Summary workshop on Technical methods

German Aquarius meeting March 2010

The aim of the Aquarius meeting in Germany on 3-5 March for the "Expert Network Group on Technical methods" is to share information for solutions and to create understanding of problems and possible technical solutions.

On the workshop on technical methods the following people participated:

- Peter Feuerbach (Sweden);
- Janne Aalborg Nielsen (Denmark);
- Angela Riedel, Ekkehard Fricke, Heinz Sourell (Germany);
- Jan den Besten (Netherlands (Drenthe)).

The Technical methods presented by the participants covered the following subjects:

- water storage for irrigation in wetlands in Sweden
- Online DSS for sprinkling in Denmark
- DSS for sprinkling and detailed measurements of soil moisture and rainfall in Drenthe
- Precision irrigation with centre pivot in Germany

This summary starts with a short overview of the differences in water shortage between the different countries. Then the main lines and learning points of the different presentations is given.
The last chapter deals with the ways the knowledge about new techniques can be spread among both farmers and Aquarius partners.

Annex I contains the answers on the short questionair. This questionair was sent around among the Aquariosu partners as preparation on the workshop.
Annex II contains the short papers that were made by the participants made as preparation on the workshop.

Differences in urgency of water shortage

In regions without need for irrigation or with plenty of water for irrigation there is no great need for investing is efficient water use. But in dry sandy regions a lot of irrigation is needed. When in such a region little water is available for irrigation, then there is a great need for increasing the water use efficiency. So to understand the solutions of the different partners on increasing water use efficiency for irrigation first of all insight is needed in the type of water shortage they face in there regions.

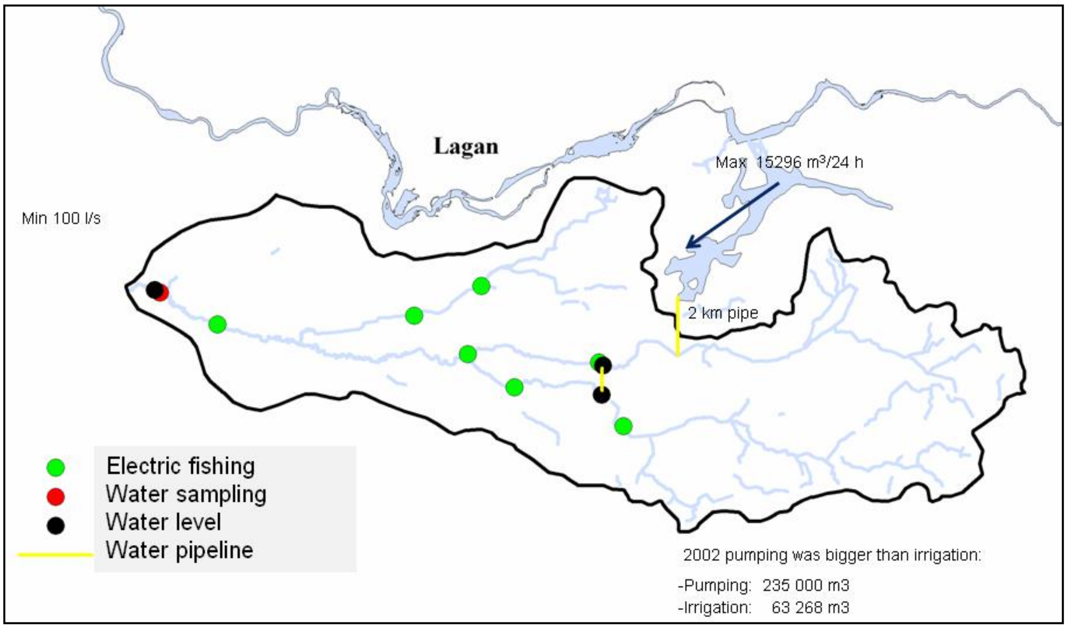
In the area of our Scottisch partner in East Scotland the climate is not dry so there is no need for irrigation.
In Norway farmers do apply irrigation but there is plenty of water availbale in a lake. So they face no water shortage problems in this region.
In Sweden farmers irrigate in the dry sandy zone near the west coast. In normal situations the rivers discharge enough water. But is in some periods however river flows are too low and storage of water is needed.
In Denmark there is much sprinkling in the dry sandy western part of the country, but there is enough groundwater available for irrigation. In future this might become more limited due to climate change and the WFD regulations.
In Drenthe in the Netherlnds only the higher sandy spots are irrigated. There is enough Rhine water pumped to the area so at the moment no real water shortage problems exists. In future problems are expected due to climate change. So to be prepared for the future new sprinkling techniques are introduced and efficient sprinkling is stimulated.
In Germany the dry sandy plateaus in the region of Uelzen need a lot of irrigation and the groundwater amount is limited. So watershortage is a big issue here and much energy is put into optimizing irrigation techniques to improve water use efficiency.

Sweden

Peter feuerbach from Sweden presented the Municipal project for construction of wetlands. The aim of the project is to reduce nutrient transport. Small lakes are constructed along the river and serve as wetland and at the same time as water storage for irrigation. By a guaranteed minimum water level biodiversity is guaranteed.
The idea is to invite farmers to invest in making such wet lands. The learning point for the other partners is that an efficient combination of agricultural and nature interests can be found that may result in more wetlands financed by farmers.

Municipal project 2001-2005; construction of wetlands

Another example of succesfull combining agricultural and nature intersts is the pumping station between the river Lagan to the smaller river Edenbergean. The small river had not always enough water for irrgating agricultural land. So the farmers got permission to pump water from the river Lagan. But under condtion that they should always guarantee a minimum flow of 100 l/s in the river Edenbergean necessary for fish (Salmons a.o.). So in a dry year as 2002 the farmers pumped nearly 4 times more water to guarantee the minimum discharge than they needed to pump for there own irragtion needs.

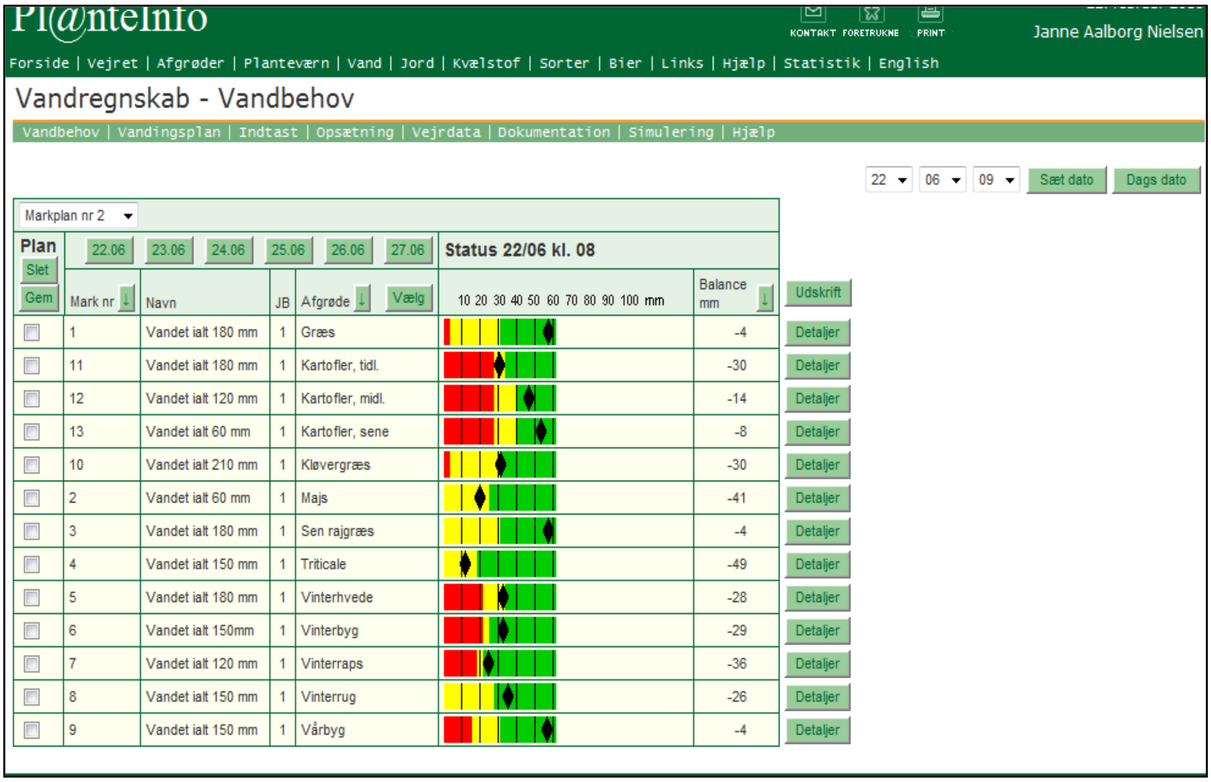


Denmark

In Denmark there is still enough gropundwater available for irriagtion. Normally farmers are allowed to irrigate 100 mm per season. Janne Aalborg Nielsen from Denmark presented the Decision Support System for Irrigation Scheduling, “Water Management Online”. The Danish Agricultural Advisory Service (DAAS) has put this DSS on internet. In the first years the program was free to use. Now farmers have to pay a very limited amount of money for the use. Ca. 300 farmers all over Denmark really apply this DSS to optimize there irrigation. This number is relatively rather low and DAAS wants to stimulate more farmers to use the DSS.

The interesting idea behind this approach is the easy acces by internet to a DSS for sprinkling. Every farmer with a PC can use it. For Drenthe this might be an option next to the DSS that is developed by a company now.

A disadvantage of this approach is the general character of the input data of soil and rainfall that normally are used. But the programme has an option to include own measurements so this disadvantage can be solved when local measurements are available.



