AN OFFLINE ALGORITHM FOR SITE-SPECIFIC NITROGEN FERTILIZATION OF WINTER OILSEED RAPE BASED ON AUTUMNAL CANOPY NITROGEN UPTAKE

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Introduction

Winter oilseed rape (WOSR) is grown in Germany on approx. 1.5 million ha (Statistisches Bundesamt 2010). Almost two-thirds of this is used as renewable resource for producing bio diesel (Fachagentur Nachwachsende Rohstoffe 2011). The bioenergy policy on the EU and national level therefore have an enormous impact on the profitability of this crop.
The EU Directives 2009/28/EC and 2009/30/EC regulate, with effect in 2017, that greenhouse gas (GHG) emissions savings from using biofuels shall be at least 50%. Applying default values for calculation, using bio diesel from WOSR reduces CO_2 emissions by only 38% (Directive 2009/30/EC). Therefore improving the GHG balance of the cropping system is essential for safeguarding the important biofuel market to WOSR.
Examining the calculation of standard values, there are two prominent items: Emissions from producing N fertilizer and N_2O field emissions sum up to more than 80% of total CO_{2eq} budget of WOSR cultivation (BioGrace 2008a). Therefore improving N efficiency is an obvious approach to improve GHG balances in WOSR production.

A recent study of Henke et al. (2009) extended by Sieling and Kage (2011) showed that under German conditions N uptake of WOSR in autumn can be taken into account for N fertilization in spring. The observed close correlation between autumnal N uptake and optimal N fertilization in spring (N_{opt}) shows that at the same location higher N uptakes lead to lower N recommendations and *vice versa*. This is quantified by the slope of regression-lines, which is identical for all years and locations. However the absolute level of optimal fertilization varies substantially between locations (Fig. 1).
Although knowing how to adjust N_{opt} using canopy N, for optimizing N-recommendation the local absolute fertilization level still needs to be estimated. Therefore regional known long-term average N uptake and the associated typical optimal N fertilization could be used. For adjustments on each field the comparison of typical and actual autumnal N uptake can be taken into account.

Site-specific fertilization seems a promising approach to improve nitrogen use efficiency above the level of a uniform optimal N fertilization without accepting yield losses. The experimental data referred above strongly suggest measuring autumnal N uptake as a suitable indicator for optimizing fertilization. The seasonal gap between measurement and fertilization caused this approach to be a so-called offline algorithm. Although commercial methods for non-destructive measurement of N uptake by the canopy have been available for several years, a convincing concept taking all this into account is still to be developed. Hence the aim of this study was to adopt the introduced principles for uniform optimization as published by Henke et al. (2009) to a site specific algorithm.

Material and methods

Algorithm development

Adopting the concept for uniform WOSR-fertilization into a site-specific offline-algorithm requires some changes in the used input parameters and their values (Table 1). New parameter values were estimated by using a site-specific data set of Müller et al. (2008). Analysis of this data also reveals potentials of the site-specific fertilization to reduce N amounts, which therefore are included in the algorithm. Hence using the algorithm decreased the mean N application rate compared to an optimal uniform fertilization.

Field experiments

The newly developed offline-algorithm was field-tested in 2008/09 on two and 2009/10 on six different commercial farms near Kiel in northern Germany. Autumnal N uptake was estimated by measuring canopy reflectance with the Yara N-Sensor®. Measurements were calibrated by analyzing geo referenced plant samples.

Three different treatments were tested in a strip-trial with 4 to 7 replicates on each field. In the treatment “Farm-level”, an *ex ante* estimated optimal uniform N fertilization was applied. The estimation included all information typically available to farmers and consultants as well as the results of Henke et al. (2009). Hence it should represent the best practice currently available for uniform fertilization of commercial farms and can be used for benchmarking the other treatments. The site-specific fertilization (“SSF”) used the offline-algorithm. In the “Reduced” treatment, the mean application rate of SSF was applied uniformly.

In spring, trials were established with farm equipment for fertilization. At harvest the farm’s standard combine harvester was used for threshing one or two core-strips out of each fertilization strip. Yield of each strip was weighed separately.

