successive SVM discriminant models** is used to separate spectra into **distinct classes**: background, soil, roots and crop residues [2;3].

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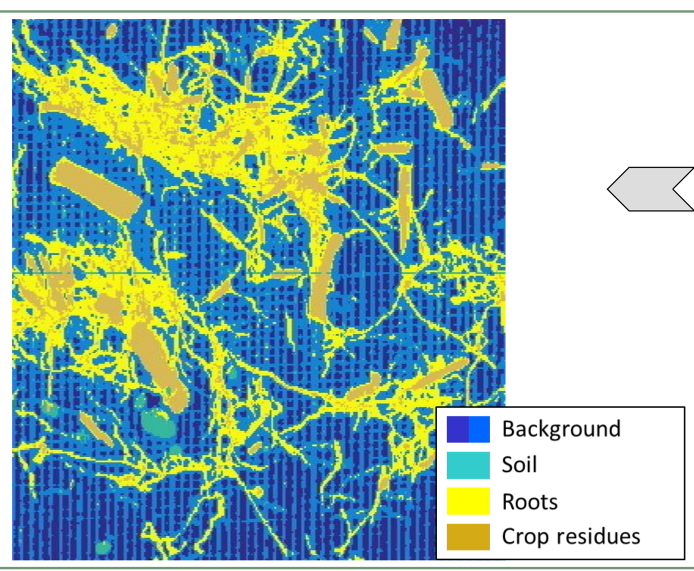
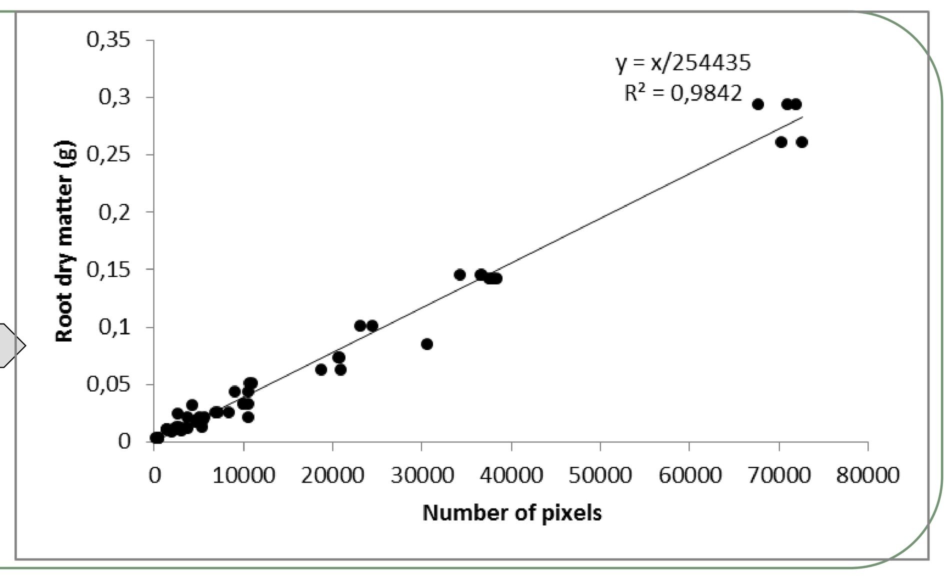


Prediction and quantification

A color is assigned to each class allowing the creation of **prediction images**.

Roots quantification is based on the number of pixels predicted as roots which is converted in an amount of dry matter thanks to a regression line.