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1	Vandet ialt 180 mm	1	Græs	-4	Detaljer
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12	Vandet ialt 120 mm	1	Kartofler, midl.	-14	Detaljer
13	Vandet ialt 60 mm	1	Kartofler, sene	-8	Detaljer
10	Vandet ialt 210 mm	1	Kløvergræs	-30	Detaljer
2	Vandet ialt 60 mm	1	Majs	-41	Detaljer
3	Vandet ialt 180 mm	1	Sen rajgræs	-4	Detaljer
4	Vandet ialt 150 mm	1	Triticale	-49	Detaljer
5	Vandet ialt 180 mm	1	Vinterhvede	-28	Detaljer
6	Vandet ialt 150mm	1	Vinterbyg	-29	Detaljer
7	Vandet ialt 120 mm	1	Vinterraps	-36	Detaljer
8	Vandet ialt 150 mm	1	Vinterrug	-26	Detaljer
9	Vandet ialt 150 mm	1	Vårbyg	-4	Detaljer

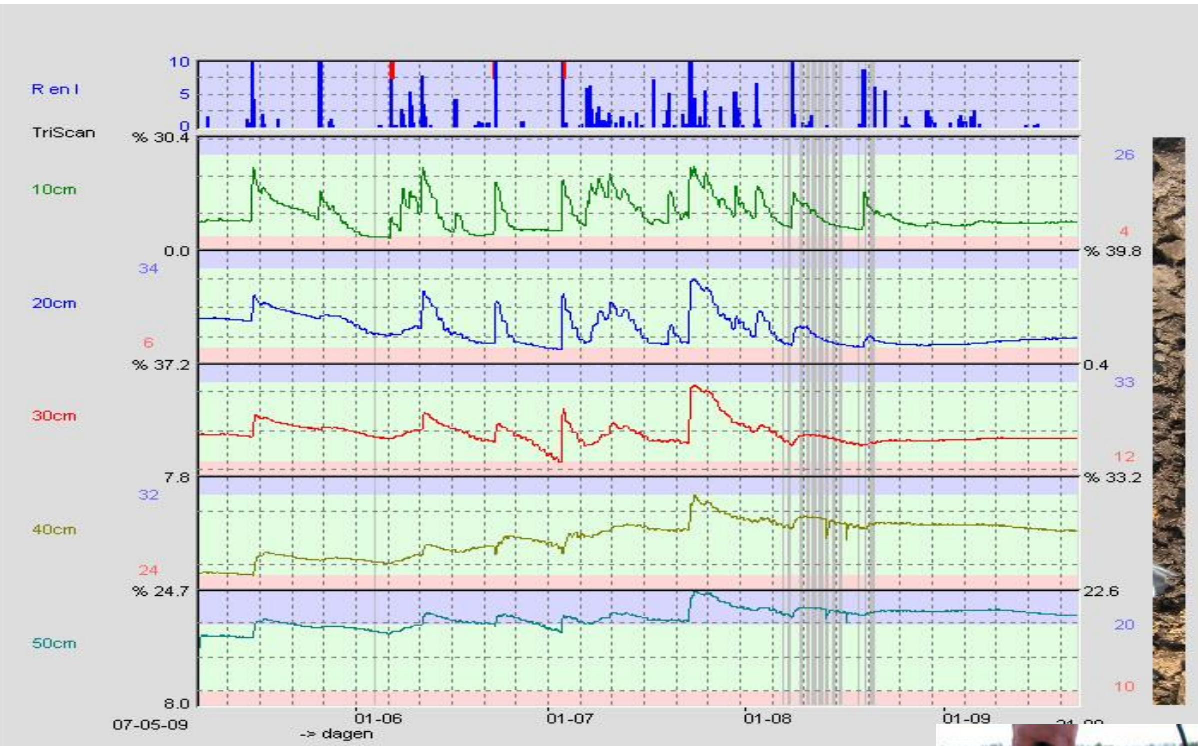
Layout of the Danish DSS for sprinkling.

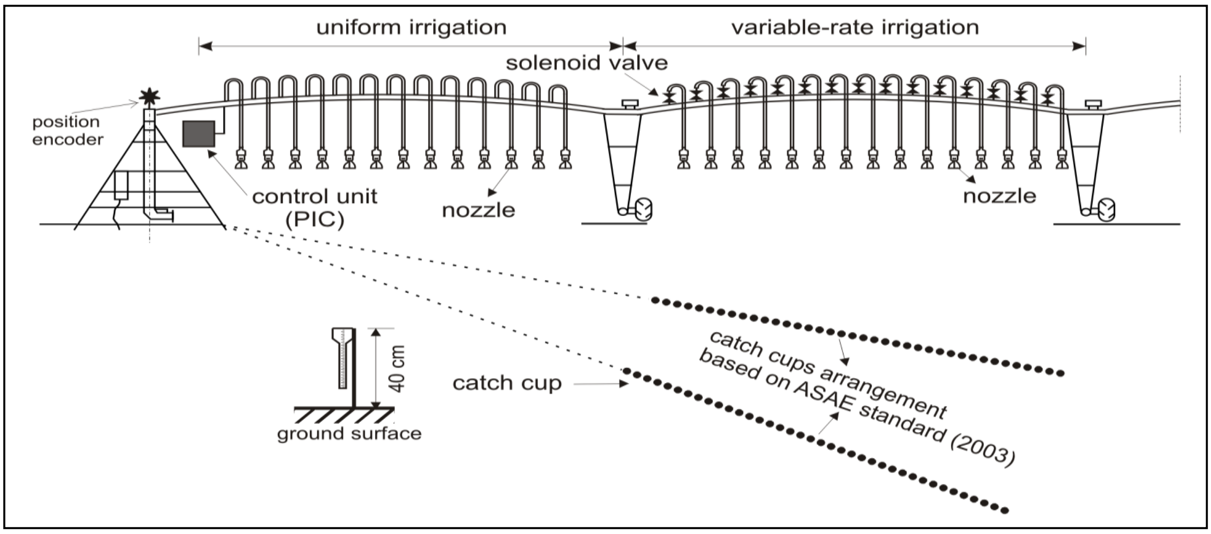
Netherlands (Drenthe)

Jan den Besten presented the measures that are used in Drentheeh to combat watershortage. Weirs are put on remote control in order to be able to operate them very quickly. In that way water can be conserved in the canals without risk of damage due to too much water in case of sudden heavy showers. The operation of the weirs is optimized by a DSS that uses soil moisture data from 100 soil sensors at farmer fields of 50 farmers.

As a new irrigation technique the labor saving pivot sprinkling systems have been introduced in the region. The investment costs are comparable to the costs of a water canon with hose-reel. But the energy costs of this low pressure systems are much lower and the water use efficiency is higher. The same soil sensors are used in combination with a DSS for sprinkling (that will be further developed) to optimize the amount and moment of irrigation.

The most important learning point is the “eye opener” that such advanced sprinkling systems as pivots are per ha even cheaper in use than the traditional sprinkling systems that are now in use in Western Europe. An important condition is that the pivots are only profitable on large fields (> 30 ha) and are less movable between fields than the water canon. Large scale Swedish farmers might be interested in this technique.



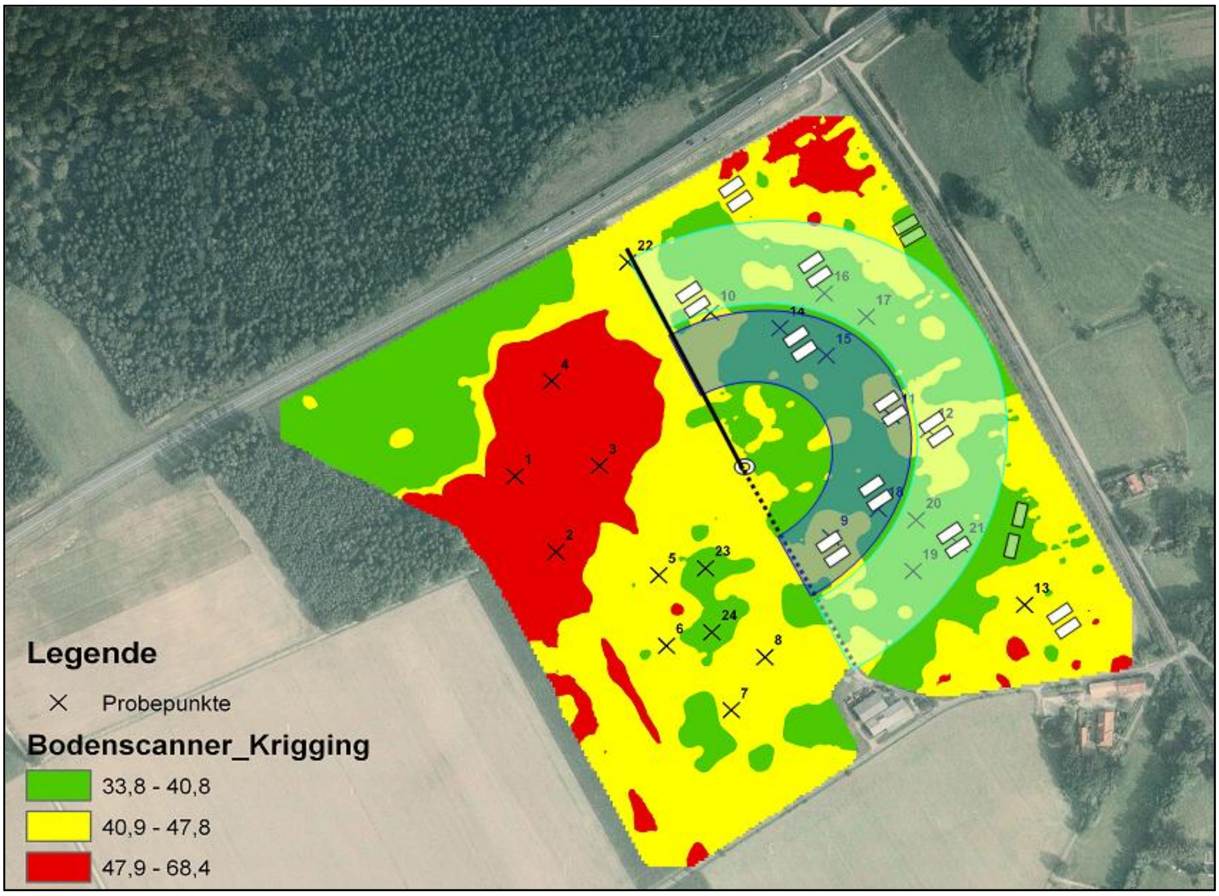


Precision irrigation with centre pivot

Germany

The Uelzen region is dry and the amount of groundwater for irrigation is limited to 80 mm per season and sometimes less. In this region in dry year the irrigation requirement is much higher. So research is started to increase the water use efficiency. Heinz Sourell and Angela presented the research on precision irrigation with a centre pivot. The nozzles of the centre pivot will be operated individual or in several groups to make it possible to give the right amount of irrigation on different spots in the field. Soils sensors will be used for detailed measurement of the soil moisture.
A field with different soil types has been selected and a detailed soil map is made by use of a soil scanner (EM 38) combined with borehole investigation. In half of the field precision irrigation will be tested by Heinz Sourell. In the other part Angela Riedel will study whether the use of irrigation water is more profitable in loamy soil than in "light" sandy soil with low water storing capacity. For this purpose several research plots will be studied.

