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Irrigation of farm land under the EU Water Framework Directive

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. This directive may have advantages for the water regime in ecologically sensitive areas but may also bring some economic disadvantages for farmers. The economic implications of the WFD for irrigated agriculture with regard to various scenarios and the implementation of alternative water policy measures are analysed. The results show that demand for irrigation water, farmers' reactions with regard to operational and strategic decisions and income effects strongly depend on the water policy measures implemented.

Key words: farm income, irrigation, linear programming, Water Framework Directive, water permits, water price.

Introduction

Irrigation has been of growing importance in the EU agriculture, especially in the Mediterranean area [Bazzani et al. 2005]. But even in the Western Europe, irrigation is of some relevance. In Germany, for instance, 4 % of farmland is irrigated [Garrido 2005]. The main irrigation area is located in the north-eastern parts of Lower Saxony, where in some areas more than 90 % of farmland is irrigated [Eggers 1999]. Due to irrigation, intensive agriculture could be established in this region despite poor natural conditions, such as summer droughts and sandy soils.

Regions with farmland irrigation are potentially subject to the EU Water Framework Directive (WFD). This directive was established in 2000 in order to protect all aquatic ecological systems. It defines chemical, ecological and quantitative indicators for assessing the quality of surface and groundwater. In Lower Saxony, water for farmland irrigation is usually taken from groundwater reservoirs. If this results in quantitative changes, the WFD pledges that responsible water authorities will implement programs to increase the quantity of groundwater [Rumm et al. 2006].

The potential impact of the WFD has gained much attention in agricultural economics [Dinar & Mody 2004; Meijias et al. 2004; Moss 2004; Hanley et al. 2006]. So far, the effects on agriculture have been analysed mainly for Mediterranean countries [Dono & Severini 2008; Bazzani et al. 2002]. These studies show that demand for irrigation water is highly inelastic in Mediterranean countries. Therefore, it is hypothesized that higher water

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prices will result in considerable additional costs for farmers but in only very little investment in water-saving technologies or moves towards more water-efficient crops [Garrido 2005]. Up to now, the potential consequences of the implementation of measures for protecting groundwater resources have not been analysed for the Western European countries. Therefore, in this paper we analyse effects the implementation of alternative measures under the WFD, i.e. reduced water permits or higher water prices, for Western European countries will have on water demand and agricultural incomes in north-eastern Lower Saxony. The knowledge of these effects is relevant for assessing the ecological effectiveness of both measures as well as their acceptance by farmers. Based on a linear programming approach, we demonstrate how a typical farm in the region under analysis will react to alternative water protection measures.

Methodology

In agricultural economics, various approaches for modelling the effects of alternative policies have been developed. In this paper we refer to a farm-level linear programming approach. The program allows for an optimization of the farm under analysis and an analysis of effects of policy changes, improvements in productivity and changes in input factors and product prices. The analysis is restricted to a 10-year period [Muench 2003]. Based on irrigation experiments [Fricke & Heidorn 2003], three irrigation alternatives were included in the linear programming approach: no irrigation, extensive irrigation and intensive irrigation. This enabled us to identify optimal production decisions taking into account the costs and benefits of irrigation and restrictions (for instance, limited water permits). The goal function was defined as the maximization of farm's total profit margins.

The program distinguishes between operational and strategic adaptations to changing water policies. Operational decisions are short-term decisions; no (dis-)investments are taken into account and existing supply obligations under longer-term contracts or quota systems are respected as long as this is possible from an agronomic perspective. Strategic adaptations also include (dis-)investments, termination of contracts and/or sales of quotas. Farmers' reactions are analysed for various scenarios defined by alternative water policies (restricted access to water or higher water prices) and alternative price scenarios. Both operational and strategic decisions were modelled for a six-year period (2008 through 2013).

In the analysis we apply a typical farm approach. This approach includes the definition of an individual farm that is typical of the region under analysis with regard to crop rotation, farm size and other characteristics. This approach has been successfully applied in a considerable number of studies on the competitiveness of farms and their adaptations to policy changes [Hemme et al. 2000; Ebmeyer 2008]. We assume a farm size of 280 hectares (ha); 60 ha are owned and 220 ha are leased. the average soil quality is 33 on a scale of 1 (= extremely bad) to 100 (= extremely good). Farm labour is provided by family members (1.7 workers) and hired labour (1 worker). The farm owns sugar beet (1980 tonnes p.a.) and starch potato quotas (1050 tonnes p.a.). Crop rotation includes winter wheat (10%), winter barley (15%), brewing barley (7%), rye (22%), winter canola (5%), sugar beets (16%), potatoes and starch potatoes (each 12.5%). Yield assumptions for each crop are based on regional crop growing experiments and expert opinions.

