Water for the irrigation in Denmark

pilot studies on estimating the volume of water

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- Pilot Study for Estimating the Volume of Water -

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0. Preface

During the last decade, Eurostat, other EU agencies, and Member States have created and agreed upon a list of agri-environmental indicators to be collected by the Member States. Two of these indicators – Irrigation and water abstraction – focus on water use within the agricultural sector.

The Member States can use administrative data, statistical surveys or a model to produce the data. The data must be connected to a holding participating in the farm structure survey.

This report describes the methodological challenges to produce the data for the water volume used at farm level for irrigation in the Danish agricultural sector. Danish farmers have been interviewed about their irrigation and reporting practises. An interview of Danish farmers concerning their irrigation and reporting practises was carried out.

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This report is produced in collaboration with Food Industries, Statistics Denmark (DST) and Institute of Food and Resource Economics (FOI), University of Copenhagen: Lene Riberholdt and Karsten Larsen (DST) and Jens Erik Ørum, Mads Boesen and Henrik Nielsen (FOI).

We wish to thank all farmers, the municipality staff, national and the local agricultural advisors, and GEUS staff for their essential contribution to the investigation. Regarding the summary and conclusion of the contributions, authors have the sole responsibility.

Kristian Hjulsager
Statistics Denmark

November 2009

Content

1. Introduction

Focus on agri-environmental issues

During recent decades, attention has to an increasingly wider extent been focused on agri-environmental issues, as the development in agricultural production had resulted in a non-sustainable use of the natural resources and pollution of the surrounding nature and environment.

Environmental laws

It has resulted in political attention and environmental laws. To monitor the development in the environment and the effect of these laws, a set of agri-environmental indicators have been agreed upon between the EU agencies and the Member States.

Agri-Environmental indicators

Agri-Environmental indicators are important tools when assessing the impact of agriculture on the environment and the efficiency of different environmental policy measures.

Weather sensitivity

When agri-environmental indicators are used it is important to analyse the development over a longer period of time. The yearly variations are often caused by the meteorological conditions. For example, the release of nutrients to the surrounding environment depends on the weather, and the need for irrigation is a typical weather-sensitive indicator.

Some of the indicators are the agricultural inputs such as fertilizers, pesticides and irrigation; others focus on the agricultural production such as tillage practice, soil cover and livestock; others again on the output to the environment such as emission and pesticide pollution of the water environment.

Irrigation

This project concentrates on the agricultural consumption of water for irrigation of crops. Agriculture in Denmark does not generally depend on irrigation, and only a small share of holdings are irrigating. However, for some crops, irrigation is needed to obtain a profit, e.g. potatoes.

Agriculture uses a third of the total water consumption in DK

All in all, the irrigating holdings accounts for a considerable share of the Danish consumption of water. From the Danish underground, we can get 1.8 billion cubic metres of groundwater annually[1]. Consumption is about 600 to 700 million cubic metres a year, of which one third is used for households, one third for agriculture and horticulture and the last third for industries and institutions[2]. When consumption is kept at this level it is sustainable.

Water is a common good

Ground water and surface water are in Denmark considered to be a natural as well as a common resource, which means that private ownership of the water cannot be possessed. The use and management of the water is administered by the public institutions. This implies that one individual can own a lake, but if he wishes to remove and use some of the water for other purposes, an application to the local government is requested and may or may not be granted.

[1] www.BLST.dk under groundwater and drinking water.

[2] www.statistikbanken.dk under Environment, under Water: VAND1

2. Objective of this report

Overall objective

The overall objective of this TAPAS project is to analyse the feasibility of producing high-quality data for the Farm Structure Survey 2010 and the sample on agricultural production methods 2011 regarding the water consumption for irrigation at holding level.

2.1 Three possible solutions to the problem

In Denmark there are three ways of gathering the data for irrigation. It can be done either by a statistical survey in this case the Farm Structure Survey, by administrative data or data can be produced by a computer-based model.

Administrative data

In Denmark it is mandatory to report the water consumption every year to the local government for water plants, industries, farmers etc. All farmers, who have a permission to irrigate crops, have to calculate the amount of water used for irrigation and report it to the local municipality. All reports are collected in a national database.

In principle, this opens up a great opportunity. Consumption is reported at holding level. By using the register as a source, all farms are included in the sample and no complicated model or understanding of agriculture and irrigation is needed. Thus, from a technical point of view the actual registration and procedures offers ideal representativeness and estimation methods.

However, combining administrative data with statistical surveys are too often a difficult job and sometimes impossible. It requires common denominators and at least one common identifier number, so that a farm in the survey can be found in the administrative register. Even when a register looks promising at first glance, it may turn out otherwise when analysed.

The reliability of the reported data is to be considered. The reliability of the reported data essentially depends on administrative resources and routines at the municipal and national levels, and the farmers' ability, incentive and willingness to report correct volume of water to the municipalities.

Statistical Survey

The straightforward solution is, of course, to include the question in the Farm Structure Survey. Data for each holding is collected at the same time. A common hypothesis in the EU is that farmers cannot give the answer for the volume of water used for irrigation. The farmer knows, of course, if he has irrigated, but he does not know the amount, not even as a round figure.

In 2010, Denmark will conduct a total farm structure census according to Regulation 1166/2008. The Regulation allows the Member States to conduct the survey on agricultural production methods in 2011 and as a sample survey – a solution Denmark will opt for.

If the 2011 survey contains a question on the use of water for irrigation in the most recent year, this information will reflect the land use reported in the 2010 survey and the

information about irrigation can be linked to the 2010 data. The same holds true if the information on use of water can be collected from the administrative sources, rather than from questions on the questionnaire. Of course, the register information must be linked to farms in the 2011 sample survey. This is not a problem since the register is updated every year.

Producing data through a model

There are several good irrigation models available for the Danish farmers. The models give advice to the farmers for optimal irrigation based on the next week's weather forecast. These models could give a good base for a statistical model to produce irrigation data. Even though there is a good base in these irrigation models, it is still very complicated and costly to create a statistical model.

Unfortunately, it is known to be the case that farmers do not make use of these irrigation models. It takes days to irrigate the fields if the farmers have more than 100 hectares, which is often the case, and farmers irrigate ahead, in case the weather forecasts turn out to be inaccurate. In this case, a statistical model could produce data of a low quality since the advice models do not reflect reality.

Danish approach

For this reason it seems that there are two possible ways of collecting irrigation data, namely use of administrative data or include the questions in the Farm Structure Survey in 2011. But which is the better?

