Detection of wheat root and straw in soil by use of Near Infrared hyperspectral imaging system and Partial Least Square discriminant analysis

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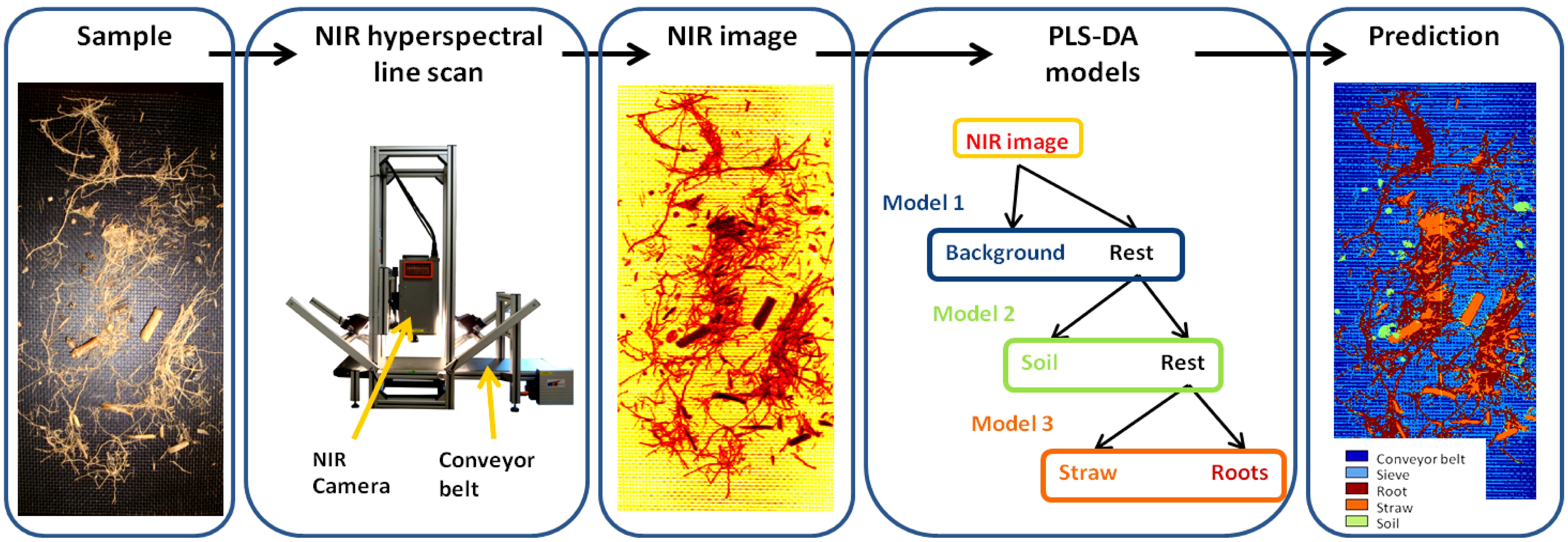
Introduction: In studies on tillage, **monitoring of root system development and crop residues decomposition** is very important to have a better understanding of crop nutrition. However, it is only possible if the different constituents can be discriminated from soil and then quantified. Current methods, based on soil coring, need to wash cores to extract individual elements (roots and straws) and then to manually separate and weight them (Huang et al., 2012). These methods are time consuming and dependent of the operator.

Objectives: Develop a **new, rapid and reliable method to detect roots and crop residues in soil** using **Near Infrared hyperspectral imaging system** (NIR-HSI) combined with **predictive models** based on the partial least square discriminant analysis (PLS-DA) chemometric's tool. This is a first step aiming to a possible quantification of the different materials.

Results: The succesive binary PLS-DA models developped in this study allowed a **good discrimination of NIR spectra from soil, roots and straw** after wheat crop (*Triticum aestivum* L.). Soil spectra are well predicted at 93%, straw at 75% and roots at 84% for an independant image (Table 1). As observed during the validation, the separation between straws and roots is not an easy task. This confusion appears mainly in the area bordering the elements and could be caused by the shadow and the close chemical composition of these constituents.

Table 1. Performances of the PLS-DA models for calibration and cross-validation as well as when it is applied to an independent test set in terms of sensitivity (proportion of spectra detected as positive for the positive class in the model) and specificity (proportion of spectra detected as negative for the negative class in the model).

	Calibration		Cross-validation		Validation	
Model	**Sensitivity**	**Specificity**	**Sensitivity**	**Specificity**	**Sensitivity**	**Specificity**
Background vs Rest	0.971	0.977	0.971	0.976	**0.992**	**0.935**
Soil vs Rest	0.990	0.985	0.989	0.986	**0.930**	**0.962**
Straw vs Root	0.917	0.879	0.916	0.877	**0.754**	**0.838**



Materials: Camera: **NIR Hyperspectral line scan** or push-broom combined with a **conveyor belt** (Vermeulen & al., 2012).

Methods:

1) **Acquisition of NIR spectra** from all classes: crop constituents (wheat roots and straw washed and dried), soil (dried and grinded), sieve and conveyor belt (background);
2) **Construction of a dichotomist classification tree** based on successive **PLS-DA models** (1000 spectra were used by class);
3) **Models validation** with and independent data set (500 spectra by class);
4) **Prediction on images** (spatial information provided by the NIR-HSI allows assigning different colours for the prediction of individual pixels in the images).

Conclusion: This preliminary work has permitted to detect, based on the NIR-HSI spectra, the presence of wheat roots and straws in a sample of soil, avoiding cumbersome manual separation. This is the **first step before a possible quantification of each material present in soil**, but for this, further research is needed to link the number of individual pixels detected on the NIR-HSI images as belonging to a certain class to the corresponding weight of the constituent in the sample. **This work is an important step in order to easily follow root development and organic matter decomposition in soil**.

References:
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