COST- AND RISK-EFFICIENT NITROGEN FERTILIZER APPLICATION FOR CEREALS CONSIDERING FARMERS' RISK AVERSION

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Abstract

Nitrogen (N) fertilizer is an essential input for plant growth and farm profitability, while its effects on coping with economic risk mitigation has been under discussion. The present study analyzes economic response of rye and wheat to N fertilizer, and compares them with respect to risk mitigation potential. Due to quality induced premiums for baking quality for wheat, uncertainties of yield response and price resulted in higher expected profit with higher N rates than the optimal fertilizer level following the average response. Protein price incentives reduced the riskiness of higher N rates for wheat, whereas higher N rates led to lower certainty equivalents and higher downside risk for rye.

Keywords

Optimum, opportunity costs, certainty equivalent, conditional value at risk, downside risk.

1   Introduction

Optimal nitrogen (N) fertilizer application is a challenge, since it is hardly possible to maximize farm profits and at the same time to minimize risk of economic shortfalls. Ex-post calculated economically optimal N rates have often been found below conventionally applied rates by farmers. Understanding the economic optimum application of N fertilizer is essential to identify crop and site conditional management measures that can provide arguments why farmers may over-apply compared to what is found as profit maximizing rate in economic analyses. MEYER-AURICH and KARATAY (2019) showed that quality premiums -rewarded according to protein concentration in wheat grains- can lead to application of higher N rates to reach maximum expected profit. In this case, increased N rates did not necessarily increase the risk of economic shortfalls, whereas N fertilizer is commonly considered as a risk-increasing farm input (MONJARDINO ET AL., 2013). Nevertheless, for other grains, for which no quality incentive is granted, the implications may be different. This study aims to investigate the effects of uncertainty of yield response and price patterns, and farmers' risk aversion on optimal N fertilizer supply in rye production as a comparison to wheat.

2   Methodology

The present study utilizes the methodology proposed by MEYER-AURICH and KARATAY (2019) and expands its investigation for profitability and risk analyses of N fertilizer for winter wheat to another cereal commonly grown in the state of Brandenburg (Germany): winter rye. Yield data for wheat and rye were used to estimate production functions based on data published in LELF (2017) for five years (2012-2016) in the state of Brandenburg. Protein response functions for wheat were used based on the data from the same field trial. Three wheat prices were considered according to protein concentration in grains (%): A-quality (>13.5%), B-quality (13-13.5%), and F-quality (<13%), observed in nine years (LFL, 2019).

For each crop, costs and revenues were calculated according to the production functions estimated and crop prices for the selected years. Specific optimal N rates were calculated based on various decision measures addressing uncertainties on yield/protein response and crop prices. Profit maximizing N rates (N_{Avg}) were calculated based on average yield and protein response (protein for wheat only) and average crop price. Yield maximizing N rates (N_{YM}) were calculated as a reference depicting the highest crop yield achievable based on the estimated production functions. Profit maximizing N rates (N_{EP}) were computed based on maximum expected profit considering a combination of all possible response functions and

prices in the absence of any risk implementation. Utility maximizing N rates were calculated based on maximum certainty equivalent with an exponential utility function subject to the "stochastic efficiency with respect to a function" method (HARDAKER ET AL., 2004), generating N rates with a low (N_{CE_L}) and a high risk aversion attitude (N_{CE_H}), following absolute risk aversion coefficients of 0.001 and 0.004, respectively. As an additional risk measure, the Conditional Value at Risk (CVaR) was calculated for each crop to analyze the implications of different N rates on downside risk mitigation (MEYER-AURICH and KARATAY, 2019). Furthermore, opportunity costs for not reaching the profit maximizing N rates were calculated in order to illustrate the cost effects of deviating from the expected profit maximizing N rates (N_{EP}).