Quality of data

The reliability of the reported data, to GEUS or Statistics Denmark, essentially depends on administrative resources and routines at the municipal and national levels, and farmers' ability and willingness to report correct volume of water to the municipalities. The question is if the data differ with regard to quality depending on whether GEUS or Statistics Denmark requests the information.

2.2. Work Questions

Thus, the questions we aim to clarify with this methodological study are:

- Is it possible to combine data from the national water consumption register with the Farm Structure Survey?
- Are farmers in a position to give information on the annual consumption?
- Is there a difference in quality of the data?
- It is assumed that farmers do not act accordingly to optimal irrigation models. But, is this so?

To enable transparency of this approach, we will describe the data and methodology in detail. First, however, we will describe the Danish agriculture and administrative system to clarify the context.

Photo 1

Non-irrigated and irrigated barley

3. Case: Denmark

3.1 Danish agriculture

About 2/3 of the Danish area consists of agricultural land. The agricultural sector has thus a considerable impact on the surrounding environment. According to the most recent farm structure survey, Denmark had 43.415 farms in 2008. These farms possess about 2.7 millions hectares of agricultural land. Over the years the number of farms has decreased considerably, whereas the agricultural area has remained rather stable.

Table 4.1 **Number of farms and agricultural area in Denmark**

	1985	1995	2000	2005	2008
Farms	92 354	68 771	54 541	51 676	43 415
Agricultural land, ha	2 834 100	2 726 048	2 646 982	2 707 236	2 667 895
Average size, ha	30,7	39,6	48,5	52,4	61,5

Area use

Cereals amount to somewhat more than 50 percent of the agricultural area with barley and wheat as the dominating crops. This pattern has not changed since 1985. Pulses and beets have decreased in the period from 1985-2008. Potatoes, which are an important crop for irrigation, have increased by about 12.000 ha from 1985 to 2008.

Fodder crops have increased in importance from about 20 percent of the area in 1985 to about 26 percent in 2008, which is mainly due to a very remarkable increase in the area with maize for fodder.

The table below shows the crops in Danish agriculture for selected years. The source is the farm structure survey.

Table 4.2 **Agricultural area by crops in Denmark**

	1985	1995	2000	2005	2008
			hectares		
Total agricultural land	**2 834 100**	**2 726 048**	**2 646 982**	**2 707 236**	**2 667 895**
Cereals	**1 600 599**	**1 447 494**	**1 499 714**	**1 510 833**	**1 505 210**
Wheat	338 536	606 666	619 160	678 735	649 440
Barley	1 093 722	714 292	731 088	702 845	707 395
Other cereals	168 341	126 536	149 466	129 253	148 375
Pulses	126 836	74 178	35 590	15 819	4 910
Industrial seeds	220 287	154 200	104 175	113 571	173 580
Potatoes	30 384	42 356	38 689	40 482	42 379
Beets	197 542	120 698	76 744	52 413	41 388
Permanent grass land	220 564	207 122	166 261	192 968	189 962
Grass in rotation	277 857	238 384	246 656	253 007	300 251
Maize for fodder	20 374	36 583	61 493	131 027	159 030
Other fodder crops	58 350	100 956	124 593	80 130	56 026
Seeds for sowing	47 042	61 556	78 949	96 122	82 058
Horticultural crops	31 047	24 719	21 678	20 113	22 154
Set aside	-	216 493	191 295	175 200	70 662
Other crops	3 217	1 308	1 146	25 551	20 285

Structural conditions

A full-time farm on sandy soil requires a large livestock or a large potato production. Crop production without potatoes or livestock is not an option. When the sandy soil is irrigated, the yield equals the yield of loamy clay soils, but only irrigation of particularly potatoes and roughage (maize and grass) is profitable. Cattle farms with extensive pasture and production of potatoes have a comparative advantage in sandy soils. And it is, therefore, not a coincidence that a large proportion of cattle farms and, especially, the organic livestock and potato production are located on sandy soils, typically west of the Israndslinien in Jutland.

Regional conditions

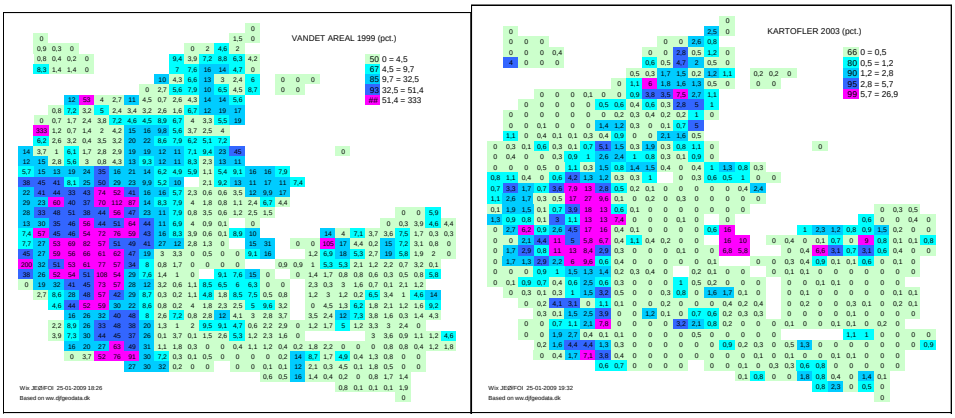
West of the Israndslinien, the landscape is characterised by sandy soils, a low population density and high precipitation surplus. This means that there is a particular need for irrigation but also a good base for production and a reservation of ground water for irrigation. In Zealand, however, there is greater pressure on groundwater resources. Precipitation surplus is less, and drinking water supply to particularly Copenhagen requires a lot from the groundwater reserve. Half of the Danish population living in Zealand, concentrated around Copenhagen, is supplied with drinking water from less than one fifth of the total area of Denmark. Without strict regulation, a large number of streams in Zealand would dry out during the summer. Consequently irrigation in Zealand is restricted to high value crops like potatoes, vegetables and fruits, and often also to night hours (e.g. from 17:00 to 10:00). West of the Israndslinien, there are generally no such limits and restrictions. The permission is generally a 110 or 120 mm per hectare allowance.

As mentioned, irrigation is profitable for roughage and potatoes on sandy soils. Even irrigation of fruit and vegetables as well as for nurseries on loamy clay soil may be profitable. Fruit, nursery products and vegetables other than

potatoes are grown on a limited area, compared to roughage and potatoes. The productivity is very high and the value added by irrigation is very high. Production of these products may pay a higher land rent and will be located closer to the market than more inferior crops, but at the same time in areas with sufficient ground water for irrigation. It is no coincidence that there is a large horticultural production in the periphery (close but not too close) of big cities like Copenhagen, Århus and Odense. In the case of Copenhagen, vegetables are e.g. produced in Frederikssund (former Slangerup, Frederikssund and Jægerspris municipalities) municipality in areas with light sandy soils and a surplus of ground water for irrigation, but next to (and thus competing with) wells producing table water for Copenhagen. In Denmark sparse groundwater is reserved for 1) table water, 2) streams and waters, 3) industry and agriculture.