Applications, results and discussion

Field experiment

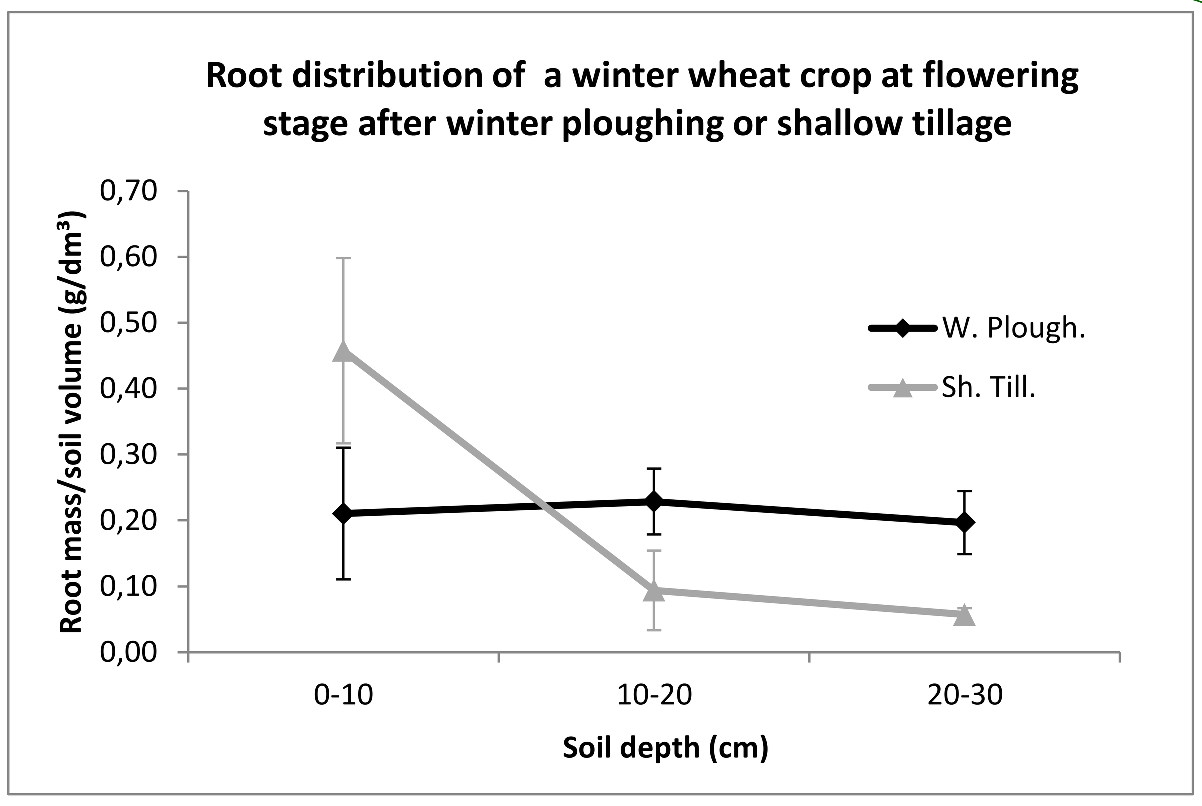
Soil samples were collected from a depth of 30 cm in a winter wheat crop in a long term field trial comparing conventional tillage and reduced tillage. Soil cores were divided into 3 soil horizons (0-10, 10-20 and 20-30 cm deep).

Winter ploughing
25 cm depth tillage

Shallow tillage
10 cm depth tillage

Roots discrimination

Images of washed and dried root samples were predicted with the SVM models organized in the dichotomist classification tree. Results showed an **important save of time** allowing to handle more samples, a **good discrimination of root spectra** (92% of root spectra were well detected) and a **good correlation between pixels detected as root and quantity of root in the sample** (R^2 = 0.98).



Root quantification

Predictions showed a **homogeneous distribution of roots in the soil profile (0-30 cm) with winter ploughing** and a **concentration of root in the top soil (0-10 cm) with shallow tillage.** These results are helpful to understand how crops adapt their root system after different types of tillage.

The method based on NIR-HSI and chemometrics allows **faster comparisons of quantities of winter wheat roots after different tillage types** than current manual sorting method.

Advantages and disadvantages of discrimination and quantification based on analysis of NIR hyperspectral images

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- Quicker than manual sorting
- No operator subjectivity during sorting
- Possible discrimination of roots from different species
- No destruction of samples
- Spectral data can easily be re-analysed when models are improved

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- Time consuming steps (field sampling, washing of soil cores and acquisition of NIR images)
- Some spectral confusion between the elements of the samples in shadow areas
- Underestimation during quantification if elements overlap on images
- Models need to be regularly recalibrated

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.