PRODUCTION ECONOMICS AND ENVIRONMENTAL IMPACT OF IMPROVED DRIP IRRIGATION AND FERTILIZER MANAGEMENT IN POTATOES

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Abstract

The objective of this study was to assess the economic and environmental sustainability of new drip irrigation and fertigation systems (applying the mineral nutrient solution with irrigation water through driplines) compared with conventional nitrogen application and irrigation systems under regional conditions in six European regions: Czech Republic, Denmark, Italy, Poland, Portugal and Slovakia. Focus is put on potatoes because the negative environmental effect in this crop is relatively high. This study indicates that the costs of applying drip irrigation and fertigation systems are relatively high compared with conventional gun irrigation systems. However, the yield simulations based on the field trials and local conditions have also indicated that the potential yield increase from drip irrigation and fertigation seems promising in many regions. Based on these findings it is clear that the implementation of new technology must be adapted to local conditions regarding field size, farm practice and climatic conditions.

Keywords: drip, irrigation, fertigation, new technologies

Introduction

European agriculture faces many challenges regarding the environmental performance of the agricultural sector. The productivity and yields have increased tremendously in many regions followed by negative impacts on the surrounding environment such as groundwater pollution from pesticides and nitrate leaching, and negative impacts on biological diversity. The demand from the surrounding society is to improve a sustainable production without harming the natural environment.

Improved water and nutrient management have for many years been key issues for sustainable development in European agriculture. This study is a part of a European research project (www.fertorganic.org) to enhance the use of fertilisers and to develop new management strategies to improve the water and nitrogen application in high value crops. Focus is put on potatoes because the negative environmental effect in this crop is relatively high.

The objective of this study was to assess the economic and environmental sustainability of new drip irrigation and fertigation systems compared with conventional nitrogen application and irrigation systems under regional conditions in six European regions: Czech Republic, Denmark, Italy, Poland, Portugal and

Slovakia. Among the six case regions, Poland is by far the largest potato producer in Europe in terms of potato area and total production. On the contrary, Slovakia is among the smallest producers.

Methodology

The economic feasibility study and cost-effectiveness analysis is based on case areas and model farms in each of the six regions. Each case area is represented with a model farm which has its own characteristics. The model farm is assumed to reflect the local conditions, farming tradition and soil characteristics in that particular region. Moreover the model farms should reflect the cropping practices in the areas near each field site that have been used for yield response and nitrate leaching simulations for different application strategies (Daisy-model). Daisy is an agro-ecological model that has been calibrated as part of the project for local soil and potato varieties for each of the six field sites. The model is capable of calculating (among other things) yield and nitrate leaching as a function of climate, soil and farm management (Abrahamsen et. al 2006).

The purpose is to examine the yield potentials and cost levels for irrigation on model farms in the specific regions of Czech Republic, Denmark, Italy, Poland, Portugal and Slovakia. The model farms enable us to compare drip irrigation and gun irrigation on each site.

In Czech Republic, the model farm is located in Bohemo-Moravian Highland. The farm is mainly characterised by growing crops on a large area and being located in the highlands. Currently there is no irrigation on the model farm, therefore irrigation level and costs are being estimated. The possible water supply comes mainly from small creeks and reservoirs. Using water for irrigation requires permission from the authorities, which will be granted based on an estimation of the available water in the river.

In Denmark, the model farm is located in Ringkøbing Amt in the Western part of Denmark. The region is characterised by sandy soil and that a large percentage of the Danish potato production is being produced here. The water for irrigation originates from the ground and it flows to the farm gate trough a well. Before irrigation is started the farmer will need permission from the local authorities. The permission will be granted based on the overall environmental effect that the irrigation will have for the area.

The Italian model farm heritages from Friuli Venezia Giulia. Moreover for the Daisy-simulations, further simulations have been made for an area near the Po-Valley region. Water for irrigation comes most commonly from small lakes and reservoirs, but also water from larger rivers is used. Only a certain percentage of the potato fields are being irrigated. The model farm is part of a consortium of local farmers that supply the water for irrigation. The common irrigation system is gun irrigation.

In Poland the region that has been chosen is from the central part of Poland near Warsaw. In this area water for irrigation originates from rivers, small lakes and reservoirs. There are no limitations of water supply and no taxes or similar associated with using water in this are. Irrigation is normally performed via gun irrigation but in general irrigation is limited in most parts of Poland.

In Portugal the analysis refers to the littoral centre of the country (Mondego and Tajus Valley). In Portugal, more than 600,000 hectares of agricultural land are irrigated, which accounts for about 75 pct of all water use Pinheiro and Saraiva (2005).

