

# Risk management for arable farms: Irrigation and weather derivatives

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**Abstract:** With the Water Framework Directive (WFD), the European Union has established a legal framework for the protection of all aquatic ecological systems including groundwater. In this paper the economic impacts of the WFD for irrigated agriculture with regard to the reduction of water withdrawal permits and various scenarios are analyzed. The results show that decreasing water permits cause decreasing total gross margins and increasing risks. To handle these additional risks, weather derivatives are a proper tool, but they cannot fully compensate the losses of total gross margins. The paper illustrates the potential of an IT-based whole farm risk programming approach that helps farmers to manage a portfolio of more or less risky activities in due consideration of their level of risk acceptance.

## 1 Introduction

Weather is a very important and non controllable production factor for crop farmers. Particularly in the northeast of Lower Saxony, early-summer and summer dryness arises pretty often, resulting in strong losses for crop farmers, so in the years 2003 and 2006. In order to protect their enterprises against the risks of unfavorable weather events and negative economic consequences, farmers in Germany use a set of risk management instruments such as the purchase of a hail insurance against yield risks [BS08]. Farmers in the northeast of Lower Saxony use irrigation systems to cover water scarcity. Here Germany's largest irrigation area has been established over the last decades [Eg99]. The water used for irrigation is predominantly taken out of the groundwater. In the context of stochastic weather conditions affecting crop production and farm income, irrigation has been identified as an important risk management strategy [GK08]. Under the WFD, a possible activity to protect water resources is, among others, a shortening of water withdrawal permits [BT10]. The use of weather derivatives as an alternative way to reduce yield risks caused by weather fluctuations is intensively discussed. Weather derivatives are financial instruments, like e.g. forward contracts, futures or options, which are used to exchange weather risks [Mu05]. In this paper we demonstrate the capabilities of an IT-based whole farm risk programming approach for managing a portfolio of more or less risky activities. It allows farmers to maximize the expected value of the total gross margin of their farm activities when weather risks occur, farmers

are risk averse, risk management instruments are available and constraints such as limited water withdrawal permits under the WFD have to be taken into account.

## 2 Methodology

In a whole farm risk programming approach the optimal production program with different kinds of risk management instruments can be determined. To measure the risk, the standard deviation of the total gross margin is used. Farmers have to manage a portfolio of more or less risky activities by having different crops in rotation or irrigating crops with different amounts of water and in a second step buying weather derivatives. This is incorporated into the model. To take the level of risk acceptance into account, a limit for the allowed standard deviation to the realized production program of the last years is set. Nine different production activities, weather derivatives and additional labor are implemented in our IT-based risk programming approach. Different limits for crop rotations, family labor, quotas and risk parameters are set as restrictions. In a further step, a variation of possible impacts of the WFD by varying the amounts of water withdrawal permits as a further restriction in the whole farm risk programming approach are incorporated. The whole farm risk programming approach can be described as followed:

$$\text{maximize} \quad E(TGM) = \sum_{j=1}^J E(GM^j) \cdot x^j \quad (1)$$

$$\text{subject to} \quad \sum_{j=1}^J a^{i,j} \cdot x^j \leq b^i \quad \text{with } i=1,2,\dots,I \quad (2)$$

$$\sigma(TGM) \leq \bar{\sigma}(TGM) \quad (3)$$

$$x^j \geq 0 \quad (4)$$

The aim of the approach is to maximize the expected total gross margin ( $E(TGM)$ ) which is composed of the expected gross margin of each crop ( $E(GM)$ ) weighted by the amount of hectares on which the crop is produced on ( $x^j$ ). To implement different kinds of risk acceptance into the approach, the standard deviation  $\bar{\sigma}(TGM)$  as accepted by the farmer is taken. This could be measured by referring to the production program of the last years. The intention behind this approach is to get the maximal expected total gross margin by staying at the same level of risk acceptance. In order to show possible water regimes within the WFD, different amounts of water are also restrictive in each calculation. In the approach the derivatives are offered with a load of 20 % on the fair premium. This load can be observed for example in Germany's hail insurance [We08] and, therefore, can be considered a realistic approach.

## 3 Data

Georg [Ge08] already specified a typical arable farm for the region under consideration.

The typical farm approach has been applied in numerous investigations of, for instance, international competitiveness of farming activities or the effects of political measures on agricultural enterprises [Is04]. In our example the farm has 180 ha land and permits to withdraw 144,000 m<sup>3</sup> of water for irrigation. In order to examine the economic consequences of a reduction of water withdrawal permits for the regarded farm, the permits are varied. Scenarios with water permits of 80 mm, 40 mm, 20 mm and the complete dismissal of the irrigation are analyzed. With its current production program (25 % potatoes, 16 % sugar beets, 22.3 % summer brewing barley and 36.7 % winter barley), a typical farm can generate an expected value of the total gross margin of 184,899 € by having an accepted standard deviation of 24,918 €. The yields implemented in the analyses are based on experimental farming results in the region under analysis in the 1982 to 2006 period (for further details see [BK10]).

## **4 Results**

The shortening of water withdrawal permits has considerable consequences for the gross margins of crop-farming enterprises. Furthermore, the reduction of water withdrawal permits raises risks in crop production [BT10]. Without having the option to buy derivatives, the total gross margin of the farm would decrease by about 75.5 % (down to 43,505 €) by staying at the same level of risk if irrigation was fully dismissed. In order to protect farmers against dryness, weather derivatives are discussed as a possible alternative risk management instrument [BS08]. In the baseline scenario (80 mm) the farmer does not have any incentive to buy weather derivatives, because the irrigation covers the whole yield risk. When water withdrawal permits are cut by 50 % (40 mm), the effects of weather derivatives are quite small, because the farmer uses them to cover less irrigation-efficient production activities, such as winter barley. Stronger cuts such as shortening withdrawal permits to 20 mm increase the demand for weather derivatives, because in this scenario the profitable and risky cultures such as sugar beets and potatoes have to be grown without irrigation. In the 0 mm-scenario weather derivatives can bring a higher expected value by staying at the same amount of risk. If the farmer gets the opportunity to buy a weather derivative with a load of 20 % on the fair premium, the total gross margin of the farm rises by about 17% or 7,396 € compared to the scenario without derivatives. In this scenario the farmer cultivates more risky but more profitable crops, such as potatoes, and does less set asides.

## **5 Conclusions**

This paper shows that weather derivatives could be instruments to lower the economic impacts caused by decreasing water withdrawal permits in the northeast of Lower Saxony. On the basis of an IT-based risk programming approach, risk management instruments for crop farmers can be evaluated. The potential of irrigation to increase yields and to protect yields against drought turns out to be quite high in the investigation area. If a shortening of water withdrawal permits would be implemented, weather derivatives could be an instrument for crop farmers in Lower Saxony to manage their yield

risks effectively. Nonetheless, weather derivatives cannot fully compensate the effects of reduced irrigation on the total gross margin. Therefore, from a farmers' perspective a continuation of the currently quite ample policy of granting water withdrawal permits would be the economically most attractive solution. The groundwater reservoirs in the region under analysis are currently under intensive observation. Depending on the final judgment on the quantity of groundwater reservoirs, water withdrawal permits may have to be reduced. In this case, the proposed IT-based risk programming approach can help farmers to make economically sound decisions on adjusting their production program and using other risk management instruments, like e.g. weather derivatives.

## Literature

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