Figures 1 and 2

Irrigated area (pct.) and areas grown with potatoes (pct.)

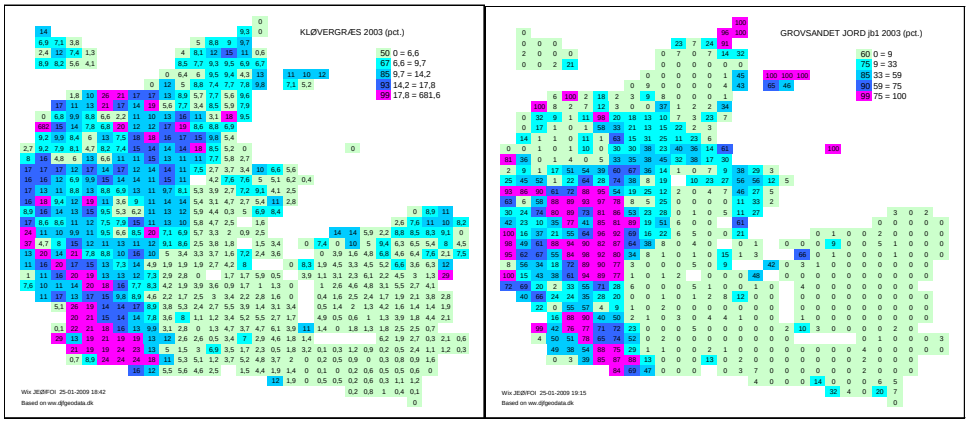


Source: www.djfgeodata.dk arealanvendelse 2003 og vanding 1999.

Cereals, roughages (grass and maize) and potatoes are irrigated with large irrigation machines, irrigating up to 6 ha per operation and sufficiently large to keep 30 ha of potatoes supplied with water even in the case of drought. The cost of a new machine, well and pump easily exceeds DKK 350,000 (50.000 €). Once equipment has been installed, the farmer has a high incentive to use the full capacity. In the case of spare capacity, e.g. early spring before the potatoes have germinated, it often pays off to irrigate the cereals. In dry years, irrigation of cereals can cover the cost of labour and energy used for the irrigation, but it cannot pay for the basic investment.

Figures 3 and 4

Clover grass area (pct.) and sandy soil (pct.)



Source: www.djfgeodata.dk arealanvendelse 2003 og vanding 1999.

Land use and dissemination of irrigation

There is a high correlation between irrigated areas (Figure 1), areas with potatoes (Figure 2) and areas with coarse sandy soils (Figure 3). However, it is also clear that areas with intensive potato production are a subset of areas with intensive irrigation. As an exception, potatoes are more prevalent than irrigation in Samsø, some areas in Vendsyssel (Northern Jutland) and Lolland.

3.2 Legislation

Organisation of the water environmental administration

The water environment and the water supply are administered by several agencies: the Ministry of Environment, the Agency for Spatial and Environmental Planning under the Ministry of Environment, the Regional Centres for Environment, the National Geological Survey Centre, called GEUS, under the Ministry of Climate and Energy as well as the municipalities. In all cases, the Minister is the main authority, but in reality most of the administration is handled by the agencies and the municipalities.

Water framework directive

Denmark and the other EU Member States adopted the Water Frame Directive in 2000. The overall purpose with the Directive is that all water should be in a good condition no later than 2015. The purpose of *good condition* implies that the water environment must contain favourable life conditions for flora and fauna. Human influences must only lead to minor deviations from what would be unaffected nature. The ground water must be of good chemical quality and the water extraction may not in the long run exceed the formation of new ground water.

For that reason all Member States must implement water management for water bodies. There can be no expectation of a general tightening of requirements for the Danish waters, but new and vital is that the Danish legislation in the future will demand that authorities take the necessary measures to achieve environmental objectives. In Denmark, the work has been based on the water environmental plans started in the 1980s, supplemented with new funding, and has been coordinated with the NATURA2000 plans to protect vulnerable and threatened areas of nature. Some changes to the legislation have had to be made, which subsequently have caused alterations in the administrative systems.

Legislation The legislation for water use has authority in the Act of Water Supply and Environmental Objectives Act. In addition, the Planning Act regulates the overall planning and mapping of water resources. The three laws have provisions that regulate the planning/management of the water resources in Denmark. This is carried out by The Water Plans, The local government measures for water environment also known as Plans of Effort and The local government measures for water supply also known as the Plans of Action.

Water plans A water plan must contain guidelines for use of and protection of the water resources as well as areas with various interests for drinking water must be pointed out. The three types of interest are, respectively, areas for special-, normal- and limited drinking water interests. The water plans are executed by the seven environmental centres in cooperation with the Agency for Spatial and environmental planning (BLST) under the Ministry of the Environment.

Plans of Effort The municipal councils compose the plans for how to manage and maybe improve the water environment in the local area. This is often drawn up in collaboration with the neighbouring municipalities. The plans cover all of the water environment; ground water, springs, creeks, rivers, ponds, lakes, coast and the sea. These plans are based on NATURA2000, the Water Frame Directive and the Green Growth Policy.

Plans of Action In contrary to the water environmental plan, the water supply plan focuses mainly on ground water, and in few cases on surface water. The municipal councils compose the plan for how the water supply is to be organized, among these which water plants will carry out the supply and to what areas, as well as the amount of water that can be extracted by private stakeholders, such as factories and farmers. The water supply plans can be drawn up together with neighbouring municipalities.

3.3 Administration by Municipalities

The permission to extract water for irrigation is given by the municipalities. If a farmer wishes to irrigate his crops an application is necessary. The farmer must state where and which fields in the holdings are to be irrigated, what kind of crops, what kind of pumps, and if a well has already been drilled. An official will investigate the implications for the surrounding area, and if the fields are located in a vulnerable area maybe pay a visit to the holding. If the holdings are located partly in a vulnerable area, permission can be given to the fields outside of the vulnerable area. In the case of a new well, the municipality will decide in co-operation with the National Geological Survey Centre where the drilling should be carried out. It is permitted to have several wells at one holding[3].

Crops The permission for the amount of water depends on the crops. Not all crops are allowed to be irrigated, and some crops need more water than others. If farmers apply for different crops, an overall amount of water is given for the applied

[3] Six municipalities have been interviewed for how there procedures are when the farmers apply for irrigation permission and how the yearly report of the use of water is carried out.

crops. It is not allowed to apply for, e.g. potatoes and then later irrigate wheat if it has not been mentioned in the application.