The learning point of this study is that advanced techniques are available for precision irrigation. The disadvantage of this approach is the high price of automated nozzles. But in future prices of sensors and atomization is expected to drop strongly. So in future this is expected to become profitable.
The communication software between soil sensors and computer is not operational yet. So a visit is organized to the Dutch company that has the software for the soils sensors.



Implementation of new techniques.

Several means to bring knowledge about new techniques to the farmers are used by the partners.

spreading kowledge to farmers by:

- Article in agricultural papers,
- Doing reserach studies together with (innovative/example) farmers on there fields and organise famer visits to these fields.
- Use innovative farmers to introduce new techniques. The "follower farmers" will accept the idea when it has been proven effective.
- Inform local advisers well; they have contact with a lot of farmers.
- Give presentations on farmers meetings of local or organzied farmer groups especially for young farmers (after the growing season).
- Make a Aquarius news letter especially for farmers (at the end of the project?).

Financial incentives:

- organize subsidies for new techniques
- organize free advise for new ideas/techniques.

Spreading knowledge between Aquarius partners:

Discuss Interesting subjects:

- how to present model results
- how to use catch crops to prevent ersosion and to catch CO_2.
- how to implement buffer zones along surface water (During field visit in Drenthe?).
- how to change field layout to make centre pivot applicable:
    - how to allow removal of ponds or (groups of) trees and create/plant new ones in set aside corners; in combination with buffer strips along edges of fields as connection zones?
    - How to organize farmers to combine there fields to make large scale pivots profitable?

organize exchange visits on special subjects;

for example:

- Germans to Dutch company on communication software for soil sensors
- large scale Swedish farmers to German pivots?
- Dutch planners & ecologists to the Swedish wetlands that serve as irrigation reservoir.
- ....

The Aquarius network group on **Technology**

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Annex I

Technical methods questionnaire

As preparation on German Workshop – Aquarius

(Answers to simple questions on techniques used in Aquarius pilots)

The aim of the Aquarius meeting in Germany on 3-5 March for the "Expert Network Group on Technical methods" is: to share information for solutions and to create understanding of problems and possible technical solutions. Also it can be a starting point for special bi- or multilateral expert meetings.
The Technical methods mentioned in the project application for the different pilots are :

a.) Precision farming irrigation (sprinkling and drop)
b.) Feasibility study on pilot for use of cleaned wastewater for irrigation
c.) Irrigation governing systems (soil moisture control systems)

In order to get a general idea of the technical methods apllied in all pilots some the Aquarius pilot gave short descritions of the techniques by answering the following questions:

- **what technical methods do you use in your Aquarius pilot to solve water shortage problems?**

- **what experience do you or your organisation have, besides the Aquarius pilot, with techniques to solve water shortage problems?**

- **do you have questions about techniques to solve water shortage that you want to ask to the expert network group?**

In the pilots of Scotland and Norway watershortage is no issue so no technical methods are studied in these pilots. So these pilots did not give a descrition of techniques used.
The description of the other pilots is attached.

Denmark (Janne Aalborg Nielsen)

- **what technical methods do you use in your Aquarius pilot to solve water shortage problems?**

In Denmark we have the biggest demand for irrigation in the western part of the country, where we also have sandy soils. In the Western part of the country we generally don't have water shortage problems yet. Although in some areas we have indications of problems with dry ends of water courses. We use ground water/subsoil water for irrigation in agriculture. The farmers typically get permission to 100 mm water catchment per hectare per year.

Irrigation of fields is very labour-intensive, and that is an important reason for many farmers to have interest in optimizing and economizing on irrigation.

The Water Frame Directive will also put some limitations on water catchment in Denmark.

The most effective tool we have to optimize and manage irrigation is a Decision Support System for Irrigation Scheduling, "Water Management Online".

The system is an online tool for the computer. It gives daily information of the timing and the amount of irrigation for a wide range of agricultural crops in Denmark.

The system includes conceptual and empirical sub models for crop development, water balance and crop yield. About 350 farmers use the system in Denmark.

- **what experience do you or your organisation have, besides the Aquarius pilot, with techniques to solve water shortage problems?**

Our experience is mostly with the computer Decision Support System for Irrigation Scheduling.

- **do you have questions about techniques to solve water shortage that you want to ask to the expert network group?**

Is there anyone else who have experiences with other computer tools for water management?

Germany. Lüneburger Heide region (Angela Riedel)

Technical methods

In answer to water shortage problems we want to implement precision irrigation:
The question is, if it is possible to manage each individual nozzle at a centre pivot irrigation machine during on farm research/ in practice? This question will be clarified in close collaboration with Heinz Sourell (vTI). Furthermore we enter into the question, whether the use of irrigation water on a heterogeneous field is more profitable in loamy soil than in "light" sandy soil with low water storing capacity. We identified the different soil areas in the field by measurement of the conductivity of the soil with an EM 38 device. The irrigation steering is the result from soil humidity.
The soil water content is measured by "EasyAG" probes from SENTEC. Irrigation starts when a section of the field goes below 50 % available water capacity.
We want to find out the best water saving distribution and the best utilisation of the irrigated water.
In addition to technical methods we are interested in plant cultivation aspects:
Which cultivar/ soil cultivation method/ plant density is water efficient?

Experience with techniques to solve water shortage problems

Another project (Klimzug- Nord) tests four irrigation governing systems. They want to ascertain the best available and practicable technology.

Questions to the expert network group?

Have you any experience with precision irrigation?
or with soil water measurement?

Feasibility study for use of cleaned wastewater

A feasibility study is not needed, because our project AQUARO is allotted. Thereby the cleaned wastewater of a municipal sewage plant and the sugar refinery of Uelzen will be used for irrigation. After watering-up the storage reservoir cleaned wastewater of the municipal sewage plant will be infiltrated at forest.

Delfland, Netherlands (Helen Hangelbroek & Karin Tromp)

- In Midden-Delfland 8,6% of the agricultural activities is greenhouse horticulture and crop farming (reference year 2005);
- Climatic change reveal the risk of periodic shortage of fresh water supply in the future. During periods of summer drought, horticulture will depend more on surface water supply for irrigation. However, due to effects of climate change, surface water become (periodically) brackish due to periods of low river discharge (influencing the inlet water quality) and salinity pressures in the region from rising sea levels;
- Higher amounts of salt in the surface water for irrigation in periods of drought, will cause accumulation of sodium in the horticulture system, damage to crops (economic damage) and eutrophication of the water system due to flushing the horticulture system (to prevent salt accumulation);
- Technical solutions/ideas: to enlarge the (above/below ground) rainwater storage capacity of greenhouses (normal situation: 3000 - 3500 m3/ha, extreme situation: up to 5000 m3/ha), production of tap water for irrigation (1 mmol sodium per liter), reverse osmosis and recycling of waste materials from reverse osmosis.

Sweden, (John Strand)

First of all it must be understood that the Swedish pilot is not a major player regarding irrigation techniques, and we are not listed in the Aquarius-application as participants in this part of the WP. With that in mind we still have areas of interest in closely related topics.

- **What technical methods do you use in your Aquarius pilot to solve water shortage problems?**

The main method to solve water shortage problems are different ways of pumping water from large rivers to smaller rivers (e.g. river Smedjeån) in order to make it possible for irrigation water outtake also in the smaller rivers. Furthermore, also buffering and storage of water in constructed wetlands are used as a mean to guarantee the water supply for irrigation.

- **What experience do you or your organisation have, besides the Aquarius pilot, with techniques to solve water shortage problems?**

We have been responsible for constructing large numbers of wetlands that can be used for irrigation.

- **do you have questions about techniques to solve water shortage that you want to ask to the expert network group?**

Mainly if there are experiences with water outtake from natural rivers and where the lower limit regarding flow is decided. Also how this limit is controlled by authorities.

Drenthe, Netherlands (Jan den Besten)

Technical methods to solve water shortage problems?

The Aquarius pilot region "Veenkoloniën" in Drenthe is a large scale agricultural region on a sandy where we have problems with water shortage. The area is rather flat. Within the farms the difference in height between the high and low parts can be 1 to 1,5 m. The field are all rectangular with many canals in between.

The water shortage we solve now with water supply from river Rhine through a large lake "IJsselmeer". This water mainly infiltrates from ditches into the subsoil. By capillary rise part of the water reaches the crops; especially in the lower parts. The relatively higher dry parts are not reached in this way. On the higher spots some farmers irrigate in dry years. But only maximal 10-20% of the total area is irrigated, mainly by sprinkling with a with surface water . As sprinkling technique a “water cannon with hose-reel” is used.

