Whole Farm Modeling of the Effect of Risk on Optimal Tillage and Nitrogen Fertilizer Intensity

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Introduction

Both nitrogen and tillage management have high impacts on the economic and environmental performance of agricultural systems and play important roles in the current discussion on mitigation of and adaption to climate change. Nitrogen fertilizers are important in terms of crop productivity, but they also have a negative impact on ground water quality through nitrate leaching and can be a driver of climate change through nitrous oxide emissions. Furthermore, the production of mineral nitrogen fertilizers is extremely energy intensive. Therefore, efficient use of nitrogen fertilizers is an important element of sustainable crop management. Like nitrogen fertilizers, tillage systems also play a significant role in the current discussion. Systems of reduced tillage have been proposed to reduce soil erosion, increase carbon sequestration in the soil and lead to cost savings from reduced inputs of machinery, labor and fuel. However, opportunity costs due to yield penalties of reduced tillage systems also must be taken into account. Furthermore, reduced tillage systems may require higher plant nutrient supply, which can lower their positive environmental and economic benefits. In terms of the risk associated with nitrogen management, available literature suggests that nitrogen fertilizer have a risk-increasing effect. So far only few studies investigated risk issues associated with different tillage systems. These studies show that the effect of risk on optimal tillage management is not as clear as it is for nitrogen management. Furthermore, there is little existing literature that analyzes the combined effects of tillage and nitrogen management. Therefore, the aim of this paper is to carry out a detailed risk analysis of long-term field experiments for various field crops (potato, wheat and corn) where different tillage and nitrogen management systems were tested. The results will show risk-reducing management practices which can be especially important as an adaption to increased production risk through climate change. In addition, the effect of farmers' risk aversion on the optimal decision will be studied. One of the key questions is, what is the extra value to farmers when they get recommendations for nitrogen application and tillage systems from models which represent risk aversion.

Material and Methods

Data for the study come from a long-term (14-year) experiment, established in 1992 at the Research Station Scheyern, 40 km north of Munich in southern Germany. Three tillage and three fertilizer treatments were arranged in a randomized split-plot design with three replications, where tillage treatments were randomly assigned to the main plots, which were split randomly by the fertilizer treatments. The investigated tillage systems represent three possible tillage intensities under the existing soil and climate conditions. One is conventional tillage system with mouldboard plough; the other two are "reduced tillage" and "minimum tillage". Fertilizer treatments were usual practice, with one increased and one reduced level of nitrogen fertilizer input. The crop rotation consists of wheat alternated with maize and potato so that wheat has been planted after maize and potato, while potato and maize have always been planted after wheat.

To analyze the effect of risk aversion on tillage and nitrogen fertilizer intensity we use an expected utility approach. Within this framework the decision maker's objective is to choose the management option which results in the highest expected utility. To facilitate interpretation of results we convert the expected utility values to certainty equivalent values.

The certainty equivalent is a theoretical money value that can be interpreted as the certain money payment that would leave a risk-averse producer indifferent between the payment and a risky prospect (crop production, in this case). Farmers are assumed to prefer the management system with the highest certainty equivalent. Using this approach we model a typical cash crop farm (average farm size: 54 ha; average farm subsidies per year: 22.990 €; average wealth per ha: 21.000 €) from the area where the long-term experiment has been established. The farm risk model represents yield and price risks. Furthermore, all statistically significant crop price correlations and crop price and crop yield correlations are represented in the model.

Results and Conclusions

From the results we conclude that lower nitrogen intensities have an increasing effect on the probability of negative net returns in systems of reduced and minimum tillage (for the whole crop rotation). Considering the probability of a negative net return as a risk measure, this means that higher nitrogen and tillage intensities are risk-reducing. This conclusion is also valid for most of the single crops analyzed. For conventional tillage (plowing) the usual fertilizer practice results in the lowest probability of a negative net return (except for wheat after corn), whereas reduced and increased nitrogen fertilizer rates (compared to the recommended nitrogen rate) have a risk-increasing effect on this benchmark. This means that either nitrogen can be considered as a risk-increasing or risk reducing input is depending on the existing tillage system.