Irrigation permission is based on economic needs and environmental sustainability. It appeared from the various plans and guidelines of the previous regional plans, which crops may or may not be authorized for irrigation in which districts. These plans and guidelines are based on a very detailed understanding and mapping of groundwater resources and water flow in rivers, etc.

Surface water is not permitted for irrigation

In general, there is no possibility to use surface water, i.e. water from rivers and lakes for irrigation. However, there are examples where permission is given to use water from the Aresø Lake and drainage canals in parts of the Lammefjord and Lolland regions. Use of groundwater near streams and lakes, and especially groundwater close to the source of streams, is not available (not permitted) for irrigation.

In Denmark there is a large net surplus of precipitation. A significant portion of the surplus is built up during the winter months. Therefore, water flow is greatest during winter and spring.

Duration of permits

The permission is given for a period of time, normally five or ten years, but can be given up to fifteen years. Due to new legislation farmers must from 2010 pay an annual tax for the permit (volume is however free of tax). In the last 5 years, only permission to 2010 has been given, due to the new tax.

Incentives to save water

The yearly symbolic tax for the irrigation permission can maximum be 330€ per farm. There is no tax on the actual consumption, but it takes energy to pump, transport and pressurise the water. With the current price relationship, the cost of energy is a very small proportion of the total irrigation costs. From that perspective, the farmer has little incentive to save water. A significant incentive to save water comes, however, from the fact that it takes time (labour) and capacity (more machines) to irrigate more.

A high number of farmers have had permission without using the right to irrigate simply in order to increase the value of the land in case they want to sell. It makes it difficult for the municipalities to calculate the consumption and it can limit other farmers' opportunity to obtain permission. This situation is expected to diminish from 2010, when new applications must be given and farmers have to pay the annual tax.

Measurement and calculation of reported volume

Farmers must report their consumption to the municipalities every year. The volume reported to the municipality has to be measured by flow meter (m3), hour meter (h) or energy meter (kWh) placed on the pump, pipes or the irrigation machine. By using this data, the farmer calculates and reports the total volume (m3). The municipality will occasionally check the meters, measurements and volumes. How accurate the measurement is depends, of course, on the type of reading and the willingness of the farmer to report the actual consumption.

Different methods in the municipalities

Some municipalities look at the consumption over a period of time, normally 3 years, which signify that farmers can use more water in a dry summer than permitted, if the consumption is less the next year. Other municipalities do not allow that option. This use of different methods indicates that farmers could be less likely to report their actual use in some areas than others.

Altered administration due to new legislation

Where planning, protection and exploitation of the groundwater in Denmark hitherto has been almost exclusively carried out on the account of using the groundwater for water supply; it has changed with the implementation of the Water Frame Directive so that consideration for the water bodies, e.g. the water level in lakes and streams, now must be involved, when handling groundwater issues and assessment of water resources vulnerability. This means that the government have changed the way of handling permissions and sometimes the amount of water given permission to extract.

3.4 Water Statistics

GEUS

The overall data collection and analysis for the consumption of the water resources is the responsibility of GEUS (Geological Survey of Denmark and Greenland), which is an autonomous research institute under the ministry of climate and energy. GEUS conducts research and provides advice on nature, environment, energy and raw materials for public authorities and companies. GEUS is responsible for mapping, monitoring, data collection, data management and dissemination of geological conditions[4].

Statistics Denmark

It is, as mentioned, mandatory for the owner of all drillings to report the annual consumption to the government every year. The municipalities gather the readings from agriculture, industries, water plants etc. and report these to GEUS via the national database system, called JUPITER. GEUS produces annual statistics on extracted ground water. Statistics Denmark publishes annual statistics on water consumption split up by provinces for the various sectors in Denmark based among other sources on the database.

The responsibility for registration have been altered between institutions

Due to the regional administrative reform carried out in Denmark in 2006 with effect from the January 1 2007, the responsibility of registration of water consumption to water plants, industrial use and irrigation was altered from county to municipality. The idea was to bring the administration closer to the citizen and thereby enhance the quality. However, the specialist function in the 14 counties was, in reality, dissolved and the employees spread out to some of the municipalities. As a result the municipalities are not yet up to the new situation. The registration is handled slowly, while new systems are implemented. Discontinuities in the series of statistics are to be expected and comparison is difficult.

[4] www.geus.dk

Photo 2 **Farmer showing irrigation machine control unit and meter**

4. Methodology

4.1 Irrigation interviews

Purpose and method

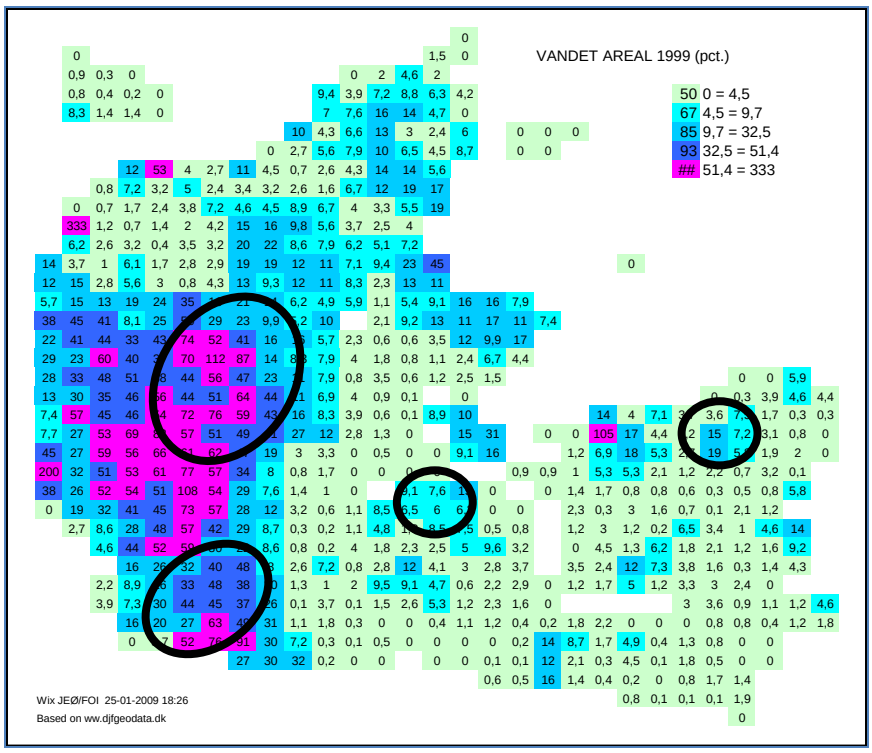
Farmer's irrigation and reporting practices have been analysed through quantitative interviews. The purpose was to assess the quality of farmers' reportings to the authorities, to identify the most common decision support system used by farmers, and to examine the quality of farmers' internal reporting of irrigations and volume per field and crop. Farmers' internal reporting is a prerequisite for reporting to the authorities. If internal reporting is absent or inefficient, ordinary decision support systems could be used to estimate the volume used for irrigation.