We expect that water shortage will increase due to climate change. So in the future we expect more farmers have to irrigate. At the same time the summer base flow of the river Rhine is expected to decrease, so less water might become available for irrigation.

To solve these future problems we want to conserve more water in our region and we stimulate efficient water use.

To increase the water availability in our region we put weirs on remote control in order to be able to operate them very quickly. In that way we can keep the water level in the canals longer high without risk of damage due to much water in case of sudden heavy showers. In this way more water is stored in the canals and in the sub soil.

Capillary rise will not go much faster when climate change causes a higher water demand of crops. So that is not a solution for an increasing water demand. That is why we stimulate sprinkling among farmers. But farmers indicated that the present way of sprinkling (with water canon and hose-reel) is very time consuming. So labour was indicated as a bottle neck for more sprinkling. To solve this labour constraint we introduced a labour saving technology (pivot sprinkling systems, already used a long time in arid areas)). It also saves energy and water.

We especially want to stimulate sprinkling from ground water (now it is mainly done from surface water) because in that way the sub-soil is used as a reservoir to store the winter rain.

With 50 farmers we use now 100 wireless rain gauges and soil sensors combined with a DSS system to optimize the amount and timing of sprinkling. We want to develop the DSS and we want to extend this system to a DSS for N-fertilizing. We also plan to give farmers small weirs for water conservation to be operated by them.

Experience with techniques to solve water shortage problems

Since 2006 we had a small projects with 10 farmers with soils sensors and a DSS. Ssince 2007 we have a small linear pivot on an research farm in our area and some pivots at individual farms (1 centre pivot (in 2007) and 2 linear pivots (in 2009).

Questions to the expert network group?

Who has experience with pivots, soils sensors and a farmer-DSS for sprinkling, seasonal Water storage?

Annex II

Short papers the Aquarius Expert Network Group 3.1.3: Technology.

Papers are made by Denmark, Netherlands (Drenthe) and Germany.

Aquarius
Short paper for the Expert Network Group 3.1.3: Technology.

Country: Denmark
Contact person: Janne Aalborg Nielsen, Specialist Adviser in Soil cultivation, Irrigation and Drainage at the Danish Agricultural Advisory Service National Centre, Crop Production.

Introduction:
Climate change may lead to greater demand for irrigation on agricultural land. Longer periods of time with dry conditions and maybe more heavy rainfalls than we have known before are a possible consequence of climate change. The Water Frame Directive will also put some limitations on water catchment in Denmark.

In Denmark we have the biggest demand for irrigation in the western part of the country where we also have sandy soils. In the eastern part of the country we have more loamy soils and less demand for irrigation. In the eastern part of the country it is generally not possible to get permission for water catchment. Here there are water shortage problems, and the water is saved for household and industry. In the Western part of the country we generally don't have water shortage problems yet. Although in some areas we have indications of problems with dry ends of water courses in the summer time. A possible solution could be to move boring for water further away from the water course if possible.

We use ground water/subsoil water for irrigation in agriculture. The farmer typically gets permission to 100 mm water catchment per hectare per year. Irrigation of fields is very labour-intensive, and that is an important reason for many farmers to have interest in optimizing and economizing on irrigation.
Our biggest challenge is to bring more farmers to use systematic water management.

Our organization:
The Danish Agricultural Advisory Service (DAAS) is a partnership made up of 32 local advisory centres and a national centre. This unique two-level advisory system is both owned and used by Danish farmers. The partnership employs approximately 3,500 professionals.
I am employed at the Crop Production department.
One of the most important tasks of Crop Production is to keep advisers at the
Local advisory centers up to date with the latest knowledge on field operations.
For example we develop and offer IT solutions for data management and optimization of agricultural holdings, such as “Water Management Online”.

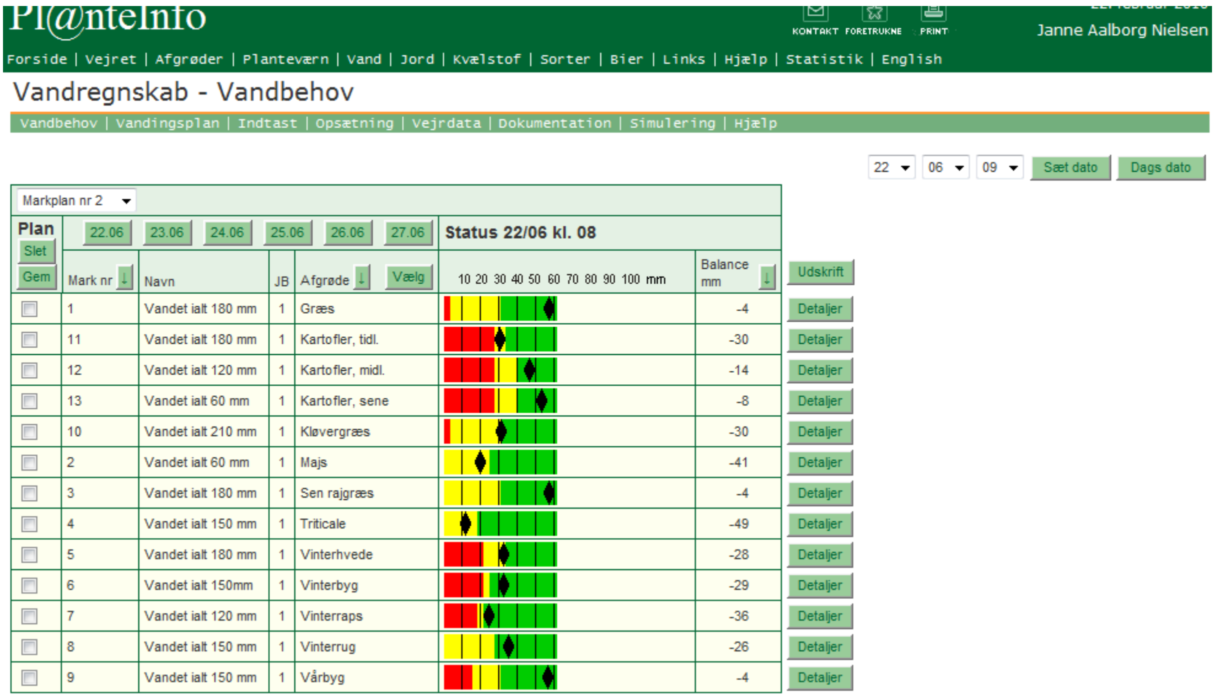
The technical methods

The most effective tool we have to optimize and manage irrigation is a decision Support System for Irrigation Scheduling, “Water Management Online”.

The system is an online tool for the computer. It gives daily information of the timing and the amount of irrigation for a wide range of agricultural crops in Denmark.

Many farmers are very pleased with the tool, but several more farmers could have profit from this tool. “Water Management Online” is very user-friendly. The farmer or the farmer’s Adviser only needs to tap in the type of crop, date for crop emergence and soil type. Then the program calculates the need for irrigation.

The overall principle in the tool is this view, where the farmer follows the need for irrigation:



The program has meteorological inputs from Danish Meteorological Institute and also gives a forecast for the need of irrigation five days ahead.

We continuously try to disseminate the use of “Water Management Online” through articles and other campaigns.

Aquarius
Short paper for the Expert Network Group 3.1.3: Technology.

Country: Netherlands, Drenthe

Contact person: Jan den Besten, hydrologist, water authority Hunze en Aa's

I. Introduction

The Aquarius pilot area is a part of the catchment that is managed by the Water authority Hunze en Aa's. It is part of the international river basin of the river Ems. The catchment area of Hunze en Aa's is ca 200.000 ha and the discharge of this area flows into the salt delta of the river Ems (see figure 1).

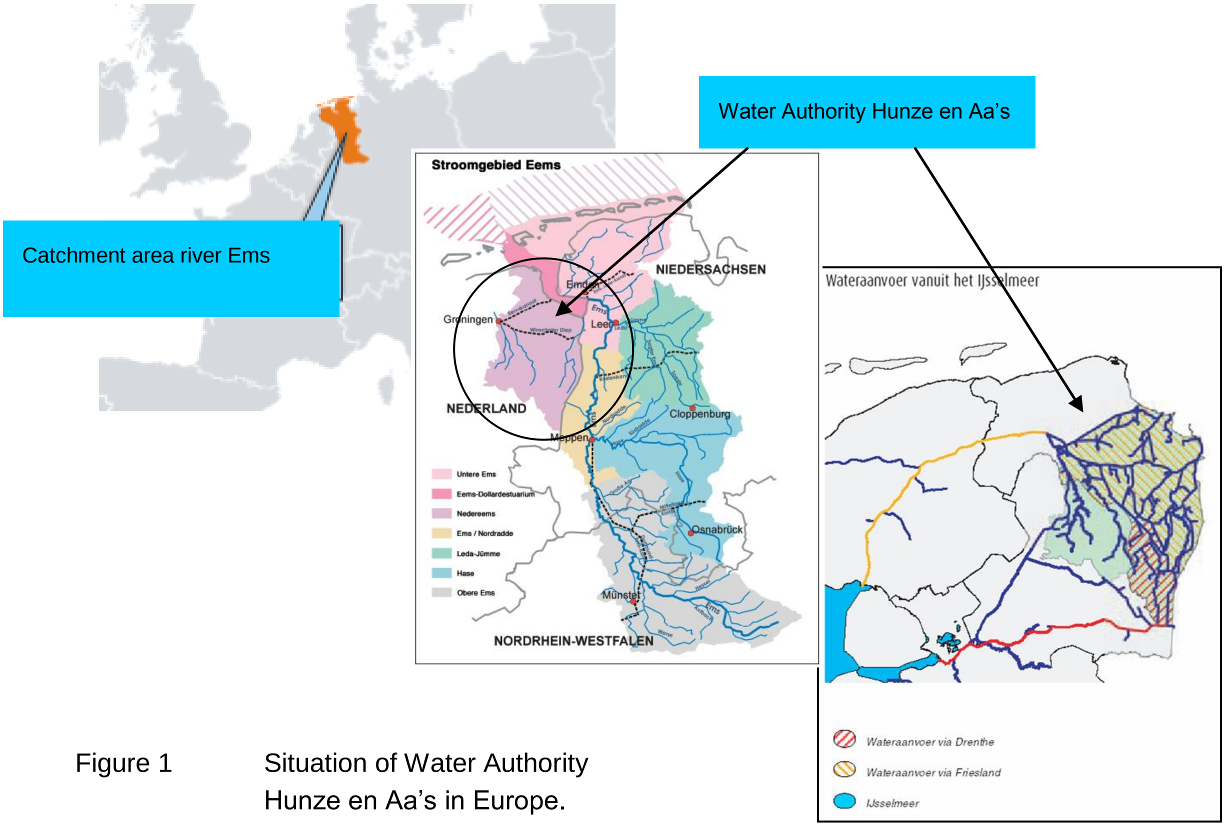
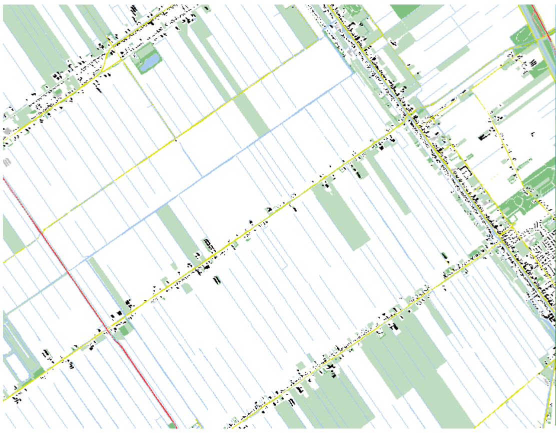