Calculations and statistics

Yield was standardized to 9% moisture and adjusted by 0.95 from plot-level to field-level. GHG emissions were calculated using the calculation scheme, standard values and pathways published online by BioGrace (2008a, 2008b, 2010). N fertilization and yields were taken from the experimental data. Other inputs were taken into account by calculating removal or using typical values for German cropping systems from the KTBL (2005, 2011). N_2O field emission was estimated by following guidelines for calculating direct N_2O emissions given by the IPCC (2006). Because standard values for crop residues from WOSR are lacking in the IPCC guidelines, they were taken from Gosse et al. (1999).

Net revenue was calculated assuming a revenue of 300 €/t rapeseed reduced by nitrogen costs of 0.75 €/kg N. Statistical analysis was done as pseudo one-way layout in R (R Development Core Team 2009) using the SimComp-package (Hasler 2009).

Results and discussion

Using the newly developed algorithm allowed a reduction of N-fertilization by 30 kg N/ha without yield penalties (Tab. 2). On the other hand, reducing fertilization uniformly by the same amount results in substantial yield losses. Calculated GHG emissions were reduced significantly by site-specific fertilization as well as by uniform reduction of N fertilization. However, site-specific fertilization achieved the highest GHG saving potential. While site-specific fertilization leads to even slightly higher net revenues than “Farm-level”, uniform reduction leads to net revenue losses of approx. 54 €/ha. Thus, in this experiment the average economic advantage of site-specific fertilization over uniform reduction sums up to 65 €/ha while additionally GHG emissions were even lower.

Conclusion
Ecological criteria continuously become more and more important for practical farming. To meet future requirements and safeguard important markets, cropping systems have to be optimized. Therefore a newly developed offline-algorithm was field-tested on different commercial farms in northern Germany. Applying the algorithm made it possible to reduce N fertilization without loosing yield potential. Although meeting the thresholds, a uniformly reduced N fertilization substantially decreased net revenue. In contrast site specific fertilization performed best on both, ecological and economical benchmarks.