The farmers involved were fully informed about the overall objective for the project; how to estimate the volume of water used for irrigation by Danish farmers. They were told that we would like to inquire about their reporting to authorities, their internal reporting, their strategies and use of decision support systems. Further, they were informed that we would like to establish whether we at the end of a year would be able to estimate their use of water that year, by means of their decision support systems, rules and strategies (ex post). Farmers were, however, not supposed to answer these general questions, but to explain their practices, leading us to the answers. In that way, we would have the opportunity to understand the rationality of their practice, and to investigate the variation in practices, rationalities and possibilities. We also decided to visit the farms during the irrigation season in order not just to discuss, but to observe their practices.

Selection plan

The interviewed farmers were selected in a way that all kinds of irrigation technologies and strategies, as well as variation in farm size, farm type, crop rotation, and farmer's age were covered. Four regions were located (see map, figure x) and for each region 8-12 relevant farmers were recommended by local advisors and authorities.

Figure 4.1 Visited regions and irrigated areas (pct)



Diversification

In order not just to interview polite, sophisticated, state of the art farmers well known by the advisors and authorities, we also asked for more traditional and reluctant farmers. From the total lists we selected a few farms from each region, just enough to justify (costs of) our visit to that region, and set up a temporary visit plan for the region. As mentioned, we wanted to visit the farms in the high irrigation season to see the irrigation equipment running and to observe how farmers manage the irrigation. The farmers could, however, cancel our visit if it turned out to be inconvenient for them.

Actual selection

Once arrived in a region we contacted the farmers to update our visit plan. In most cases we managed (preferred) to start the visit in the field, and farmers were then interviewed in the field, at home and/or at their farm office. In several cases farmers requested that our visits were cancelled or postponed. New farmers were then chosen from the original list or by recommendation from other farmers. At several occasions we also asked farmers if they knew about farmers using decisions support systems or growing crops that we, so forth, missed in that region. In each region all interviews were carried out in two days, and around half of the visits were arranged the same day or a few days in advance. That way we managed, as a dynamic process, to increase the quality and quantity of the interviews. All in all, we feel that we managed to cover the variation in practices as well as the variation in farm size, age of farmers, technology, land use and regions.

Development of interviews

As our investigation progressed, from region to region, we improved our understanding of irrigation, so the first and the last interviews are very different in style and content. At the first visits, numbers of hectares, wells, pumps and volume used for each crop were carefully noted, following the interview guide. The last visits were more like a

conversation, where our understanding of irrigation, as a complex of rationality, incentives, economy, technology, strategies, know-how, research, environment, and crop protection, etc., was tested and discussed with the farmers. A great number of farmers, situations, crops, pumps, wells and equipment have been pictured (Nokia, Hewlet Packard, and Fuji).

The visits took from 1 to 3 hours. In some cases farmers invited us to take part in staff meetings and coffee breaks. We also took part in early morning rearrangements of irrigation machines, and dedicated farmers gave us thorough (obviously needed) explanations of new machines and technologies, and field trips to underline issues and matters related to the irrigation. At the end of each visit, farmers were offered a bottle of liquor, as a small compensation for their time and patience.

Municipalities

After a day or two in a region, a dominant or typical municipality was chosen for a meeting and an interview. In all regions we had the pleasure of meeting relevant staff, responsible for ground water and irrigation. In this report, visited farmers and municipalities are anonymous. In practice, however, most farmers; including those figuring on photos and all municipalities did not claim their anonymity.

Interviewers

All visits and interviews were arranged and managed by Institute of Food and Resource Economics (FOI). The visits to the first region were split up into two one-day trips. Senior associate professor Christian Richard Jensen, a crop-growth and irrigation expert from University of Copenhagen, accompanied us the first day. The second day, including a visit to a municipality, we were accompanied by head of section Lene Riberholdt, Statistics Denmark, and external advisor Niels Henrik Nielsen. Senior advisor Jens Erik Ørum, FOI, conducted all site visits and research-assistant Mads Boesen, FOI, participated in all visits, except for the last region.

Interview guide

Interview guide

1. Which crops are irrigated and how much land is irrigated?
2. Does irrigation vary from year to year?
3. How do you decide when and how much to irrigate? What kind of decision support systems?
4. What type of water is used (surface, own well, etc.)?
5. Type and number of wells, pumps, and irrigation machines?
6. How to measure the reported volume? Hours, volume or kWh?
7. Would you be able to report the volume used per crop? How?
8. Preferred period for reporting?
8. Do you have more than just one crop per field per season (rotation)?
9. Do you have any idea about the effective, marginal costs of water for irrigation?
10. Irrigation strategy? When to start and stop the season, what doses and when?
11. Irrigations strategy? Priority to crops and other on-farm activities? Capacity and limits?

4.2 Methods for analysing survey or use of administrative data approach

Farm structure survey

In Denmark, the farm structure survey (FSS) is conducted once a year, most often as a sample survey. The most recent total census was held in 1999. The next total census will be conducted in 2010 according to Regulation 1166/2008.

FSS 2009

In the farm structure survey 2009, Statistics Denmark decided as a test to include questions on the use of water in order to investigate the farmers' ability to give information on irrigation. There are two questions:

- Number of hectares with irrigated area in the recent year
- Number of cubic metres of water used for irrigation in the recent year

Regarding the question on the use of water, Statistics Denmark gives the farmer a possibility to tick off "information cannot be given". The hope is that enough farmers can provide the figure and that reliable estimates can be made for the remaining farms.

FSS Irrigation

The most recent survey conducted according to EU requirement was the 2007-survey. In 2008, Statistics Denmark included a few rather simple questions on irrigation, namely if the farmer has equipment for irrigation and the source of water:

Table 4.1 **Farm with irrigation by size of agricultural area, Denmark 2008**

	< 10,0 ha	10,0-19,9 ha	20,0-29,9 ha	30,0-49,9 ha	50,0-99,9 ha	>= 100,0 ha	Total
	number of farms						
Irrigation, total	856	988	838	1 049	1 908	3 129	8 768
On-farm ground water	699	908	763	997	1 763	2 938	8 066
Waterworks	117	47	39	36	31	78	347
Surface water	62	57	36	32	155	221	563
No irrigation	9 358	7 169	4 105	4 316	4 711	4 986	34 647
All farms	10 214	8 157	4 943	5 365	6 619	8 115	43 415

The above table shows the number of farms with irrigation. The majority of all the farms with irrigation have ground water as the source. About 20 percent of the farms have equipment for irrigation. This share is higher among big farms.