Figure 1 Situation of Water Authority Hunze en Aa's in Europe.

The provincie Drenthe is responsible for the strategic water policy. Water authority Hunze en Aa's is responsible the daily operation of the water management in the area. Both are partners in Aqarius.

The Veenkoloniën is a former high-moor bog area. Between 1500 ac until the early 20th century all the peat has been dug away. The peat was dried into turf and transported by ships to be used as fuel. To be able to dry the area and to transport the turf a detailed network of straight canals was made. This dense network of canals is still present. At the moment the area is a mainly flat and sandy and used for agricultural. Some line-shaped villages are present along some of the bigger canals.



The Veenkoloniën is area is a rather flat area. Within the farms the difference in height between the high and low parts can be 1 to 1,5 m. The fields are all rectangular with many canals in between.

II. Water shortage in the Veenkoloniën

water shortage in the present situation

Because of the sandy soil the higher parts of the area have yield reduction due to water shortage. The water shortage problem is solved now with water supply from river Rhine through a large lake "IJsselmeer". In a dry year as 2003 ca. 75 million m³ water is pumped up 5 to 10 m high to this area. This water mainly infiltrates from ditches into the subsoil. By capillary rise only part of the water reaches the crops and mainly in the lower parts. The relatively higher dry parts are not reached in this way. On the higher spots some farmers irrigate in dry years. In a dry year like 2003 only 10-20% of the total area is irrigated, mainly by sprinkling with surface water. As sprinkling technique a “water cannon with hose-reel” is used.

The present policy for permits for sprinkling gives high priority to sprinkling from surface water instead of use of groundwater.

Water shortage in the future situation

We expect that water shortage will increase due to climate change. Model studies combined with scenario’s for climate change indicate an increase of the water demand in the area of 15 to 75%.

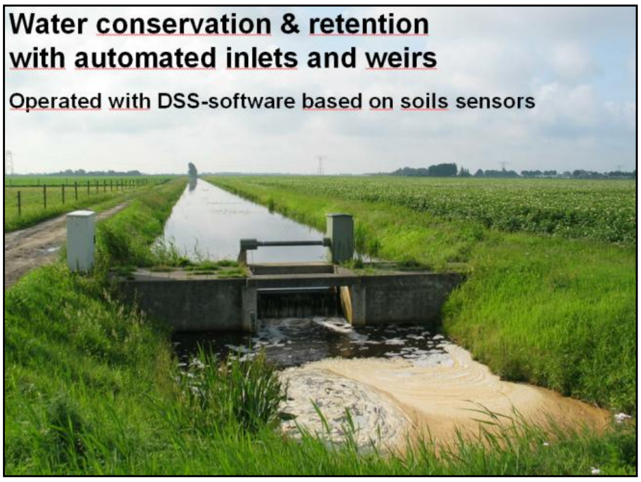
At the same time the summer base flow of the river Rhine is expected to decrease, so less water might become available for irrigation.

III. Techniques used to cope with water shortage

Capillary rise will not go much faster when climate change causes a higher water demand of crops. So that is not a solution for an increasing water demand. That is why we stimulate sprinkling among farmers. But farmers indicated that the present way of sprinkling (with water canon and hose-reel) is very time consuming. So labour was indicated as a bottle neck for more sprinkling. Besides labour also sprinkling costs can be a reason not to irrigate.

So in the future we expect more farmers have to irrigate. At the same time the summer base flow of the river Rhine is expected to decrease, so less water might become available for irrigation.
To solve these future problems we follow two lines. The first line is to conserve more water in our region in this way we hope to be able to solve a part of the extra water demand of the future in our own area. Secondly we want to stimulate efficient water use. In this way we hope to reduce our water demand to some extend.

In the Aquarius project we have the following activities on these aspects:



<u>Water conservation:</u>

- **raising surface water levels in order to conserve more water in canals and in the sub-soil.** For this aim we put weirs on remote control in order to be able to operate them very quickly. In that way we can keep the water level in the canals longer high without risk of damage due to much water in case of sudden heavy showers. The operation of the weirs is optimized by a DSS that uses soil moisture data from 100 soil sensors at farmer fields.
- **Small conservation weirs to be operated by farmers.** In this way in higher dry areas farmers can raise the water level in the ditches and small canals and so store more water in the subsoil.

<u>Efficient water use</u>

- **introduction of water efficient sprinkling technique (Pivots)** that also save labour and energy.
- **Efficient planning of irrigation**: soils sensors in combination with rain gauges and a DSS.
- **Sprinkling with ground water.** Up to 80% of the water supply infiltrates unused into the sub-soil. Farmers can pump up this water to sprinkle their crops. In this way the over all efficiency of the water supply system increases very much (from 10-20% up to 50% or more).

In this paper I want to go give a general description of the techniques of pivot irrigation and of the soil sensors we use.

IV. Pivot sprinkling technique

Farmers indicated that they see bottle necks for increasing their sprinkling activities. Next to the costs of sprinkling they indicated that the present way of sprinkling (with water canon and hose-reel) is very time consuming and also forms a bottle neck for irrigation.
To solve this labour constraint we introduced the labour saving sprinkling technology of the pivot sprinkling systems. These systems are already used a long time in arid areas.

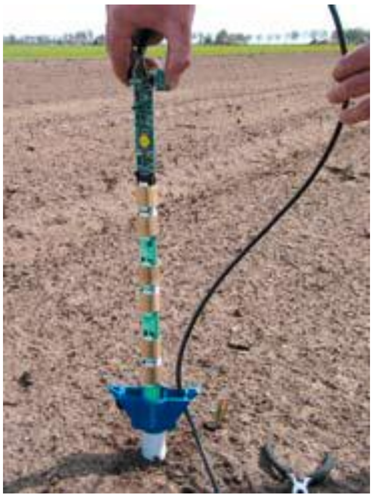
We got the idea of using this technique in western Europe from our German colleagues in a former interreg project (No Regret). It is a low pressure sprinkling system. Compared to the high pressure system of a water canon this low pressure pivot system saves energy costs. It has a more efficient water distribution as it is less sensitive for wind disturbance. The investment costs are comparable to the costs of a water canon with hose-reel.
The disadvantage of the pivot system is its in-flexibility. During the growing season you cannot drive a pivot from one field to another field some km away. That makes the pivot a technique that is suitable for large scale farms with large field (> 30 ha). In the Veenkoloniën we see a continuing scale enlargement. So in the future more farms will become suitable for the pivot technique.
The most labour saving pivot is the centre pivot (see picture above). It is also the most suitable pivot for sprinkling with ground water. But it requires square (or even circular) fields. As most fields in the Veenkoloniën are long stretched rectangular blocks the linear pivot is more suitable for this area (see picture below). This linear pivot is one arm with sprinkling nozzles on it. It drives along the field and some types have the flexibility to go to bordering fields. In the Veenkoloniën it takes its water from the

ditches or the canal along the field. Sprinkling with ground water with the linear pivot is more complicated than with a centre pivot.
Since 2007 we have a small linear pivot (80 m) on a research farm in the Veenkoloniën for testing and demonstration. As a result some individual farmers bought already a pivot themselves. 1 centre pivot was bought in 2007 and 2 linear pivots in 2009.

V. Soils sensors and a DSS for sprinkling

Water use efficiency can be improved by better planning of the right moment and amount of irrigation.
Until now farmers start irrigating when they “feel” that is necessary or when the neighbour starts.
In this way he often starts when he notice some drought stress in the crops. And then he is in fact already too late as stress means that the crop has already a reduced grow and so less yield.

By measuring the soil moisture in his field a farmer see what is exactly going on in his field on the spot of the measurement. Since 2006 a small group of farmers together with a private company (DACOM) experimented with the use of soils sensors and a simple DSS to optimize the planning of the moment and amount of irrigation. Starting in 2009 a sister project called "Watersense" in the pilot area of Aquarius 100 soils sensors were placed at the fields of 50 farmers. The soils sensors are combined with a rain gauge and are wireless connected to the main frame of the company. The company presents the data to the farmers PC. The soil sensor measures at several depths in the root zone the soil moisture and the conductivity.