In Slovakia, the model farm is located in the South Western part of Slovakia. At the model farm most of the equipment used for irrigation is leased, which makes it different from the other model farm where most of the equipments are owned by the farmer. Rivers supply the water that is used for irrigation of the various crops. In Slovakia the total irrigated area is about 314.000 ha of which about 300.000 ha was in operation in 1999.

Table 1: Model farms in the three case regions

	Czech Republic	Denmark	Italy	Poland	Portugal	Slovakia
Total field size, ha	1400	130	25	45	29	585
Irrigated potato field size, ha	144	25	2	10	2	145
Water source	Creeks and reservoirs	Ground	Lakes, rivers and reservoirs	Lakes, rivers and reservoirs	Rivers and reservoirs	Rivers
Current irrigation system	No irrigation	Gun	Gun	Gun	Gun	Gun

As indicated above, the farmers use different ways of getting and distributing the water for irrigation, which leads to different cost levels. The fact, that the field sizes and crop compositions differ so much between the various model farms also contribute to the variation. All model farms are or would most likely use gun irrigation if they were to irrigate. A comparison between gun irrigation and drip irrigation is implemented to see if the water saving from drip irrigation can compete with the traditional gun irrigation.

The following examples summaries some differences among case areas.

Field sizes differ – between 2 and 145 ha with potatoes.

Differences in water supply (surface water and groundwater)

Depreciation periods for driplines and other equipment depending on quality etc.

Reservoir costs

Differences in wages

The main supply of water originates from lakes or rivers. However, the Danish location is the only site in this study where ground water is used for irrigation. Therefore Denmark is the only country where the cost of establishing a well is included. In other countries water supply is based on rivers and reservoirs.

The model farm in Slovakia differs from the other model farms because most of the equipments are being leased. Wage rates varies from 3 EUR/hour on the model farm in Poland and Slovakia to about 17 EUR in Denmark. These gabs in wages are likely to be reduced in the years to come.
Depreciation periods for the equipment also vary depending on equipment and region.

Labour for retrieving and laying down drip lines are also assumed to vary among the model farms.

In this study we have focused on the Daisy-simulations to estimate the yields and revenue from various gun and drip-irrigation systems.

The following scenarios are compared with average yield and input application estimates based on 10 years of historic climatic data.

T4 DSS – Drip irrigation with fertigation - Static nitrogen need estimate

T5 DSS – Drip irrigation with fertigation - Dynamic nitrogen need estimate

TC: local irrigation (gun irrigation) and local fertilization.

The above strategies have been simulated over a 10 years period, with a different climatic history, to compare the average yield potential, water and nitrogen application and nitrate leaching for the various fertigation and drip irrigation strategies. These strategies (T4 and T5) are then compared with conventional irrigation and fertilisation strategies based on local farm practices with gun irrigation (TC).

The aim of the two drip irrigation and fertigation strategies (T4 and T5) is to improve yields with minimal application of water and nitrogen. For T4 DSS: FERTIGATION between 17-136 kg N/ha of nitrogen originates from organic fertilizer. In this scenario mineral fertilizer is prefixed in the beginning of the growing season. The T5 DSS: FERTIGATION scenario is like T4 DSS but this scenario also allows for the use of mineral fertilizers during the growing season.

TC (local irrigation and local fertilization), which is similar to gun irrigation is regarded as a reference technology, with sprinkler irrigation (gun) and traditional use of fertilizers. In some regions organic and mineral fertilizers are used parallel whereas in others like Denmark and Italy only mineral fertilizers are used.

The climatic data are representative for the field sites in DK Poland, Czech Republic and Slovakia. In Portugal and Italy it has not been possible to use the same locations for climatic data as for the field sites. However, we expect that the weather data from these locations are fairly similar to the site climates and thereby gives a reasonable estimate for the historic weather.

For the simulations we have used the following potato varieties in the various countries: Agria in Czech Republic, Portugal and Slovakia and Triada in Poland and Folva in Denmark (Abrahamsen, 2006)

Since the water utility is higher with drip irrigation an additional 20 pct water use is added for gun irrigation compared with drip irrigation. Moreover, the Daisy model only simulate total dry matter yield. Dry matter content in table potatoes usually vary between 18-25 pct depending on variety and seasonality. In this report we assume that the dry matter content is 20 pct in all potatoes for all regions.

Moreover, we assume that the total yield from drip irrigation may have an additional marketable value compared with traditional irrigation. The model at present cannot predict how this yield is distributed into different potato size classes. In fact some trials indicate that it might be possible with drip irrigation to improve the marketable yield with up to 20-30 pct. compared with gun irrigation (Plauborg et al., 2006; Plauborg et al., 2007).