Irrigation with ground water

An important observation is that by far the majority of the Danish farms with irrigation use ground water for irrigation. Since GEUS data also contain information on ground water, it seems to be a good choice to collect irrigation data from GEUS and combine this information with the farm structure survey

Photo 3 **Field site well, meter (kWh and hours), and control unit**

5. Results from Interview

The interviews and visits resulted in a valuable insight in the rationality and complexity of farmers' irrigation practices and administrative routines. In this report, the insight is used to answer the basic questions asked by Statistics Denmark and EUROSTAT about ability and quality of farmers' internal and external reporting, as well as our ability to estimate and simulate farmers irrigation practices (ex post).

Professional management of irrigation

From a farm and production economic point of view all the visited farms were professionally managed. It takes time and capacity to irrigate the fields. For that reason no farmers were irrigating more than necessary. The farmers had a clear priority (a hierarchy) for irrigation of the crops.

Irrigation structure

Some farmers were irrigating crops for their neighbours, some rented land including irrigation permits; others used their own permission to irrigate more hired land. Not least dairy farms and potato farmers had a lot of these exchanges. In that way, potato farmers could uphold a sound percentage of potatoes, and at the same time grow more potatoes.

Irrigation advice systems is not common

In many cases, farmers have access to more than just one measurement in which case, reporting in hours is preferred by the farmers. Even though the interviewed farmers managed the irrigation with no support from computer-based decision support models, the same farmers were using a lot of electronic devises and mobile phones to control the irrigation, and most of the new irrigation machines were controlled by onboard computers and programmes.

Out of 24 farmers, just one farmer used (occasionally) a decision support system; just one farmer kept a record of the volume and number of applications per crop; just one farmer used potentiometers or electronic devises for measuring (just one field).

Dived pumps are popular, but it is difficult for the inspector to check the capacity of these pumps. In practice, new pumps and wells increase the capacity, and new machines with higher capacity require more water. An increased capacity makes it possible to irrigate more and faster. Computer-based decision support systems for irrigation have been available for Danish farmers for decades. The most advanced system; Vandingsregnskab Online (online irrigation account) (Dansk Landbrugsrådgivning 2009), was developed from Vandregnskab i Planteinfo (irrigation account) (Thysen et al. 2006), Vandregnskab på Internettet (irrigation account at the internet) (Dansk Landbrugsrådgivning 2004) and Markvand (Irrigation) (Plaugborg et al. 1996). However, none of the interviewed farmers are using these systems.

Networking groups

Local crop production advisors are often involved in crop protection, but it seems that they are not that much involved in day-to-day decisions, related to irrigation. There is, however, a widespread use of networking and regional irrigation-based field trials on irrigation. These trials and networking groups are organised by potato growers' organisation, local advisory service, and the potato processing companies. It seems that new technologies and strategies are effectively tested, improved and distributed within theses networks. As an example, the idea, that 15 mm

instead of 25-35 mm per application is optimal in potatoes, had thus been effectively spread to most farms in one of the regions we visited.

How to improve survey quality

Farmers must respond to questionnaires from DST, but the quality of the response depends on what we ask about, how we ask and when we ask. The interviews showed that almost no farmers take notes for more than a week, or use log books or computer programs to keep track of volume and timing of irrigation. Most farmers make up their tax statement and stocktaking 1st of January. In that process, they will also read and log hour, electricity and flow meters. Thus, after New Year the farmer can easily (less trouble) calculate how much water was used for irrigation in the past year. If, however, we ask farmers before the 1st of January, some of them will be reluctant to read and log all hour, energy and flow meters to calculate the consumption. They may instead report a qualified guess (a gestimate).

- Calendar year reporting improves the quality (reliability) of total volumetric data If we would like some more detailed reports on irrigation, related to fields, crops, doses and applications, we should ask the farmers just at the end of the irrigation season. At that time, they still remember how much water they have used in each field, in terms of applications, mm or volume per filed and crop. By using a questionnaire based on the farmers' actual land use (Danish Food Industry Agency and Plant Directorate), it would be easy (less mistakes and less hassle) for farmers to report their irrigation, and it would be easy (less mistake and less hassle) for us to calculate the total consumption in terms of m3 per crop and per farm.

- A late summer questionnaire with pre-printed field and crop data from DFFE and Plant Directorate will improve the quality of reported crop level data

Instead of using decision-support tools, most farmers rely on own experiences and observations interpretation of crop growth, soil moisture, and weather forecasts. This indicates that we cannot use the exact same decision support system as the farmers, to calculate the volume of water used for irrigation. And even if they used a decision support system, local conditions, sowing dates and time of harvest, number and capacity of wells and irrigation machines vary so much in practice that the accurate volume cannot be estimated (ex-post) for individual fields and crops.

Modelling the water consumption

In reality, farmers' irrigation practices are very similar when concerning major irrigated crops like cereals, grass, maize and potatoes. It seems that farmers think and act very alike, and it gives the impression that farmers have developed almost identical strategies and models, independent of size and irrigation technology. The irrigation rules for priority to crops at different growth stages are very similar, but, conditions for start and stop of irrigation may be the most important difference. These differences are, however, not shortcomings of the farmers' "model", but caused by differences in input to the "model" like actual soil moisture, variety of crop, etc. In a way, VANDREGNSKAB ONLINE is a formalized IT-based version of farmers' "model", and farmers' "model" on the other hand is also a product of systems, like VANDREGNSKAB ONLINE, used by advisors and for

training of farmers. How come that VANDREGNSKAB ONLINE is not used by more farmers? The answer could be that it provides almost the same, it is neither cheaper nor easier, and the solutions like those of the farmers' "model". If, however, it was mandatory for farmers to keep a logbook of the irrigation, more farmers would probably use the IT-based system, not in order to irrigate more efficiently, but to ease the logging and reporting to authorities.

A decision system for irrigation is useful to model water consumption for some crops…

Although VANDREGNSKAB ONLINE cannot be used to estimate the exact volume of water used for irrigation in the each individual field, it could provide a qualified estimation (ex-post) for crops at the regional level. It would probably give a better estimation of the volume than a limited farm survey. The VANDREGNSKAB ONLINE method requires preliminary knowledge of the irrigation capacity and soil quality at farm and field levels, whereas the survey method requires a model to generalise (upscale) the results of a limited sample to a full sample for crops, soil qualities and regions.