Furthermore, we conclude from the results that a farmer’s risk level of aversion should have no effect on decision making regarding nitrogen and tillage management, since the ranking in terms of certainty equivalent values of analyzed management options does not change with increasing risk aversion. Regarding the whole rotation, conventional tillage with usual fertilizer practice is the dominant strategy for the whole range of analyzed relative risk aversion coefficients from 0 (risk neutrality) to 4 (very risk averse). This is due to the fact that the certainty equivalent values of net returns as a function of risk aversions show almost equal slopes for the analyzed management options. The consequence is that even for a very risk-averse farmer, the cost of using a risk-neutral model for decision making is zero. Therefore, we conclude that the effort of representing farmers’ risk aversion in this context is not worthwhile. These conclusions are not sensitive to the amount of subsidies farmers receive. Even a total cut of decoupled subsidies had no effect on the decision making about nitrogen and tillage management neither under risk neutrality nor under risk aversion (as long as farmers keep farming within this system).

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BACKGROUND

From literature we know that in most cases nitrogen fertilizers are a risk increasing input

⇒ Should we account for farmers' risk aversion when giving nitrogen fertilizer and tillage recommendations?

⇒ **What is the cost of using a risk neutral model in decision making?**

DATA

Data come from a long-term (14-years) experiment in southern Germany where three nitrogen and tillage systems (**conventional**, **reduced** and **minimum**) were tested.

Rotation: Wheat-Corn-Wheat-Potato

Tested Nitrogen Fertilizer Rates			
Crop	**low**	**medium**	**high**
		- kg N/ha -	
Wheat	90	135	180
Corn	60	100	135
Potato	50	100	150

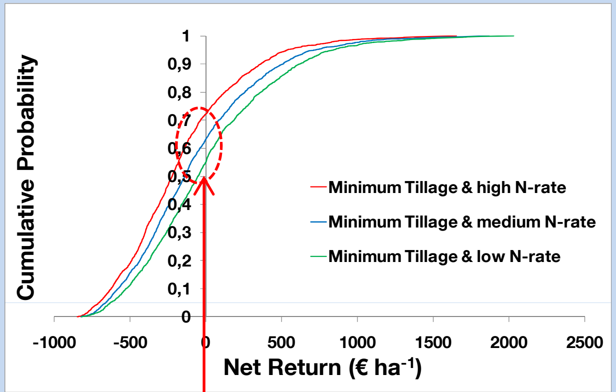
Assumptions for the **farm risk model** (expected utility framework):

average farm size:	54 ha
average farm subsidies:	22.990 €/year
average wealth per ha:	21.000 €
utility function:	negative exponential

The **farm risk model** represents **yield and price risks** and all relevant correlations.

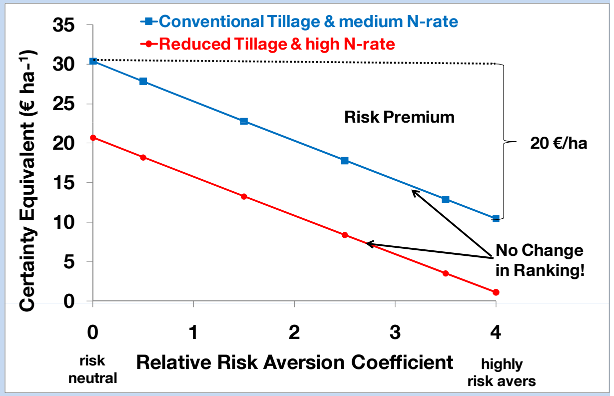
RESULTS

Cumulative probabilities of net returns for the analyzed tillage and nitrogen intensities for the whole rotation



=> lower nitrogen and tillage (not shown in the graph) intensities have an increasing effect on the probability of negative net returns!

Certainty equivalents of net returns for the whole rotation as a function of relative risk aversion*



* (only the best and second-best options are shown)

=> low slope of certainty equivalents as a function of risk aversion

=> no change in the ranking of management options due to increasing risk aversion

CONCLUSIONS OF THIS CASE STUDY

- farmers' risk aversion has no effect on decision making regarding nitrogen and tillage management
- a risk avers farmers' costs of using a risk neutral model for nitrogen and tillage management are zero
- there is no need for accounting for farmers' risk aversion when giving nitrogen fertilizer and tillage recommendations

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