ESTIMATION OF SOIL PROPERTIES WITH NEAR INFRA-RED SPECTROSCOPY: APPLICATION AT FARM SCALE FOR PRECISION FARMING

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Introduction
NIR (Near Infra-Red) spectroscopy is a low-cost, fast and non-destructive analytical technology, currently used for agricultural products. Approaches with NIR technology to analyse soils were presented in the early nineties and are now increasingly used with improved estimation performances (e.g. Reeves et al., 1999). At the same time, technologies were developed for managing spatially variable yield-determining factors (precision farming). However, a limiting factor in the development of site-specific fertilisation is the high cost of soil analyses. The aim of this work was to explore advantages of site-specific fertilisation based on NIR analyses compared to conventional approach.

Methods
Soil samples were collected, air-dried and sieved at 2 mm in 1999 over the entire area (55 ha) of the experimental farm "A. Menozzi" of the University of Milano (Landriano, Pavia, Italy). The sampling was carried out on a regular grid (50 m × 50 m). The samples were analysed for organic carbon, total nitrogen and available phosphorous by using official reference methods (RM). Analyses were replicated two or more times until coefficient of variation was less than 5%. On the same samples sieved at 1 mm, NIR spectra were collected with a FOSS NIRSystem 6500 in the interval 1100-2500 nm at the resolution of 2 nm. Both multiplicative scattering correction and second derivative (SG 2,17) were performed on the spectra. C, N and P were estimated through a PLS regression with 100 samples for calibration/cross-validation and 133 samples for independent validation. The optimal number of loading factors for each variable was determined by leave-one-out cross-validation. We used Matlab 6.0 (Matworks, Inc.) with PLS_Toolbox 2.1 (Eigenvector Research, Inc.). A software and a database were designed and implemented to calculate the amounts of cattle slurry to be applied at each single field (or at each grid node) by comparing three different approaches:
1. ordinary field management based on one average datum per field (ORD);
2. site-specific management based on RM results at each grid node (REF);
3. site-specific management based on NIR cross-validated and validated results at each grid node (NIR).

The third approach is a practical possibility of precision farming, while the second is merely a research step due to its high costs. The software determines the amount of slurry-N to be applied by considering a simplified N budget (inputs: mineralization of soil organic N, residues and slurry; output: crop N uptake). N from mineral fertilisers ("mineral N") can be applied to integrate slurry-N. Slurry-P applied is derived by considering slurry N:P ratio. No slurry was applied when available P soil content was above 115 ppm, full dose (based on N budget) was applied below 85 ppm and intermediate amounts between.

Results
Statistics of RM and NIR results are reported in Table 1. NIR results for N and C are comparable with RM for agronomic purposes (standard error less than 10% of the population average). The performance of the method for P is semi-quantitative, but acceptable for discriminating samples in few classes of P availability.
Table 1 - Results of conventional analyses and NIR predictions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Reference methods</th>
<th>NIR-PLS</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>Cross-validation (n=100)</th>
<th>Independent validation (n=133)</th>
<th>R²</th>
<th>SECV</th>
<th>R²</th>
<th>SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>C (g/100 g)</td>
<td>1.130</td>
<td>0.3</td>
<td>2.410</td>
<td>0.939</td>
<td>0.079</td>
<td>0.89</td>
<td>0.088</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>N (g/kg)</td>
<td>1.219</td>
<td>0.5</td>
<td>2.220</td>
<td>0.908</td>
<td>0.088</td>
<td>0.89</td>
<td>0.079</td>
<td></td>
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</tr>
<tr>
<td>P (ppm)</td>
<td>74</td>
<td>10</td>
<td>170</td>
<td>0.779</td>
<td>16</td>
<td>0.770</td>
<td>15</td>
<td></td>
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</tr>
</tbody>
</table>

SECV and SEP are standard errors for cross-validation and independent validation, respectively.

Results of fertilisation plans are shown in Table 2. Total amount of N and P applied is very similar for REF and NIR. Traditional approach (ORD) generates greater application of slurry and lower application of mineral fertilisers because field averages of available soil P are always lower than the threshold of 115 ppm.

Table 2 - N and P applied with slurry and mineral fertilisers for the entire farm

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Slurry N (kg N)</th>
<th>Slurry P (kg P₂O₅)</th>
<th>Mineral N (kg N)</th>
<th>Mineral P (kg P₂O₅)</th>
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<tbody>
<tr>
<td>ORD</td>
<td>7557</td>
<td>4580</td>
<td>2776</td>
<td>0</td>
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<tr>
<td>REF</td>
<td>6773</td>
<td>4105</td>
<td>3442</td>
<td>0</td>
</tr>
<tr>
<td>NIR</td>
<td>6877</td>
<td>4168</td>
<td>3317</td>
<td>5</td>
</tr>
</tbody>
</table>

In Figures 1 and 2 the spatial variability of the amount of slurry-N applied is represented for each field: the differences between REF and NIR approaches are not relevant.

Figure 1 – Slurry-N applied, kg N/ha (REF)  Figure 2 – Slurry-N applied, kg N/ha (NIR)

Conclusions

NIR might be a reliable analytical technique for N management in precision farming, provided that robustness of calibrations can be maintained through a sufficient number of years to reach economic competitiveness.

References


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