In collaboration with the Danish Agricultural Advisory Service, we have described a simple, VANDREGNSKAB ONLINE based, simulation model to estimate how much water is used for irrigation in different crops and regions. The model could be useful to estimate total water use based on land use (DFFE and Plant Directorate) for all farms.

…but not for all

Decision support systems are, however, not an option when it comes to fruit, nurseries and crops like vegetables. There may be more than one crop per season, individual varieties and cultures may be started at different times in one and the same field, and productions are so insignificant volume-wise that models have probably not yet been developed.

- Decision support systems like VANDREGNSKAB ONLINE could be used to estimate (ex-post) volumes used in major groups of irrigated crops like cereals, potatoes, maize and grass at regional level.

Incentive to report correctly

Farmers have very different opinions and expectations towards authorities, some farmers have plenty of water, whereas others use more water than permitted. The farmers who use less water than permitted may have an incentive to report a volume closer to the permitted consumption. This way they claim their right to the permission, they avoid measuring and estimating the exact volume, and it is nice to have a god conscious (opposed to cheating). An overdraft may result in sanctions; in worst cases a cancellation of the permission. Thus, farmers using more water than permitted may also have an incentive to report a volume closer to the permitted consumption.

- Farmers using less or more water than permitted may have an incentive to report a volume closer to or similar to the permitted consumption.

Administration of municipalities

Some municipalities encourage farmers who use too much water to apply for a new permission. In other municipalities there is no more water to apply for. In some municipalities farmers are allowed to exceed their permission in case of dry summers, etc. A few years ago administration of permissions was passed from the regional authorities to the municipalities. New practises may have developed in the municipalities, or the farmers are not yet (if ever) aware of

the practices. Therefore farmers exceeding their permission may have an incentive not to challenge the municipality.

Inspection

It varies a lot from municipality to municipality how often farmers are checked. Some municipalities make an announced, routine visit to the farms every time a permit is prolonged or extended. Here wells, pumps, flow and hour meters may be checked. In other municipalities such visits are not planned. In some municipalities, there is a higher focus on well constructions to protect groundwater than farmers' possible excessive use of water. Some municipalities take care that all permissions are reported once a year, while other municipalities (have to) accept that more than 20 percent of the permissions are not reported. It was not discussed with the municipalities, how the missing reports affect their reporting to GEUS.

- Farmers are not always well-informed about the local administration of permissions. In municipalities with sufficient water supply, more and correct information to farmers could motivate more farmers to adjust their permissions and to report their actual volumes.

Future work

It could be useful to analyse variation in volumes reported from individual farms to GEUS from year to year. Does the variation reflect the actual climate and land use? If so, a model could be established to estimate the total volume based on reported volumes from a few farms (a limited sample) reported to DST.

For future analysis it would be fruitful to register wells, irrigation permits (max. volume, and crop restrictions) and hydrants on existing digital field maps (Danish Food Industry Agency and Plant Directorate). Then we would know which fields and crops farmers are able to irrigate. By using this knowledge in combination with the Danish Agricultural Advisory Service simulation and/or data from sample farms, we would be able to estimate the total volume of water used for all crops, fields and farms.

6. Data analysis for Irrigation

6.1 Combining GEUS data with the farm structure survey 2009, the administrative data solution

GEUS data set 2008

We received a data set for 2008 from GEUS with 6.001 reporting farm units. There are still problems with the reporting from the municipalities. 10 percent of the municipalities have not yet delivered their data for the 2008 data set. Unfortunately, it is mostly municipalities from Jutland which are delayed – these municipalities have the highest share of holdings with irrigation. This signifies that more than 10 percent of the holdings with permission to irrigate have not yet been reported. However, the lacking data does not cause a problem to investigate the feasibility to combine the two registers.

In this analysis, it is assumed that the unit in GEUS corresponds with the statistical concept of a farm. Unfortunately, GEUS has very poor identifying information implying that it is difficult to link GEUS and Statistics Denmark's statistical farm register.

GEUS has for each farm unit the code of the property only as identifier, and not the business number, which is generally the best identifier when linking two registers of business units. However, the information on property codes is also contained in the statistical farm register so creating a match is not impossible.

But even the information on property codes in GEUS is incomplete:

2.765 cases: The property code is missing.
255 cases: The property is not valid (must have 9 digits to be valid).
2.981 cases: The property *might* be valid since it has 9 digits.

It means that there are 2.981 farms from the GEUS dataset where a link may be established with the statistical farm register.

But even for these 2.981 farms the information is incomplete:

259 cases: Use of water is missing
414 cases: Use of water is zero
2.308 cases: Use of water > zero

And for the 2.308 farms with apparently valid information on use of water and farm identifier only 836 farms can be found in the statistical farm register. The reason for such a low match is most likely invalid property codes in GEUS.

In the farm structure survey 2009, Statistics Denmark decided as a test to include questions on the use of water. There are two questions:

- Number of hectares with irrigated area in the recent year

- Number of cubic metres of water used for irrigation in the recent year

Regarding the question on the use of water, Statistics Denmark gives the farmer a possibility to tick off "information cannot be given". The hope is that enough farmers can give the figure and a reliable estimate can be made for the remaining farms.

The GEUS solution

In the 2009 survey, which is a sample survey, 2.792 farms have indicated that they have irrigated in the recent season. If the GEUS approach is a sufficient solution it must be possible to find the use of water for the 2.792 farms in the GEUS data set or at least a good deal of them allowing for a valid estimate for the remaining farms.

This does not seem to be the case. Only 226 farms fulfil the two necessary conditions:

- They indicate in the farm structure survey 2009 that they have practised irrigation in the recent season
- They can be found in the GEUS dataset through match with the property code and with valid information on the use of water

When taking a look at the 226 farms with a perfect match between the two sources, it is difficult to see a clear pattern. The following cases can be identified:

Table 6.1

Case	Number of farms
Use of water not recorded in FSS	87
Difference between FSS and GEUS is small (less than 5 percent)	31
FSS use of water exceeds GEUS use of water with 5 percent or more	65
GEUS use of water exceeds FSS use of water with 5 percent or more	43

About 8.000 Danish farms practice irrigation, so it can hardly be expected that 226 farms can constitute a sufficient sample when taking into consideration that use of water should be described by farm structure: Regions, type of farming, size of farm etc.

6.2 Use of the farm structure survey 2009, the pure survey method

The question is if the FSS survey itself can give a better result than the administrative data from GEUS. This seems to be the case.