In order to analyse farmers' reactions to water policies under the WFD, various scenarios were taken into account. In a baseline scenario we analyse the current situation with regard to water policies (irrigation up to 80 mm per year; water price EUR 0.00511/m^3). Then we analyse four alternative restrictions for water consumption: no irrigation at all, unlimited irrigation, 60 mm per year and 40 mm per year. Furthermore, we analyse the effects of higher water prices (up to EUR 0.25/m^3, i.e., up to 50 times higher water prices than in the baseline scenario). Since farmers' incentives to irrigate crops strongly depend on prices for agricultural products, we assume two different price scenarios: a baseline scenario (wheat EUR 180/t, rapeseed EUR 320/t) and a low-price scenario (wheat EUR 120/t, rapeseed EUR 210/t). The outcomes of all scenarios are assessed under two criteria: development of water demand and farm income. The latter is discounted in order to improve the comparability of different scenarios.

Results: Operational adaptations by farms

Water demand

Water use in agriculture depends on agronomic factors, such as the water demand of different crops, and economic considerations; the latter take into account the costs (including water price and energy costs) and benefits (yield and quality effects) of irrigation. Cost-benefit considerations have to comply with the regulatory framework, for instance limited rights to use groundwater for irrigation. The WFD seeks to internalise the negative external effects of irrigation by setting higher water prices that reflect the true societal costs of the use of groundwater (Pigou tax). In the Mediterranean area, higher water prices motivated a more efficient use of water, whereas flat pricing systems, which calculate farmers' water bills on a per ha instead of a per m^3 basis, did not have positive motivational effects [Saraiva & Pinheiro 2007].

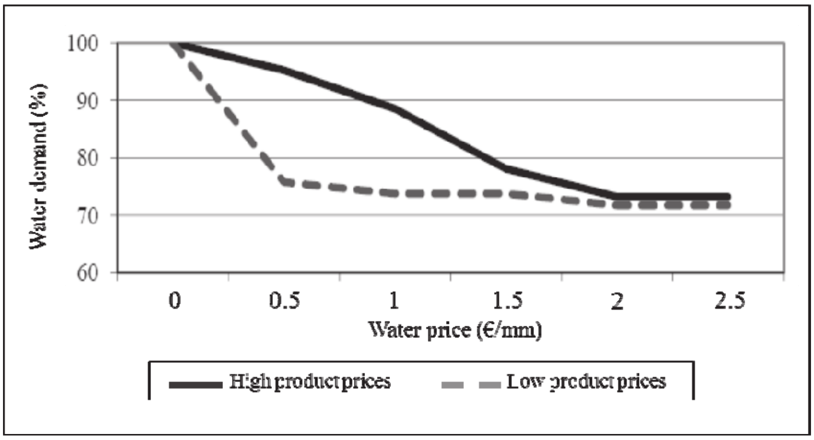

Fig. 1. Water demand as a function of water price under different product price scenarios

The results show that the ability to reduce water demand through higher water prices is limited and that setting prices can therefore be a tricky matter. Water prices that are able to motivate farmers to an efficient use water in the low-price scenario are ineffective in a high-price scenario. Since responsible water authorities cannot adjust water prices very quickly in reaction to volatility in the prices of agricultural products, the effectiveness of a pricing system seems questionable.

Income effects

Reduced water permits limit the farmers' production opportunities and induce changes in crop rotation. Figure 2 shows that farm profits strongly depend on irrigation. Compared to the baseline scenario, reductions in water permits result in lower farm profits. Water-intensive crops, such as potatoes, vegetables and sugar beets, are most strongly affected by measures under the WFD. They will be replaced by crops with less water demand if water permits are reduced.

