



Fertilisation strategies for improving nutrient utilisation in field-grown potatoes and vegetables

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Foreword

Water quality in Europe

Deteriorating water quality in Europe led to the introduction of the EU Water Framework Directive, one of the most comprehensive EU directives formulated to date. The Directive replaces the previous fragmentary collection of directives and management strategies for water and facilitates integrated policy.

An overarching perspective on Europe's water resources will lead the way to the ultimate goal: *To create and maintain good water status and sustainable water use*. This overarching perspective permeates the new water administrations, which are based on catchment area. The countries of Europe have been divided into water districts, each managed by a separate water authority. The role of the water authorities is to make decisions regarding the environmental goals for water and ensure that these goals are achieved within their individual district.

The main tools available are introduction of remediation programmes and management plans, which will place demands on all actors within the catchment area who are using or influencing the water. The ability of these actors to co-operate and collaborate with each other and their implementation of remedial measures in practice will be decisive in achieving the goals.

One of the most important actors in catchment areas with intensive cropping are potato and vegetable growers.

With the aim of highlighting the importance of co-operation between water interests in the different Nordic countries and concrete remedial measures in individual catchment areas/cultivated landscapes, the following were organised:

- Workshop at Tune Agricultural College near Copenhagen, Denmark, in 2004, which brought together around 30 invited researchers from the Nordic countries. Keynote speakers were specially invited in from England, the USA and the Netherlands.
- NJF seminar in Malmö, Sweden, in 2005, which brought together around 50 researchers, advisors and representatives of authorities and potato and vegetable growers from northern Europe.
- The project described in this report initially had the following general aims:
- To form part of a long-term conscious effort that would lead to optimal nutrient utilisation and a better environment. This goal would be achieved by building up efficiently operating inter-Nordic networks of water interests.

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- To host, together with Nordic/European experts, one or more workshops/seminars dealing with nutrient utilisation, fertilisation strategies and achievement of environmental goals in potato and vegetable growing.
- To create ideas for new efficient advice support that would be compatible with the need for new strategic measures to achieve the environmental goal of good water status in compliance with the EU Water Framework Directive.
- To lead to proposals that would increase the possibilities of achieving the environmental goals of the Nordic countries.
- To propose concrete measures that could increase crop nutrient utilisation.
- To assess how the new measures would affect grower finances.

The primary target groups for this report were growers, crop production advisors and authorities with the power to influence events in the cultivated landscape. However, researchers, interest organisations and other parties interested in the EU Water Framework Directive and its implementation in the Nordic countries may also find the report useful.

This report forms part of the project documentation. Other documentation can be found at www.Improved.com.



The river Vinnån near Kristianstad flows through one of Sweden's most intensively cultivated arable areas. There is a great need for better protection of watercourses in intensive arable areas. [Photo Håkan Sandin 2006].

Summary

Conclusions drawn of the project

In compliance with the initial funding application, a working party (scientific committee) of Nordic researchers was convened to implement the project. The scientific committee also formulated the proposals that you will find in the following texts.

A general observation is that great differences exist between the Nordic countries as regards fertilisation recommendations for various field crops.

Instead five strategies for improving nutrient utilisation formed the basis for the approach adopted in the project.

1. New improved crop rotations

New crop rotations must be developed on the basis of the knowledge available at present regarding when and how nutrient leaching occurs and how it can be prevented. At the same time, research must be increased in several areas and a holistic approach must be adopted to synthesise new and old knowledge into new crop production expertise and cropping systems.

We therefore propose a combined Nordic/Northern European pilot project focusing on the effects of potato and vegetable crop rotations on leaching of plant nutrients and crop protection chemicals, using the knowledge we have today and implementing new tools as EU-Rotate_N (see point 2).

2. Risk analysis with respect to nutrient deficiency

Using more fertiliser than necessary is often regarded as a risk premium by potato and vegetable growers. In high-value crops, the increased cost of this practice is not particularly significant. Can we contribute to altering this perspective and thereby obtaining environmental gains?

EU-Rotate_N is a computer-based decision support tool that can be used to increase the reliability of fertilisation decisions that advisors and growers have to make in potato and vegetable crop rotations.

We propose that EU-Rotate_N will be developed for Nordic conditions.

3. Forecasting irrigation

Good forecasts are very important for irrigation. Irrigation forecasting is therefore a good instrument for optimising cropping.

An internet-based decision support system has been developed in Denmark and would be a suitable subject for Nordic collaboration.

We therefore propose that the use of decision support systems for forecasting irrigation needs should be obligatory connected to the authorisation to irrigate. Fertilisation strategies for improving nutrient utilisation in field-grown potatoes and vegetables 10

4. Increased protection of watercourses in arable areas

Field production of potatoes and vegetables is often carried out near water in vulnerable areas with light soils and with high inputs of fertilisers and crop protection chemicals.

Potato and vegetable production is often the point source of large emissions of pollutants, nitrogen, phosphorus and chemicals in particular.

We therefore propose a pilot project, preferably on a Nordic/Northern European basis, to implement and evaluate known and new measures to reduce the risks to the environment arising in the intensively cultivated landscape.

5. Improved advisory services

The advisory services both can and should be improved with the insight that we can improve our environmental protection work. This is to a very great extent a matter of increasing the precision of advice by including both business and national economic calculations as a complement to environmental risk analyses.

We propose an investigation into how the Nordic countries can find incentives to and fund (see point 4 above) effective environmental and waterprotection activities in the cultivated landscape.