The farmer sees the data on his PC in a graph (see picture below)

The DSS for sprinkling is at the moment based on a simple water balance model of the root zone. In Further development of the DSS is going on and will include more advanced crop grow models. All sensors of 2009 can be read on the website of the project www.projectwatersense.nl .

A disadvantage of this system is that it provides only point measurements at the spot of the sensor. A few meters away the soil moisture can be totally different due to differences in soil type or in height. We tried to minimize theses effect by scanning the soil of the whole field with a soil scan sensor behind a tractor. In this way we selected a spot for the sensor that is as representative for the whole field as possible.

Some sensors also measure conductivity so than some indication is available of soil salt. These measurements are combined with soil samples that are analyzed for nutrients. Combined with models of the nutrients balances in the root zone this system also can give an indication of the nutrient level in the soil. In the project Watersense research is going on to develop this part of the system into a DSS for fertilization of Nitrogen.

The sensor system costs 3000-5000 euro per system. In the Watersense project subsidy is found s the farmer contribution is now only 250 euro per system. It is expected that within 10-20 years the price of this type of sensors will drop drastically.

Other sensor based DSS systems for irrigation

The advantage of the system with soil sensors is that it is based on detailed measurements of rainfall and soil moisture directly in the field of the farmer concerned. Other system work with general measurements of rainfall and soil moisture is often based on data that are calculated with a rough model of the rote zone. So the advice is rather general and not very field specific.

Another type of sprinkling DSS system uses satellite remote sensing data to derive data of crop evapotranspiration and crop grow. The advantage of this system is that it gives a spatial picture of the field. Disadvantage of this system is the low frequency of some satellite data. In a cloudy month you have sometimes only one or two usable satellite pictures. To “fill the gaps” models are used to calculate the daily soil moisture.

A remark on the spatial details is necessary. Some satellite data are only available for pixels of 150 x 150 m.

As we do not have experience with DSS –systems for irrigation based on general measured data or on satellite data we are interested in experience of others with these systems.

Research and extension

The research farm in the Veenkoloniën is involved in the Aquarius project and in the Watersense project. Field research is done on the effect of sprinkling and fertilization on yields in combination with use of soil sensors for moisture and conductivity. The research farm is part of the University of Wageningen and scientists participate in the Watersense project to develop the models for soil nutrients and moisture and crops grow models.

<u>extension</u>

The research farm is visited by hundreds of farmers during “open days”. So the pivot is demonstrated in this way to many farmers. During the last 4 years in several cooperation projects we built a cooperation network on water use with farmers in the Veenkoloniën. As a result we now have a group of 50 farmers that are actively involved in the sprinkling-DSS. So we spread innovative ideas by starting to work together with innovative farmers. In case of a successful idea the other farmers will follow little by little.

Aquarius
Short paper for the Expert Network Group 3.1.3: Technology.

Country: Germany

Contact person: Ekkehard Fricke; Irrigation adviser in the Chamber of Agriculture of Lower Saxony

Introduction

In the northeast of Lower Saxony we have sandy soils, less rain and therefore the largest continous irrigation area in Germany. Nearly 200.000 ha of arable land could be irrigated in this region. We use mostly groundwater for irrigation, only in the near of the “Elbe-Seiten-Kanal” we use canal-water. The amount of groundwater the farmers use for irrigation is limited to nearly 80 mm per season and 560 mm per 7 years.

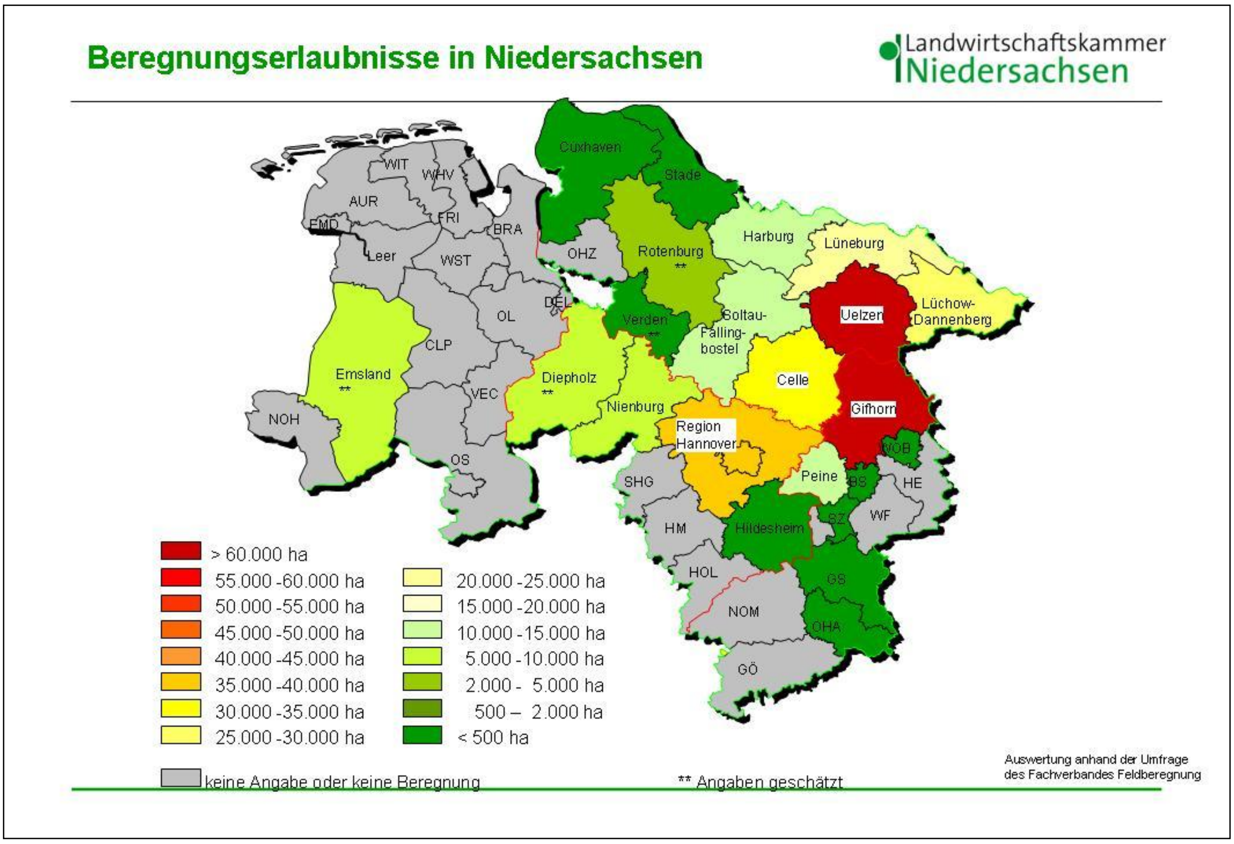


Abb.1: Irrigation within Lower Saxony

Irrigation is the main reason for sinking groundwater-levels and dry-falling creeks (only in summer). Watershortage is a problem and climate change with longer periods of drought will intensify this. We expect, that the water demand for irrigation will increase.

Our organisation

Consulting service, implementation an analysis of field tests and representation of interests are unified in the Chamber of Agriculture for Lower Saxony (Department of plant production, subject group irrigation) and the association for field irrigation (Fachverband Feldberegnung e.V.). The Chamber of Agriculture has responsibility over about 2.6 million hectares of agricultural land and about 500.000 hectares of private woodland. There are about 53.000 enterprises in agriculture and forestry that form the membership and customer base of the Chamber. As the body officially responsible for agriculture and 'public interests', the Chamber works closely with municipalities and districts and represents the professional interests of farmers. The association for field irrigation is established in the house of the chamber of agriculture, that's why the employees in the subject group irrigation also work for the association. It's a work with many synergistic effects in the interest of the farmers.

Technical methods

In answer to water shortage problems we want to implement precision irrigation:

The question is, if it is possible to manage each individual nozzle at a centre pivot irrigation machine during on farm research/ in practice? This question will be clarified in close collaboration with Heinz Sourell (vTI). Furthermore we enter into the question, whether the use of irrigation water on a heterogeneous field is more profitable in loamy soil than in "light" sandy soil with low water storing capacity. We identified the different soil areas in the field by measurement of the conductivity of the soil with an EM 38 device. The irrigation steering is the result from soil humidity.

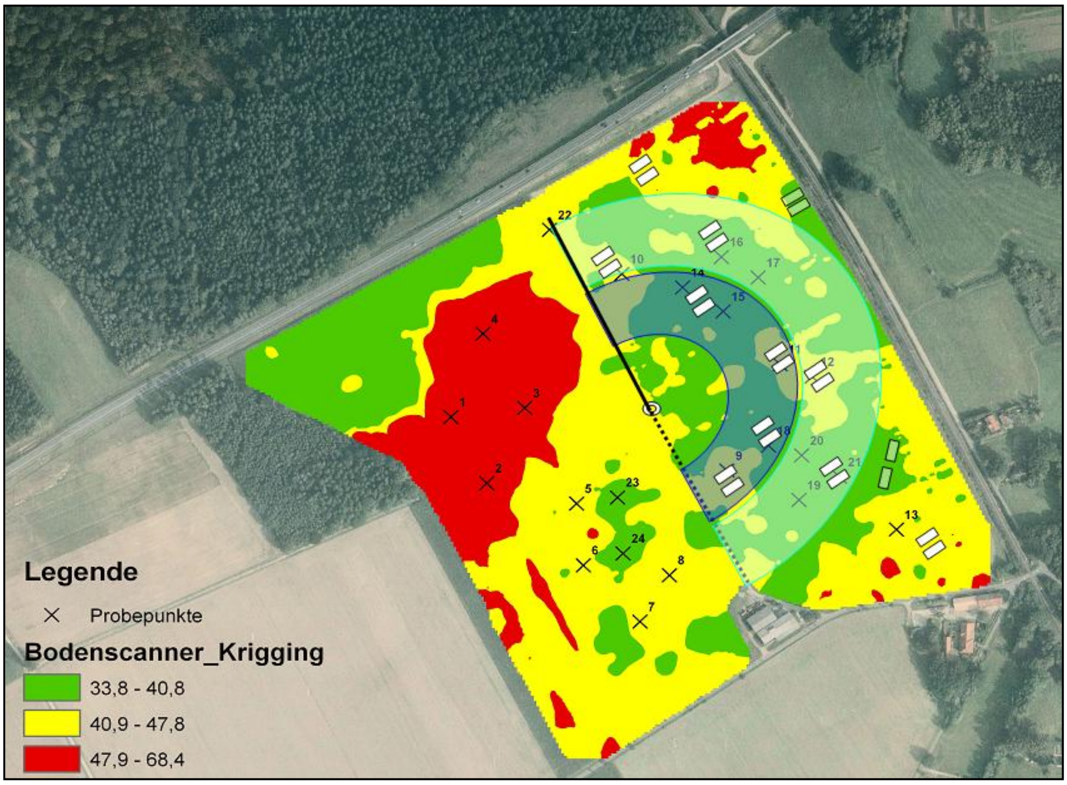


Abb. 2: Conductivity of the different soil measured by EM 38

The soil water content is measured by "EasyAG" probes from SENTEC. Irrigation starts when a section of the field goes below 50 % available water capacity.