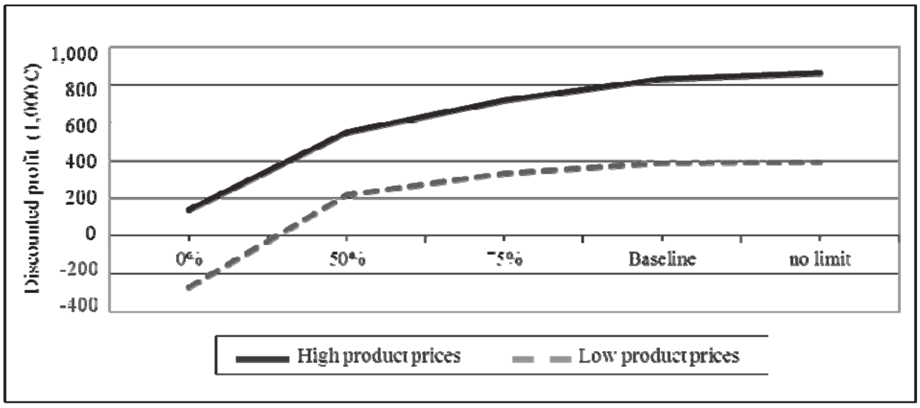

Fig. 2. Reduced water permits and discounted profits for the 2008 through 2013 period

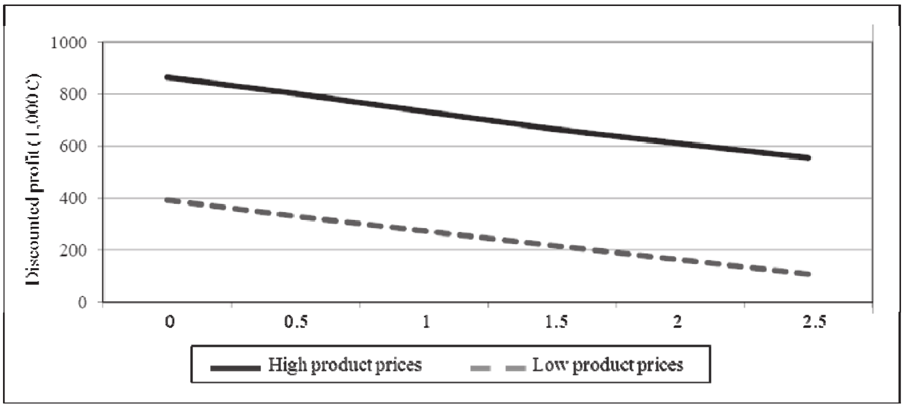

Fig. 3. Different water prices and discounted profits for the 2008 through 2013 period

Higher water prices increase production costs and result in income losses for farmers. Figure 3 shows that farms will barely be profitable if prices for agricultural products, especially grains and oilseeds, are low.

A comparison of both measures reveals that they have very different effects on farm profits. Due to the extremely inelastic demand for irrigation water for tuber crops, the effects of higher water prices are similar to a linear tax on farm income until these crops become economically so unattractive that they are replaced in crop rotations. Reduced water permits can have varying effects. Compared to the baseline scenario, income effects are low if water permits are reduced moderately. If water permits are reduced by more than 50 %, however, farm incomes decline remarkably. The differing effects of moderate and higher reductions of water permits are due to differences in economic incentives to irrigate crops and in marginal utilities of water for different crops. If water permits are reduced, farmers will first reduce irrigation for crops which are economically least efficient. These crops will receive less water or be removed from crop rotations, resulting in relatively low reductions in profit margins. The more water permits are reduced, the more it is necessary to reduce irrigation of water-intensive but highly profitable crops (for instance potatoes).

Results: Strategic adaptations by farms

Strategic adaptations

If farmers are convinced that environmental policies will permanently change their external environment, they will not only optimise their crop rotation decisions but also adapt their farm strategies [Theuvsen & Inderhees 2008]. In our study, the following strategic reactions to reduced water permits were analysed.

- Leasing of the sugar beet quota: when yields decrease to 4 tonnes per hectare or lower, it is more profitable to lease the sugar beet quota instead of producing sugar beets. It is assumed that leasing the sugar beet quota will result in a reduction of prices for lease land by EUR 36 per hectare. This is because prices for leasehold are derived from the net profits that can be achieved by cultivating the land. Leasing prices for sugar beets are EUR 4 per tonne per year. When no sugar beets are produced, machinery can be disinvested.
- Termination of potato production: the tractor and machinery required for potato production are sold in order to reduce fixed costs.
- Lay-off of non-family workers: due to the reduced work intensity in the strategically adapted farm, the farm can be run solely with family labour.
- Changes in crop rotation: due to the termination of sugar beet and potato production, winter grains and winter canola dominate crop rotation.
- Due to quality problems, summer brewing barley is excluded from crop rotation in the event of irrigation not being allowed.

Water demand

The strategic changes made by the farm described above have effects on water demand depending on water prices and the prices of agricultural products. It becomes apparent in Figure 4 that, after the strategic redesign, water demand decreases remarkably even without increases in water prices. This is due to the lower share of water-intensive crops grown after the adaptation of farm strategies. Furthermore, the elasticity of water demand increases due to the dominance of grains and oilseeds in the crop rotation. This effect is strongest when prices for agricultural products and, as a consequence, incentives to irrigate crops are low.

