Assessment of nitrogen nutrition index from biophysical variables obtained by remote sensing

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Theme 3 **Poster**

Assessment of Nitrogen Nutrition Index from biophysical variables obtained by remote sensing.

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Introduction

Precision agriculture's goal of matching nitrogen supply with crop requirements at any point in a field requires spatial information on the nitrogen status of the crop. Some operational methods (e.g. JUBIL®, Hydro N-Tester) have been developed at a field level but their implementation at a within-field level with a high spatial resolution is not conceivable. Remote sensing techniques combine with the inversion of reflectance models allow to estimate the values of leaf chlorophyll content on an leaf area basis (CHL_{La} : g chlorophyll/m² leaf), Leaf Area Index (LAI : m² leaf/m²soil) and, with a greater precision, the product of both, that is to say total canopy chlorophyll content (CHL_{La}×LAI : g chlorophyll/m² soil) (Jacquemoud *et al.* 1995). Since nitrogen has not a direct effect on reflectance (Baret and Fourty 1997), we aim to determine nitrogen status of the crop thanks to these variables. A reference index, the Nitrogen Nutrition Index (NNI), has been defined (Lemaire & Gastal 1997) in order to determine the nitrogen status of the crop by comparing its real nitrogen content (N_r) and a critical nitrogen content (N_c) : NNI = N_r/N_c. The latter is determined by the dilution curve and is a function of the aerial dry mass (W). This index has already been linked to CHL_{La} determined by remote sensing among several varieties (Gate 2000). The aim of this study was thus to determine different ways to calculate NNI from CHL_{La}, LAI or CHL_{La}×LAI and to evaluate their reliability.

Material and methods

Field trial

A field trial was conducted near Laon (north of France) on winter wheat (*Triticum aestivum* L.), Shango variety. Five nitrogen levels were used, from 0 to 300 kg $N.ha^{-1}$ after the last treatment. 60 kg $N.ha^{-1}$ were supplied at five dates, each of them differentiating a new treatment (March 6, March 20, April 11, May 5, May 24).

Sampling and data treatment

Four sampling were realised in April and May 2000. Plants was divided into shoots, leaves and ears. Measurements of LAI ($m^2.m^{-2}$), aerial dry mass (W, $t.ha^{-1}$), leaves nitrogen and chlorophyll content (N_{Lm}, $g.g^{-1}$ and CHL_{La}, $g.m^{-2}$), crop nitrogen content (N_r, $g.g^{-1}$) and NNI were realised.

Three different methods were developed to estimate NNI from CHL_{La} and LAI and the accuracy of the different relationships was compared using their Root Mean Square Error (RMSE). According to the fact that a nitrogen shortage begin when NNI=0.9 and that nitrogen nutrition is optimum when NNI=1.0, it seems reasonable to say that we have to predict NNI with a precision of at least 0.05.

Results

1) Direct relationship between NNI and CHL_{La}

For a given date, NNI can be described as follows : $NNI = a.\ exp^{\ b.CHL}$ [1].

This relationship was parameterised with all the points and the result gave an RMSE value of 0.12. No significant improvement occurred by parameterising *a* and *b* by sum of degree-days since emergence Σ(°C.day). This way of determination has to be improved.

2) Relationship between CHL_{La}, LAI and NNI

We tried to calculate NNI from CHL_{La} and LAI by the following way :

- NNI numerator : $N_r = f(N_{Lm}) = fog(CHL_{La})$ [2] ; RMSE = 21.6%
- NNI denominator : $W = a.\ ln(LAI) + b$ [3] ; RMSE = 10% (with $N_c = 5.35 \cdot W^{-0.442}$)

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Combining these two relationships to find out NNI, we obtained a RMSE of 0.15, *i.e.* worst than with the direct relationship.