3   Results

Figure 1 presents the optimal N rates according to different measures described in the methodology section, the CVaR, and the change in expected profit due to deviations from the economic optimum for winter rye and winter wheat.
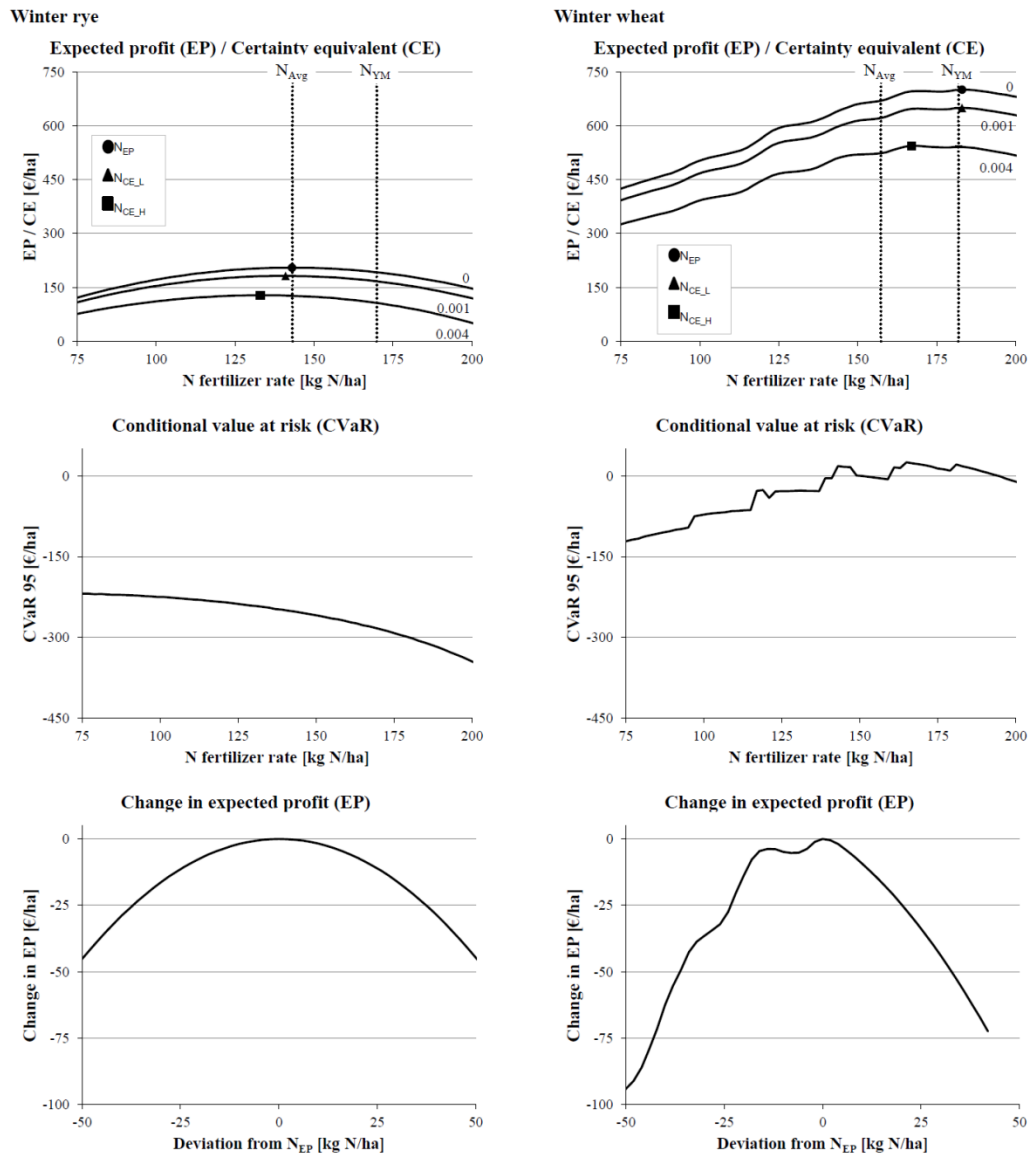

Figure 1:   Expected profit (EP), certainty equivalent, conditional value at risk, and the change in EP with deviations from optimum (N_{EP}) for rye and wheat

Source: Results for winter wheat were adopted from MEYER-AURICH and KARATAY (2019).

The expected profit maximizing N rates (N_{EP}) were found higher than the economically optimal N rates based on the average yield and protein response and price (N_{Avg}) for wheat, but lower for rye. The certainty equivalent (CE) considering low risk aversion showed no considerable difference to expected maximum profit (EP), while CE with high risk aversion was found lower for both crops. While higher N rates resulted in higher CVaR values for wheat until 180 kg N/ha, a risk-increasing effect of increased N rates was observed for rye, based on the CVaR. The change in expected profit due to change in the optimal N rate was smoother (flatter) for rye than for wheat over a broad range of N rates. The reason for this is that there are certain quality losses for wheat deviating from the EP maximizing N rate leading to lower crop prices which is not the case for rye. Opportunity costs of deviating from the respective optimum remain moderate for both crops, while the cost response of the deviation for rye was less pronounced. Farmers' different attitudes towards risk aversion did not result in considerably differentiated N rates for both crops.

4   Conclusions

Quality premiums for wheat provide incentives to fertilize at higher N rates, since they further flatten the profit function around the economic optimum, reducing risks of economic shortfalls with high N rates. Therefore, for wheat it is economically justified to fertilize for the good years. This offers some insight why estimated economic optimum based on yield function may be found lower than commonly applied N rates, if the crop quality aspect is not considered. However, in the absence of price premiums for quality, such as the case for rye, higher N rates lead to higher downside risk. In conclusion, wheat growers may tend to go beyond the ex-post estimated profit maximizing N rates securing on average higher protein content possible at the expense of environmental harms, unless they are forced to limit the N supply by legislation. However, rye growers may not similarly act to over-apply N fertilizer, since higher N rates may lead to economic shortfall increasing the riskiness of high N levels.

References

HARDAKER, J.B., J.W. RICHARDSON, G. LIEN and K.D. SCHUMANN (2004): Stochastic efficiency analysis with risk aversion bounds: a simplified approach. In: *Australian Journal of Agricultural Research* 48, 253-270.

LANDESAMT FÜR LÄNDLICHE ENTWICKLUNG, LANDWIRTSCHAFT UND FLURNEUORDNUNG (LELF) (2017): Jahresbericht 2016. Landwirtschaft. Ministerium für Ländliche Entwicklung, Umwelt und Landwirtschaft, Potsdam.

LANDESANSTALT FÜR LANDWIRTSCHAFT (LfL) (2019): Deckungsbeiträge und Kalkulationsdaten, Bayerische Landesanstalt für Landwirtschaft, München.

MEYER-AURICH, A. and Y.N. KARATAY (2019): Effects of uncertainty and farmers' risk aversion on optimal N fertilizer supply in wheat production in Germany. In: *Agricultural Systems* 173, 130-139.

MONJARDINO, M., T.M. MCBEATH, L. BRENNAN and R.S. LLEWELLYN (2013): Are farmers in low-rainfall cropping regions under-fertilising with nitrogen? A risk analysis. In: *Agricultural Systems* 116, 37–51.