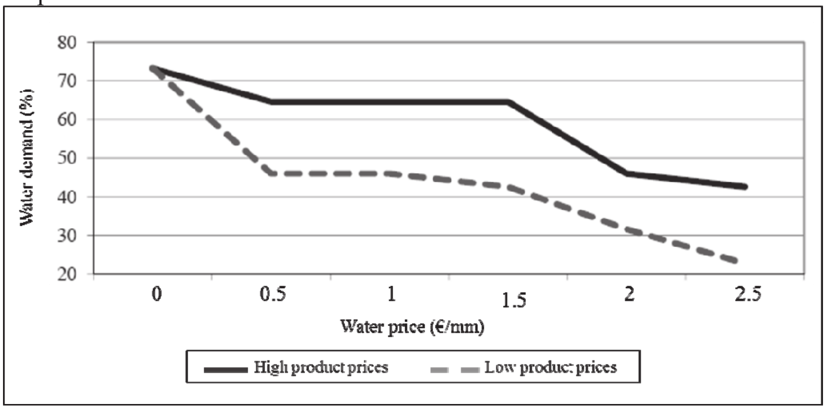

Fig. 4. Water demand as a function of water price in case of different product price scenarios after strategic adaptation

It can be reasonably argued that the strategic adaptations will occur more often in the peripheral areas of the region under analysis and less frequently in the core region. Thus, the effects of higher water prices will be lowest where there is the greatest need for reduced water demand for irrigation. Contrariwise, the effects will be the strongest where the use of groundwater reservoirs is the lowest. This implies a comparatively low ecological effectiveness of water price as a regulatory instrument.

Income effects

Figure 5 shows that the strategic adaptations allow farmers to stabilize their income despite lower water permits if prices for agricultural products are high. In such cases, the new strategy is most profitable if irrigation is reduced by 25% to 60 mm per year. Compared to the baseline scenario, profits will increase by about 7.6%. Only if irrigation is reduced by more than 50% are farm profits considerably reduced. The stabilization of income is due to a reduced need for irrigation after strategic adaptation: grains and oilseeds are much more water efficient than the potatoes and sugar beets they have replaced in farmers' crop rotations. Thus, the strategic adaptations allow an economically sustainable development of farms in the region under analysis despite reduced water availability if prices for agricultural products are high.

The situation is completely different if product prices are low (Figure 6). In such cases, farm incomes decrease considerably despite the implementation of new strategy. Changing to more water-efficient crops and terminating the cultivation of water-intensive crops such as sugar beets and potatoes results in an economically unsustainable situation for a typical farm under analysis. This will foster faster structural changes in agriculture.

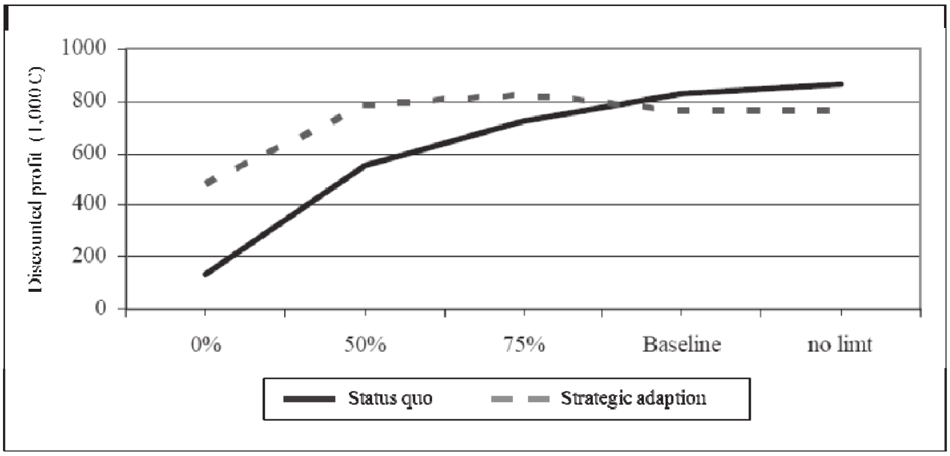

Fig. 5. Discounted profits for the 2008 through 2013 period after strategic adaptation in the event of high prices for agricultural products and reduced water permits