3) Relationship between CHL_{La}×LAI, LAI and NNI

Considering that the product variable CHL_{La}×LAI is better assessed by remote sensing than CHL_{La} and LAI individually, we tried to deduced NNI from this product variable :

$$NNI = \frac{N_r}{N_c} = \frac{N_r \times W}{N_c \times W} = \frac{Total\ amount\ of\ \ N\ in\ the\ crop}{5.35 \cdot W^{1-0.442}} \qquad [4]$$

The numerator can be estimated from the product CHL_{La}×LAI which is the total amount of chlorophyll contained in all the leaves of the crop. The best result for the relationship $N_r{\times}W = f(CHL_{La}{\times}LAI)$ is obtained using as intermediary the amount of nitrogen contained in the leaves : N_{La}×LAI (leaves nitrogen content on an area basis multiplied by LAI) :

$$N_r{\times}W = f(N_{La}{\times}LAI) = fog(CHL_{La}{\times}LAI) \quad [5]$$

The first relation, $N_{La}{\times}LAI = g(CHL_{La}{\times}LAI)$ is quite stable with time, which is encouraging (Fig.1). The second relationship, $N_r{\times}W = f(N_{La}{\times}LAI)$, (Fig.2) can be parameterised by Σ(°C.day). It could also have been parameterised by the stage of the culture because the change of the relation is certainly mainly related to the evolution of the ration stem on leaf.

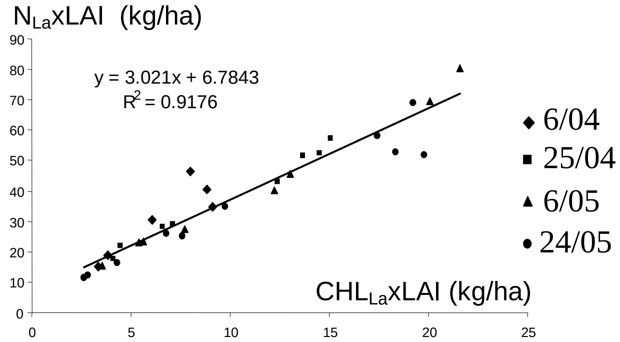

Fig. 1 : Amount of nitrogen in leaves vs amount of chlorophyll in leaves

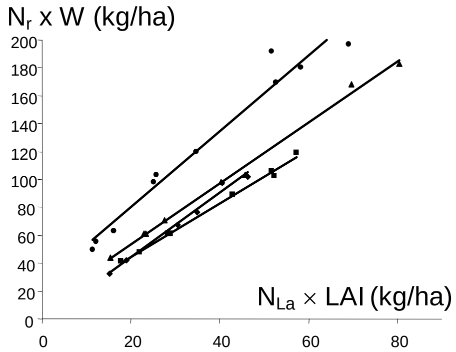

Fig. 2 : Amount of nitrogen in crop vs amount of nitrogen in leaves

Using relationships [5] and [3] and equation [4], the numerator of NNI is obtained with RMSE=9.1% and NNI with RMSE=0.10.

Conclusion

All the relationships presented above have to be improved if we want to estimate properly the nitrogen status of a crop from remote sensing data by the way of NNI, with an RMSE of at least 0.05. In particular, the relationships should be parameterised with the crop stages instead of Σ(°C.day) alone. However that may be, equation [4] is the most promising one because it is based on a value well assessed by remote sensing, it is less parameterised (more robust) than equation [2] and give the best result. Use of a crop model should improve the determination of aerial dry mass, W.

References

- Baret F., Fourty Th. (1997). Radiometric Estimates of Nitrogren Status of Leaves. Diagnosis of the Nitrogen Status in Crops, Chapter 12, G. Lemaire (ed) © Springer-Verlag Berlin Heidelberg.
- Gate Ph. (2000). La prise de décision face à la variabilité – exemples d'applications sur les céréales à partir de la télédétection. Actes du colloque UMR Cemagref-ENESAD, Dijon (France), 29-30 mai 2000. © Educagri Editions, BP 87999, F21079 DIJON Cedex.
- Jacquemoud S., Baret F., Andrieu B., Danson F.M. and Jaggard K. (1995). Extraction of Végetation Biophysical Parameters by Inversion of the PROSPECT+SAIL Models on Sugar Beet Canopy Reflectance Data. Application to TL and AVIRIS Sensors. Remote Sensing Environnement, 52:163-172.
- Lemaire G. and Gastal F. (1997). N Uptake and Distribution in Plant Canopies. Diagnosis of the Nitrogen Status in Crops, Chapter 12, G. Lemaire (ed) © Springer-Verlag Berlin Heidelberg 1997.