We want to find out the best water saving distribution and the best utilisation of the irrigated water.

In addition to technical methods we are interested in plant cultivation aspects:

Which cultivar/ soil cultivation method/ plant density is water efficient?

Spread the knowledge

We write articles in agricultural papers, give presentations on farmers meetings and organise field visits with farmers and also with multiplicators. Also we have a research farm for irrigation studies, where many farmers come. That’s the place to tell about innovations and new successful techniques.

(Background article about precision irrigation with centre pivot)

Variable Water Application Depths from a Centre pivot Irrigation Control System

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ABSTRACT

Current commercially available centre pivot (CP), linear-move and other sprinkler irrigation systems are normally capable and manage to apply relatively uniform controlled amounts of water, whereas the need for irrigation may differ between different zones of a particular field due to spatial soil variability. The 2nd span of CP including 15 nozzles was modified for site-specific irrigation using solenoid valves (SV), programmable logic control (PLC) and EIB-Bus communication protocol to evaluate the validation of site-specific irrigation control system and system modification and to examine water application uniformity. The PLC and the SV functioning were (open and close) were able to able to vary the amount of water proportionate to pulsing level and directly proportional to the fraction of time the valve was opened. There were no apparent problems with the pulsing water delivery system as in field tests were conducted. Except for 10 % pulsing level, measured irrigation depths were within 10 % of the target application rate. Error application of irrigation depth under low pulsing level of 10 % was found due to SV closing delay. Neither pulsing level of SV nor system movement speed had a significant effect and discernable impact on overall application uniformity.

Key Words: Site-specific, Variable rate, Centre pivot, Irrigation, Application uniformity

INTRODUCTION

Current commercially available centre pivot (CP), linear-move and other sprinkler irrigation systems are normally capable and manage to apply relatively uniform controlled amounts of water and injected chemicals laterally along the system. Thus over and/or deficit irrigation in some portions of the field will be unavoidable due to spatial soil variability. Modernized irrigation systems with advanced technology have developed by industrialized countries in the past 50 years (Sourell and Sommer, 2002; Maohua, 2001; Faci et al., 2001). Self-propelled commercial travelling irrigation systems, such as centre pivot (CP) and moving lateral, are particularly amenable to site-specific approaches because of their current level of automation and large area coverage with a single pipe lateral. However technology for varying water application along the mainline of self-propelled sprinklers is not commercially available. But several technologies have been developed by researchers to variably apply water with self propelled sprinkler systems. The last idea for VRI is Pulse concept by using solenoid valves to control single sprinkler or manifold (Fraisse et al. 1992, 1995; Giles et al. 1996; King et al. 1999; Sadler et al. 1996; Evans et al. 1996; Eberlein et al. 2000; King and Wall, 2001; AL-Karadsheh et al., 2002; Moore et al, 2005). In each case, spatially-variable water application was flexible and successfully achieved, and relatively, the water depth measured reached the target depths on a limited scale. It is important to ensure that the pulsing technique produces the desired amount of irrigation under different pulsing levels. Moreover, while a high standard coefficient of water distribution uniformity (CU) of an irrigation system is required, the effect of the overall CU by the ON and OFF cycling of sprinklers to achieve variable application rates must be evaluated, especially with due attention to limitation of literature in this case. Dukes and Perry (2006) found that in spite of some delay because of the time required for the valve mechanism to function for VRI during valve opening and closing, a high average overall CU of 93 % and 84 % were obtained by modified VRI centre pivots and linear moves, respectively. Also, preliminary testing indicated that variable-rate irrigation cycling had no effect on CU (Perry and Dukes 2004), however, this was limited to partial testing across cycling rate and movement speed for both the centre pivot and linear move systems. Perry et al. (2002) obtained 88 % CU by variable rate pivot irrigation control system. Also King and Wall (2001) obtained a range of CU from 87 to 92% for relative application rates of 33 to 100% and mean water application depths within 10% of the target depths. Therefore, the objectives of this study were 1) to evaluate the validation of site-specific irrigation control system and system modification and to determine if the actual applications were within design specifications and 2) to examine water application uniformity for several different levels of VRI control at three different speeds of system movement under low wind and low evaporation conditions.

MATERIAL AND METHODS

Irrigation System: A two-span of 90 m total length and with an overhang commercial centre pivot system located at the Federal Agricultural Research Centre (FAL), Institute of Production Engineering and Building Research, Braunschweig, Germany, was modified for VRI. The irrigation system included “NELSON R3000” rotator nozzles (U4-8°, blue plate). The irrigation system could be operated in forward or reverse, with and without applying water, which is pumped from an underlying network.

Irrigation System Modification: The 2^{nd} span of CP, including 15 nozzles, was controlled for variable-rate water application with a pulsing technique of “Baureihe 82340/82440” solenoid valve (SV) from the Buschjost company (www.buschjost.de) and PLC at control unit installed on CP at 3 m distance of pivot point. In this study, every four solenoid valves were wired together in one box with an EIB-Bus communication protocol (Europäischer Installationsbus) and connected to a control unit installed 3 m from a pivot point that opened and closed. But solenoid valves were individually controlled based on data- base values and the location in the field (using a position encoder). EIB-BUS is a free-cost and simple communication protocol that can control many SVs together with one cable. All electrical output devices including SV, position encoder, etc,. were controlled by a prototype PLC and EIB-Bus communication which were developed by the office for control technique and switching (www.schudzich.de). The control unit was mounted on the CP about 3 m from pivot point. Spatial location of each depth was to be determined by the system operating parameters: angle of rotation and location along the truss using position encoders. The integrative PLC had an on-board PC as data logger, which can read a saved data file, allows changes in the system information, and can convert the map of control to on/off setting in the directly-addressable solenoid control registers of the PLC. The application rate was varied based on pulsed ON for a fraction of 100 seconds, directly proportional to the desired fraction of the uniform (100 %) application rate. For example for pulsing level of 70 %, SV were opened 70 seconds and closed 30 seconds during each 100 seconds (one second for 1 % pulsing level). Three hypothetical irrigation management zones (IMZ_1, IMZ_2, and IMZ_3) were considered along the length of CP. Thus three different pulsing levels of SV could simultaneously be considered for 15 NELSON sprinklers to irrigate these three IMZs. Therefore IMZ1 was irrigated with the first three sprinklers (1, 2, and 3), IMZ_2 was irrigated with Sprinklers 4, 5, 6, 7, and 8 and IMZ_3 was irrigated with Sprinklers 9, 10, 11, 12, 13, 14, and 15. IMZ_1, IMZ_2, and IMZ_3 had about 9, 13, and 19 m width along the length of CP. Because of some economic reasons, only the 2nd span of CP was modified for VRI.

Field tests of PLC validation and CU performance: Tests of water distribution were conducted using catch-cups along the length of CP to validate the PLC, system modifications, and CU under SV pulsing. Seven pulsing levels and three CP speed levels were considered to investigate the feasibility of using pulsing techniques to produce the desired amount of irrigation under different pulsing levels. The tests were run while the machine was operating under 15 and 30 % of CP speed and programmed on three different pulsing setting of 10-40-70 %, 30-60-90 % and 100-100-100 %. Irrigation target depths were defined based on 100 % pulsing level and fraction of time the valve are opened. Therefore error of measured irrigation depth at different pulsing levels was measured relative to target irrigation depth.

Uniformity tests were currently being conducted to ensure that the irrigation system is applying an even distribution of water over the entire span of the CP lateral. With due attention to the short width of IMZ_1 along the length of CP and also overlapping of sprinkler from neighbour zones with different irrigation rates (effect of border area or where irrigation zone receives water from sprinkler which are installed inside neighbour irrigation zones by overlapping), it was not practically possible to calculate CU inside IMZ_1. Therefore CU was calculated only for IMZ_2 and IMZ_3 without considering transition zones (overlapping area) and also for all three zones when all sprinklers were operating under 100 % pulsing level CU tests were conducted based on ASAE standards (2003) by using the Heermann et al., formula (1992):

$$CU_{HH} = 100 \left[1 - \frac{\sum_{i=1}^{n} S_i \left| V_i - \overline{V}_m \right|}{\sum_{i=1}^{n} V_i S_i} \right] \quad (1)$$

where CU_{HH} is the Heermann et al., uniformity coefficient, n is the number of collectors used in data analysis, i is a number assigned to identify a particular collector beginning with i = 1 for the catch cup located nearest to pivot point and ending with i = n for the most remote catch cup from the pivot point, Vi is the volume (or alternately the mass or depth) of water collected in the i^{th} catch cup, S_i is the distance of the i^{th} catch cup, and $\overline{V_m}$ is the weighted average of the volume of water caught by all collectors. The tests were conducted during the early morning hours to minimize wind draft. Water was collected in a two rows of 38 catch-cups placed 40 cm from the ground and spaced 1 m between catch-cups with two replications as shown in Figure 1.