Results

The cost analysis indicates that the differential costs between drip irrigation with fertigation systems and conventional gun irrigation with traditional fertilising varies between about 700 and 900 EUR/ha in favour of conventional gun irrigation in potatoes. However, for most of the regions there seem to be a potato yield increase from using drip irrigation and fertigation systems (see table 2).

In Denmark, yield improvements are modest for T4 fertigation compared with local irrigation and fertilizer strategies. In Portugal, both T4 and T5 strategies have resulted in lower yields compared with a local strategy and In Italy (Po Valley area) and in Czech Republic there seems to be relative high average yield improvements with both T4 and T5 strategies. Moreover, yield improvements in Slovakia are significant compared to local practices.

Table 2: Average potato yields with fertigation and local management strategies, 10 years for field sites in various EU regions/countries, tons/ha

	Tons/ha	**Czech Republic**	**Denmark**	**Italy-Po valley**	**Poland**	**Portugal**	**Slovakia**
1.	T4 DSS – fertigation/drip irrigation	80	69	64	58	33	58
2.	T5 DSS – fertigation/drip irrigation	80	68	64	39	40	55
3.	Local irrigation and fertiliser strategy (gun irrigation)	70	68	53	53	47	53
1-3	**Difference (tons/ha) T4 and local strategy**	**+10**	**+1**	**+ 11**	**+ 5**	**- 14**	**+ 5**

The results are not representative for the entire regions but may give an indication of different yield potentials in different climatic regions and with different management practices.

Based on these yields in table 2 and price differences partial revenue and related costs can be estimated for each of the case areas with drip/fertigation techniques and conventional irrigation (gun irrigation).

Figure 1: Basic scenario: Differences in revenue (minus partial costs), EUR/ha/y Field site scenarios, 10 years average

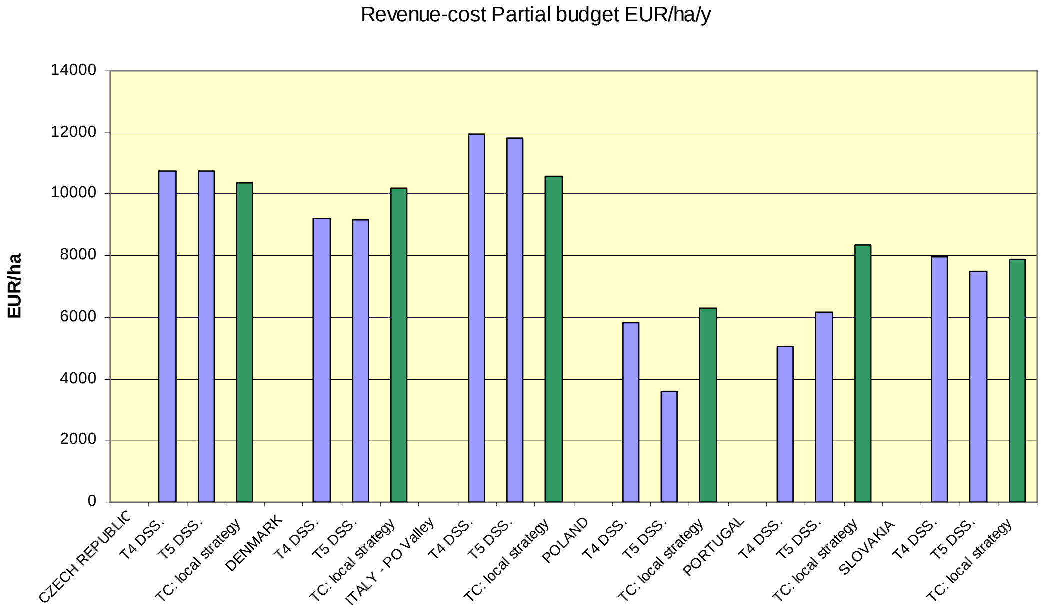

Figure 1 shows the basic (partial) net revenues between the two drip irrigation and fertigation scenarios T4 and T5 and conventional and local management practices. In this matter "partial" indicates that there are other costs related to the various scenarios regarding potato production (not included) but they are assumed to be similar for both drip/fertigation and local gun irrigation practices. The partial costs that are included above are only related to those costs that might differ among the various technologies.

Based on these basic scenarios it is clear that drip irrigation could be an economic viable option in several regions compared to local management practices. For both the Italian region in the PoValley and in Chech Republic it may be economic viable to use drip irrigation and fertigation systems based on certain assumptions.