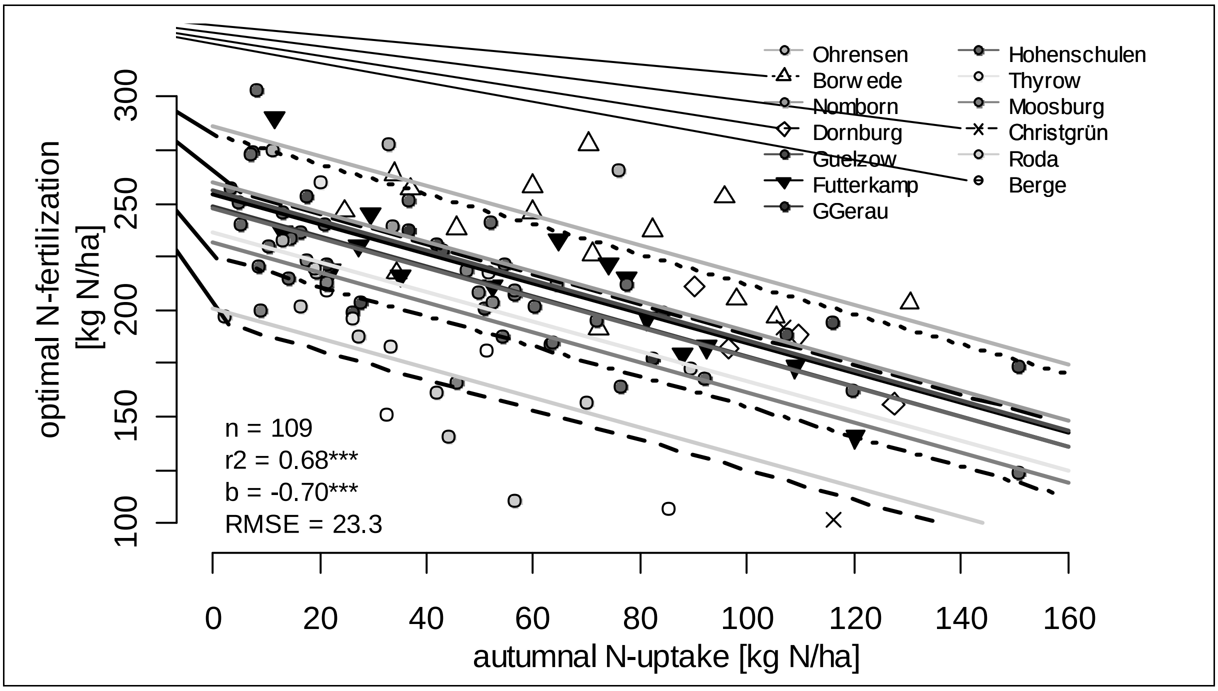

Fig. 1: Regression of optimal N-fertilization and autumnal N-uptake of winter oilseed rape. Field experiments on different locations in Germany in four years (Sieling and Kage 2011).

Tab. 1: Adoption of the concept for uniform fertilization to site-specific application.

Parameter	Uniform	Site-specific
Input measurement	Mean N uptake of field	Site-specific N uptake
Slope	Identical at all locations	Identical at all sites
Estimation of intercept	Typical mean N uptake	Mean N uptake of sites
	Typical optimal N fertilization	Mean of site-specific optimum
Output	Estimated uniform optimum	Estimated site-specific optimum

Tab. 2: N fertilization, yield, GHG emissions and net revenue.

Treatment	N fertilization [kg N/ha]	Yield [t/ha]	GHG emissions [g CO_{2eq}/MJ_{RME}]	Net revenue [€/ha]
Farm-level	218	4.88	43.4[a]	1322
SSF	188	4.84	40.7[b]	1333
Reduced	188	4.63	41.7[b]	1268

Means of treatment within a column followed by different letters are significantly different at P<0.05.

References

BioGrace (2008a): BioGrace_GHG_calculations_-_version_3_-_Public.xls. Available on: www.biograce.net/content/ghgcalculationtools/excelghgcalculations (accessed 2011-01-26)

BioGrace (2008b): Biofuels pathways RED method 14Nov2008.xls Available on: http://www.biograce.net/content/ghgcalculationtools/methodology (accessed 2011-01-26)

BioGrace (2010): BioGrace_standard_values_-_version_3_-_Public.xls. Available on: http://www.biograce.net/content/ghgcalculationtools/standardvalues (accessed 2011-01-26)

Fachagentur Nachwachsende Rohstoffe (2011): Anbau nachwachsender Rohstoffe in Deutschland. Available on:http://www.nachwachsenderohstoffe.de/fileadmin/fnr/images/aktuelles/medien/-RZ_Grafik_Anbau_2010_300_rgb.jpg (accessed 2011-03-02).

Gosse, G., P. Cellier, P. Denoroy, B. Gabrielle, P. Laville, B. Leviel, E. Justes, B. Nicolardot, B. Mary, S. Recous, J.-C. Germon, C. Hénault and P.K. Leech (1999): Water, carbon and nitrogen cycling in a rendzina soil cropped with winter oilseed rape: the Châlons Oilseed Rape Database. Agronomie, 19, 119-124.

Hasler, M. (2009). SimComp: Simultaneous Comparisons for Multiple Endpoints. R package version 1.4.3. http://CRAN.R-project.org/package=SimComp

Henke, J., K. Sieling, W. Sauermann and H. Kage (2009): Analysing soil and canopy factors affecting optimum nitrogen fertilization rates of oilseed rape (Brassica napus). Journal of Agricultural Science, 147, 1-8.

IPCC (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan

Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL) (2005): Faustzahlen für die Landwirtschaft. 13. Auflage.

Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL) (2011): Leistungs-Kostenrechnung Pflanzenbau online. http://www.ktbl.de

Müller K., U. Böttcher, F. Meyer-Schatz and H. Kage (2008): Analysis of vegetation indices derived from hyperspectral reflection measurements for estimating crop canopy parameters of oilseed rape (Brassica napus L.). Biosystems Engineering, 101, 172-182.

R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Sieling, K., and H. Kage 2011: Optimizing N fertilization of winter oilseed rape. 13th International Rapeseed Congress. Prague 2011.

Statistisches Bundesamt (2010): Fachserie 3 Reihe 3.2.1 Land- und Forstwirtschaft, Fischerei. Wachstum und Ernte. Feldfrüchte. Juli/August 2010.