FSS 2009

The size of the sample survey 2009 is about 16.000 farms. The survey is in November 2009 not yet completed, but only about 800 farms are missing. Due to the survey method where crops are collected from the IACS system (system of crop subsidies) the survey cannot yet tell anything about irrigation in combination with different crops and size of area.

2.820 farms in the sample have indicated on the questionnaire that they have irrigated in the recent year, the survey date is May 15 2009. They have all informed about the irrigated

area at hectares, which does not seem to be a difficult question for the farmers to answer.

Farmers reported the consumption

1.160 farmers have not indicated the use of water but have ticked off "information cannot be given" whereas 1.660 farmers have informed about the use of water. On the questionnaire, it is mentioned that a "round figure" is acceptable.

Imputation

A method of donor imputation is used to estimate the use of water for the 1.160 where the information is missing. It is done by selecting a random donor among the 1.660 farms. In each case a farm in the same municipality is chosen. The use of water per hectare of the donor farm is used to calculate the total use of water for the farm where the information is missing.

When the farm structure survey 2009 is completed, a more sophisticated donor selection can be chosen, for example, cultivation of different crops.

Non-irrigation farms is a majority

About 8.000 farms have practised irrigation in 2008/09. It is somewhat less than twenty percent of all Danish farms, so obviously non-irrigation farms constitute a big majority in Danish agriculture.

Use of water in Denmark by regions 2008/09

	Farms	Use of water, mio km3	Irrigated area, hectares	Use of water per farm, km3	Use of water per hectare, km3
All Denmark	**7 888**	**293**	**456 784**	**37 198**	**642**
Capital region	235	2	3 764	7 865	492
Zealand	337	4	6 492	10 781	560
Funen	227	4	5 899	16 060	618
South of Jutland	3 183	119	197 716	37 297	600
East of Jutland	524	15	22 288	27 737	652
West of Jutland	2 780	135	191 943	48 472	702
North of Jutland	601	16	28 683	27 070	567

The sample survey shows as expected that almost all water for irrigation is used in West Denmark with its sandy land where irrigation much more often is necessary than in East Denmark.

6.3 Methods of the analysis

The analysis described in this passage has been made by means of rather simple SAS-programs:

Step 1) Match of the GEUS data with the statistical farm register. 836 farms from GEUS can be found in the statistical farm register through match using the property code as match criterion.

Step 2) A match of the 836 farms found in step 1) with the farm structure survey 2009. 226 farms are found.

Step 2 ends the GEUS analysis and hereafter the focus in on the farm structure survey only.

Step 3) Calculation of new extrapolation factors. The farm structure survey 2009 is a sample survey and about 3 percent of all farms have not answered yet so it is necessary to create new extrapolation factors to address the non response.

Step 4) Imputed results are created for farms with irrigation but with no information on use of water, 1.160 farms. 1.660 farms with irrigation have answered the question on use of water. An SQL procedure combines the 1.160 no answer farms with 1.660 answer farms finding a donor farm for each no answer farm.

Step 5) Statistical results are created by adding 1.660 farms with authentic information with 1.160 farms with imputed information. These sample results are for each farm multiplied with the extrapolation factors calculated in step 3). The final results are 293 millions square metres of water for irrigation.

7. Concluding observations

In 2011 Statistics Denmark is going to produce data regarding the farmers' water consumption for irrigation, and the choice of methods has been between use of register data or collecting data via the farm structure survey.

This project is to be seen as a methodological study. The objective of this project was to:

- Determine whether use of administrative data from GEUS or collecting data via the farm structure survey was the best approach to produce data for irrigation
- Analyse the quality of both the administrative data and survey data
- Seek knowledge of the farmers irrigation methods

7.1 Farm structure data versus register data from GEUS

Administrative register solution

At first hand using data from an administrative register seemed to be the best solution to produce irrigation data. Statistics Denmark has used the data from GEUS for several years, when producing statistics for the overall water consumption from the various sectors in Denmark, and the co-operation between Statistics Denmark and GEUS function exceptionally well.

Statistics Denmark is continuously working on reducing the response burden for the farmers. Making use of already existing data would not lower the response burden, but would at least not increase the burden when the amount of questions was extended.

Unfortunately, the methodological study has shown that it is not possible, at present, to make use of register data. Even though common denominators exist, as both Statistics Denmark and GEUS work at farm level, there is a problem with the common identifier number.

We have come to realise that it is not mandatory for the municipalities to report the consumption using the property number, which would be the common identifier number between Statistics Denmark and GEUS. Other numbers like drilling number and geo reference etc. are used as the mandatory identifier number, but these are not usable as a common identifier numbers. Only a fraction of data has been registered with the property code. The result is only a few percent of the administrative data can be merged with the farm structure survey.

Survey solution

The hypothesis was that it was too difficult for the farmers to give information about the water consumption for irrigation. However, at least 60 percent of the farmers gave the information. In the questionnaire they were given the possibility to tick off 'Cannot give the information'. If this possibility is removed a much higher share is expected to provide the data. For those holdings where the farmers do not have the ability or willingness to provide the data, Statistics Denmark can produce the data through imputation.

7.2 Data quality

Quality of register

At the beginning of this project, we had great confidence in the quality of the administrative data from GEUS. The ground water resource exits. In general, it is not difficult to obtain permission to irrigate, especially in Jutland where irrigation is needed due to the sandy soil. From 2010 the farmers must pay a minor annual fee for the permission, but until now there has not been an economic reason to report a lesser consumption than used.

Variation in reporting depending of institution

However, the study has shown that a share of the farmers report different figures to Statistics Denmark than GEUS. When interviewed, several of the farmers expressed awareness of the fact that information given to Statistics Denmark is not transferred to other authorities.

Difference is 50 percentages

Overall the consumption reported to Statistics Denmark is about 50 percent more than to GEUS. When analysing the difference between the data it is seen that farmers, who reported a small amount of water in reality use less, and the farmers reporting a large amount of water in reality irrigate more. The reason farmers report more than used is probably to avoid that the permission will be reduced to under what they actually need. Farmers, who report less than the actual use, probably do so to avoid the trouble with the municipality and a possible fine.

It can be assumed that the farmers are more accurate when giving data to Statistics Denmark compared to the municipality, as there are no direct consequences of reporting a larger consumption than permitted.

Water scarcity

We have come to the belief that, whether or not it is true, some farmers are beginning to see water resource as a scarcity, maybe as a result of the implementation of the Water Framework Directive.

Development over time

The smaller inaccuracies are perhaps of less importance if the purpose of the indicator is to monitor the national and regional development over time. If the problems and delimitations remain the same, it will not influence the purpose of the indicator.

7.3 Conclusion

It can be concluded that collecting the information on the use of water directly from the farmers is the best choice.

Photo 4

Meadows and a stream

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