In Denmark, the basic scenario with drip irrigation and fertigation techniques are not economical viable compared to TC (local strategy). However, a sensitivity anaysis indicate, that an average price increase in favour of drip irrigated potatoes of 10 pct. should be sufficient to cover the additional costs.

In general, there seems to be potential revenue from using drip irrigation and fertigation technologies in various case areas. However, not all regions have improved yields with the above fertigation strategies.

Moreover it seems to be possible to reduce the use of nitrogen with the above fertigation strategies compared with conventional and local farm management practices.

The ridge design and dripline design (depreciation periods) and distances between rows and driplines may have a significant impact on cost reductions and economic revenue. Moreover, the farm structure and climatic conditions are important parameters for the potential economic viability.

In addition there seems to be indications from field trials that drip irrigation and fertigation may have a positive impact on the marketable yields, Nonetheless, for many regions it is still necessary to take a wait and see position since the costs of drip lines are relatively high compared with conventional gun irrigation technology. Especially on large farm areas where the gun irrigation technology can be fully utilized.

In Denmark and Italy, water consumption is reduced with 78 m^3/ha and 24 m^3/ha per year on average with T4 DSS compared with a local strategy. In the other regions such as Poland and Slovakia where irrigation is not that common there seems to be a minor water increase with T4 and T5 DSS compared with the local strategy.

Average nitrate leaching has been reduced in all case regions when shifting from a local fertilizer strategy to T4 DSS. Most significant is reductions in nitrate leaching in Czech Republic and Denmark with 54 kg/ha and 37 kg/ha respectively.

Discussions

The economic analysis and technology assessment should be regarded with some reservations. One reservation about the economic feasibility study could be the obtained average yields from the field trials. Potato yields seem significantly higher than observed in conventional farming. That seems to be the case for both the DAISY-simulations for local irrigation practice and the 10 years average yields based on T4 and T5 decision support systems. However, it is common that yields from research trials are higher than yields observed in practise due to better control and harvest on small field plots. The economic impact of an overall percentage reduction of actual yields could be relevant to assess.

Another reservation is the inclusion of labour costs in the feasibility study. In some regions of for instance Italy and Portugal it will be the case that small family farms will save money in terms of family labour. In this respect it will be possible to save money by using the drip lines for two years because it doesn't matter if you spend some extra time on retrieving the lines. In other regions it may be necessary to use costly labour time for these operations.

Another element that may favour drip irrigation systems in many regions could be heavy wind, simply because it may be inefficient to use pesticides and gun irrigate at the same time. Under these circumstances, drip irrigation and fertigation may improve these farm operations.

In practice, input application varies tremendously among the 6 regions. For most of the East- and Central European countries it is common to apply organic fertilisers such as farm yard manure and slurry. In Denmark and Italy it is more common to use mineral fertilisers. Potato prices and quality also seems to vary significantly, which may depend on the application levels and to what extent the farmer produce early or late potatoes.

Findings from (Pedersen et. al 2005): show that potato cropping practices appear to vary between regions with significant differences in yields and costs. In Portugal and Italy, irrigation is a commonly used practice due to limited precipitation and high temperatures. In Denmark, irrigation is also a common practice in potatoes on sandy soils, whereas several east and central regions in Europe do not irrigate.

Especially in the highlands of Czech Republic and Slovakia irrigation is rarely applied due to the land topography. Moreover in Poland the average farmer is more likely to grow potatoes on very small plots where it is difficult to justify investments in irrigation systems.

Based on these findings it is clear that the implementation of new technology must be adapted to local conditions regarding field size, farm practice, animal production, access to organic farm yard manure, reservoirs and climatic conditions. Therefore, advisors and farm managers need to continue and make producers aware of the most profitable farming practices for their local conditions and markets.

Conclusions

This study indicate that the costs of applying drip irrigation and fertigation systems are relatively high compared with conventional gun irrigation systems. However, the yield simulations based on the field trials and local conditions also indicate that the potential yield increase from drip irrigation and fertigation seems promising in many regions based an average yield response from 10 years climatic scenarios.

On model farms/case area in the Italian Po Valley region and Czech Republic there seems to be an economic potential for applying drip and fertigation systems, which to a large extent is related to significant higher yields. In Denmark, the yield response from improved decision support is not sufficient to cover the costs of implementing new drip and fertigation systems. It is important to note though, that these findings were based on simulated total dry matter yield of all potato tubers, whereas results (Plauborg et al., 2007) have shown that the high value potato grading (size 40-60 mm) may increase with more than 30 % with the new system. Based on these findings it is clear that the implementation of new technology must be adapted to local conditions regarding field size, farm practice and climatic conditions.

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