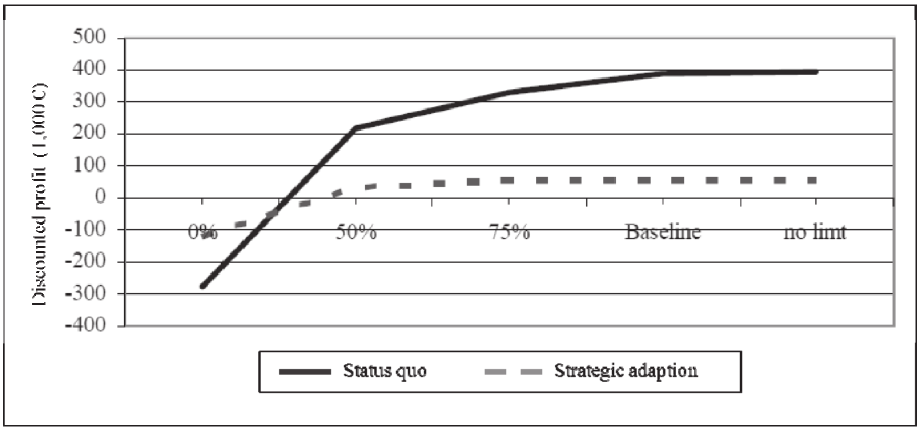

Fig. 6. Discounted profits for the 2008 through 2013 period after strategic adaptation in the event of low prices for agricultural products and reduced water permits and

Discussion and conclusions

The EU has incrementally tightened its water policy through the enactment of such measures as the WFD. In this study, it has been shown that measures that seek to protect groundwater reservoirs motivate farmers to use water more economically. But the results also show that the operational and strategic adaptations induced by such measures can have considerable effects on farms in the region under analysis. These effects are most severe if the prices of agricultural products are low. When this is the case, farmers have no chance to fully compensate for reduced water permits or higher water prices and face major reductions in profit margins and farm incomes. This can have devastating effects on farmers' acceptance of measures for the protection of groundwater reservoirs. Since irrigation is crucial for satisfactory farm incomes and serves as an important risk management instrument in a region characterized by summer dryness and sandy soils [Battermann et al. 2011], farmers will strongly oppose political attempts to reduce the use of groundwater for irrigation.

The analyses also show that the implementation of measures for the protection of groundwater reservoirs results in an extensification of agriculture. Capital and work intensive tuber crops are replaced by extensive forms of grain and rapeseed production. Further effects can be expected in the local agribusiness. Whereas starch potatoes and sugar beets are processed locally, grains and rapeseed are processed elsewhere. Thus, reduced irrigation can also have indirect negative effects on the regional economy. How to weigh the positive ecological effects on the one hand, against the negative economic effects of reduced irrigation on the other, is a political decision.

The WFD allows the implementation of regulatory instruments (reduction of water permits) as well as economic instruments (higher water prices). This study strongly supports the view that regulatory instruments are a more effective way to protect groundwater reservoirs. The effects of higher water prices can be offset by high prices for agricultural products. In this case, the ecological effectiveness of higher water prices is very low. Similar effects have already been shown with regard to other agricultural input factors, such as mineral fertilizers. Since prices for water or mineral fertilizers only indirectly influence the farmers' behaviour (i.e. an efficient use of groundwater or a reduction of nitrogen surpluses), their ecological effectiveness is low [Schou et al. 2000]. Especially in the case of high product prices, regulatory instruments, like a reduction of water permits or a limitation of nitrogen surpluses, are more effective. Regulatory instruments are also more effective if farmers' willingness to pay for input factors is very high due, for instance, to product quality reasons [Schmid 2001]. Therefore, higher prices for input factors should only complement but not replace other instruments, such as a reduction of water permits. The price instrument is then used for motivating the efficient use of limited water resources. Water permits will be transferred to those farmers who have the highest willingness to pay for groundwater, and water will be used in the most efficient way, that is, where its marginal utility is the highest. Similar effects were observed after the introduction of pollution rights in the United States [Lal 2009].

On principle, this study proves the effectiveness of the measures allowed for by the WFD but also reveals a strong conflict between the ecological and economic goals. Since agriculture still has an above-average relevance in the structurally weak region under analysis, the search for a compromise between economic and ecological sustainability is paramount. One way of their reconcilement could be to improve the efficiency of irrigation (for instance drip irrigation instead of sprinklers). Another solution could be to use alternative water sources, like waste water or surface water from the nearby rivers or canals. Subsidies for more efficient irrigation technologies or the provision of alternative water sources could also help to improve the compatibility of economic and ecological goals.

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