RESEARCH RESULTS

The PLC and the solenoid valve functioning (open and close) were able to pulse the water on and off for any given application rate at a programmable pulsing level from 0 to 100 % of 100 seconds pulsing interval and under 15, 20 and 30 % of given CP speeds. Figure 2 shows the pulsing effect on nozzle irrigation depth with a relative comparison between measured

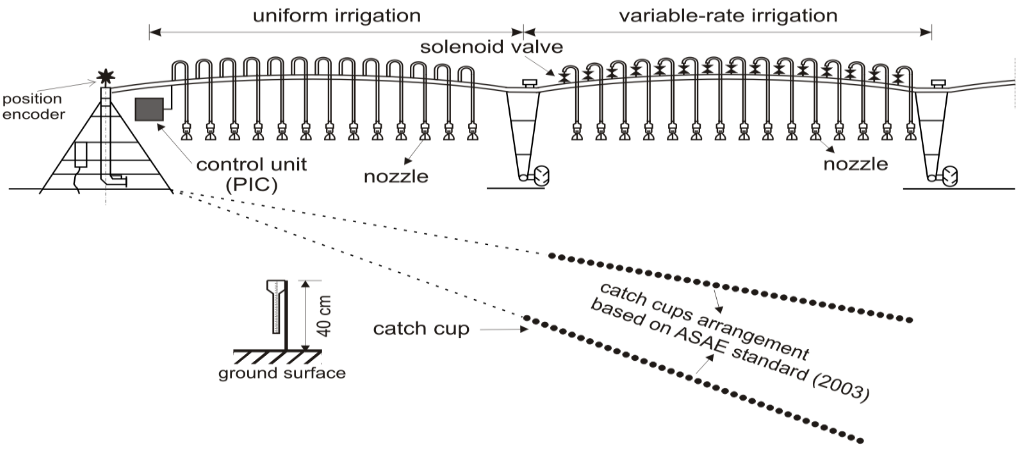

Figure 1: Modified centre pivot for site-specific irrigation and catch-cups arrangement for PLC validation and CU test

and target application depths for three different sets of time. Generally measured irrigation depths reached the target depths. Although measured irrigation depth at 10 % pulsing level of 15, 20 and 30 % CP speeds showed significant measured irrigation depth error higher than 10 % relative to target irrigation depths, generally measured irrigation depths were within 10 % of the target application rate.

Measurements indicated some deviations at the border of IMZ with less/more irrigation depth than the target depths. The error is considered very small when compared to typical sizes of irrigation zones and when considering that at the border area there will be a blending of water application rate. This is because the sprinklers used in the package had a relatively large wetted radius, which indicates the importance of using sprinklers with smaller wetted radius to reach depths much closer to the target depths. Moreover the selection of the proper sprinkler packages also has an effect on the size of the management unit in the application map, which depends mainly on the ability to measure and manage it (Blackmore, 1994). Therefore, as suggested by Omary and Sumner (2001), the throw radius of the spray nozzle should not be larger than three times the spacing between the spray nozzles. The contrasts between the target and measured depths at the borders area are decreased and increased when the required change in water depth is small or big, respectively. This indicates that this variable rate irrigation system is appropriate for applying variable target amounts step-wise, otherwise some deviations in the applied amount are expected.

In site-specific irrigation, the distribution uniformity within each IMZ must be as uniform as possible. The coefficient of uniformity for conventional CP irrigation systems ranges from 0.85 to 0.95 (Scherer et al., 1999). The coefficients of uniformity at different pulsing levels and the CP speed of this study are shown in Table 1. The solenoid valve

functioning (open and close) had no effects on the CU, and the uniformity of the nozzle output was not adversely affected by using the pulsing technique for water application as compared to the uniformity of a conventional CP system, although an insignificant deviation in water distribution patterns could be attributed to the small loss in pressure due to the solenoid valve installation which has a low impact on the distribution patterns (Fraisse et al., 1995). In this study, and based on Equation 1 (Heermann et al., 1992), the CU was between 86.4 and 97.8 % as shown in Table 1. Michael et al. (2006) came to a similar conclusion that tested uniformity of the variable-rate centre pivot and linear move irrigation control systems and measured CU equal to 93 and 84 % for centre pivot and linear move, respectively. Also Moore et al. (2005) found a high quantity of CU between 79 to 95 % for irrigation depths between 6 to 25 mm by a variable rate linear move. Although high values of CU were obtained under all pulsing levels, but slightly lower application uniformity was obtained for reduced application rates (in agreement with King and Wall, 2001).

Figure 2. Measured application depths (curves) relative to the target irrigation depths (horizontal lines which are showing the target depths) for three different sets of spatially variable application test and three different speed dial setting of 15, 20 and 30 % on CP control box.

DISCUSSION AND CONCLUSIONS

Higher error application of irrigation depth under low pulsing level of 10 % found in this study is in agreement with our field observations and also in agreement with Fraisse et al. (1995) and Duke et al. (1997) as valves had a discrete response time for opening and closing (valves open quickly but required a longer time to close) and solenoid-actuated diaphragm valves close slower than they open. This valve closing delay was not accounted for in these

Table 1: Average coefficient of uniformity from different pulsing level and CP speed

Pulsing Level (%)	CU at CP speed of 15 % (%)	CU at CP speed of 20 % (%)	CU at CP speed of 30 % (%)
10	89.9	92.0	86.4
30	92.7	97.6	89.8
40	93.8	94.7	89.3
60	96.5	92.7	97.1
70	---	---	---
90	---	---	---
100	97.8	97.5	96.3

feasibility tests but can be easily incorporated into the PLC. This was important to prevent any other factor affecting the water distribution except the open/close time of the solenoid valves. However it is concluded that determination of irrigation depth must be based on field measurement not based on theoretical calculation. Field observation showed that 20 seconds pulsing interval was too short due to valves being turned on and off at various pre-planned locations in the field (because of water hammer). Therefore the pulsing interval was increased to 100 seconds, but it is proposed to apply a pulsing interval longer than 100 seconds. However results exhibited that with some exceptions a pulsing technique operated successfully, meanwhile providing a flexible means of applying variable water treatments in agreement with other mentioned literatures.

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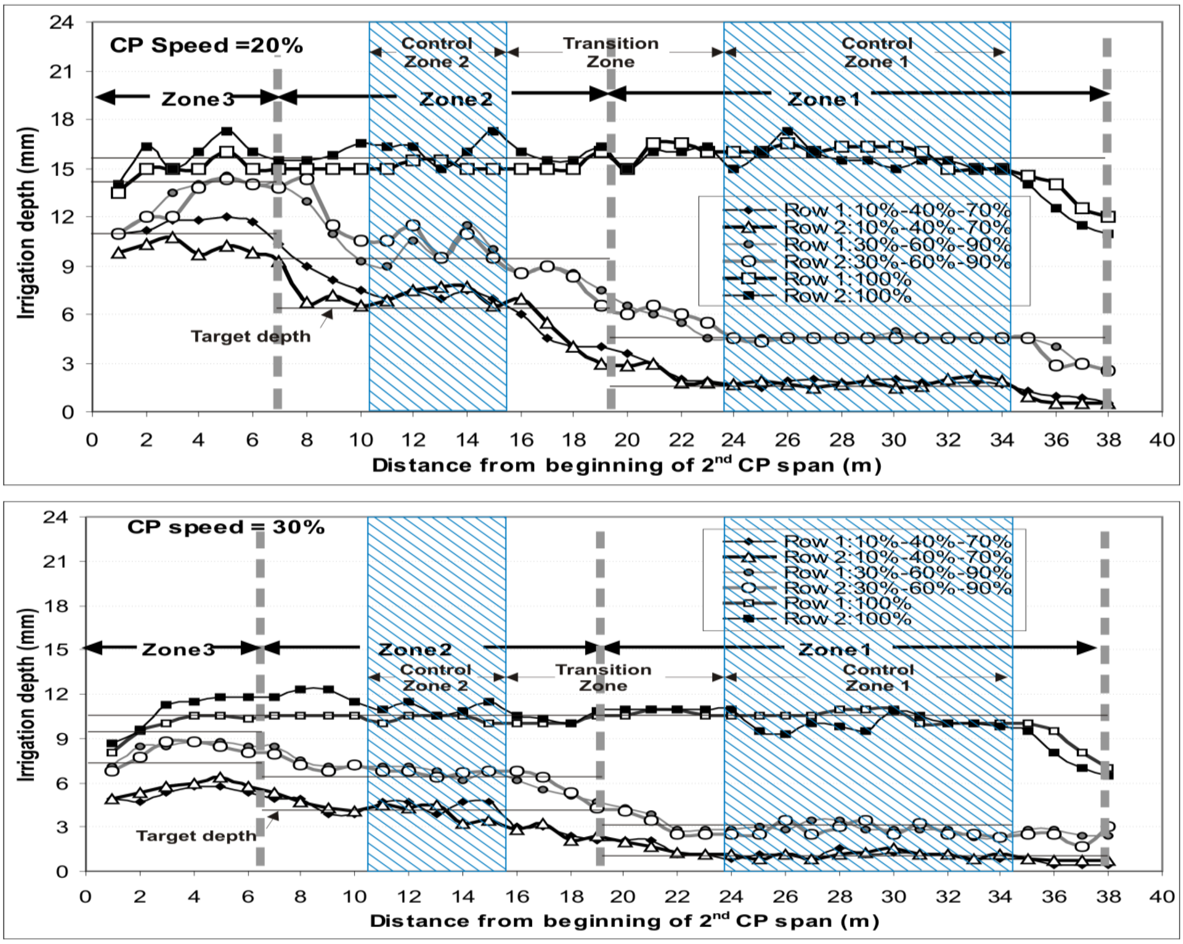

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