Advisory work based on the concept of On-farm research, and that aims to demonstrate various cropping and management strategies on farms in different arable districts represents an efficient way of improving the advisory services supplied to farmers.

We therefore propose a Nordic/Northern European pilot project (see point 4 above) in which joint strategies for reducing nutrient leaching are tested and evaluated on a carefully selected group of potato and vegetable producers.

Merit requirements for researchers currently mean that they are obliged to acquire merit by publishing their work in internationally recognised journals in order to obtain continued funding. There is currently no merit to be acquired in solving the problems that exist within production.

We therefore propose that the societal terms and public commissions imposed on universities and colleges be reviewed, and that this review examine the merit

requirements currently applied to researchers, meaning that better possibilities should be provided for researchers to implement their findings. Fertilisation strategies for improving nutrient utilisation in field-grown potatoes and vegetables 11

Proposals for Nordic strategies

1. First proposal

The most important task within agriculture is to improve the protection of waters in the cultivated landscape (particularly in intensive arable areas) to reduce the loads on groundwater, lakes, watercourses and the final recipient, the sea, as regards phosphorus, nitrogen and chemicals.

Political measure. Commission a Nordic study, in conjunction with revision of the various national programmes, to devise a collective concept for strengthening protection of waters (groundwater, watercourses, lakes and the final recipient, the sea) in intense agricultural landscapes in connection with potato and field vegetable production.

2. Second proposal

By 2010 at the latest, EU member states must have a viable pricing policy for water, and such a pricing policy may involve imposing fees or taxes on water withdrawals by farmers.

Political measure. Commission a Nordic investigation in order to implement this possibility in accordance with the text under “1.3. Proposals for Nordic strategies”.

Supplementary projects

A number of supplementary projects have been developed as a result of the initiatives taken since the start of this project in 2004. Most of these projects have been initiated and funded by the Swedish Board of Agriculture, which aims in this way to take responsibility for ensuring that the process does not stagnate. However, a number of these initiatives have originated from the ideas and presentations that emerged during the workshops in 2004 and the results presented during the NJF seminar in 2005.

The lectures presented both during the workshop in 2004 and at the NJF seminar in 2005 and the discussions carried out during these events formed the basis for the proposals for new strategies and political measures presented above.

You will find the complete programme and all the presentations on the internet on the following website www.Improved.com

Sammanfattning

Projektets slutsatser

I enlighet med ansökan har följande genomförts. En arbetsgrupp, ”scientific committee”, med nordiska forskare har satts samman för att genomföra projektet. Denna ”scientific committee” formulerade också de förslag, som ni finner i nedanstående texter.

Övergripande kan konstateras att det finns stora skillnader mellan de nordiska länderna när det gäller rekommendationer för gödsling av olika fältodlade kulturer.

Nedan presenteras fem strategier för ett bättre växtnäringssutnyttjande som utgör grunden för projektgruppens ställningstagande.

1. Nya bättre växtföljder

Nya växtföljder måste utvecklas på grundval av de kunskaper vi idag besitter. Kunskaper om när och hur växtnäringssläckage uppstår och hur det kan förhindras. Samtidigt måste forskningen förstärkas inom flera områden och ett holistiskt arbete måste inledas som syntesiterar nya och gamla kunskaper till nytt odlingskunnande och nya odlingsystem.

Vi föreslår därför en gemensam nordisk/nordeuropeisk pilotstudie, som fokuserar på potatis- och grönsaksväxtföljers inverkan på växtnäringssläckage, genom att använda den kunskap vi idag har och dra nytta av beslutstöd som EU-Rotate_N. (se punkt 2)

2. Riskanalys med tanke på växtnäringssbrist

Att använda mer gödsel än nödvändigt betraktas ofta som en riskpremie av potatis- och grönsaksodlaren.

Sakligt betraktat anser vi att det är viktigt att komma bort från generella (allmängiltiga) gödslingsrekommendationer för att istället koncentrera arbetet på metoder och strategier, där man tar hänsyn till platsbundna förutsättningar.

EU-Rotate_N är ett databaserat beslutstöd som kan användas för att öka säkerheten i de gödslingsbeslut som rådgivare och odlare måste fatta i potatis- och grönsaksväxtföljder.

Vi föreslår att EU-Rotate_N utvecklas för nordiska förhållanden.

3. *Prognoser för bevattning*

Betydelsen av bra prognoser för bevattning är avgörande. Det är lätt att göra fel när man vattnar. Bevattningsprognoser är därför ett bra instrument för att optimera odlingen.

I Danmark har man utvecklat ett webbaserat beslutsstöd, som vore ett bra objekt för nordiskt samarbete.

Vi föreslår därför att användningen beslutsstöd avsedda att förutse bevattningsbehovet skall vara obligatoriskt för att få tillstånd att bevattna.

4. *Ökat skydd kring vattendragen i odlingslandskapet*

Fältmässig produktion av potatis- och grönsaker förekommer ofta nära vatten i känslig miljö på lätta jordar och med stora insatser av gödsel och bekämpningsmedel. Ofta är potatis- och grönsaksodlingen punktvis anledning till stora utsläpp av framförallt kväve, fosfor och kemikalier.

Vi föreslår därför en pilotstudie, gärna på nordisk/nordeuropeisk bas, som implementerar och utvärderar kända och nya åtgärder för att minska de risker för miljön som föreligger i det intensiva odlingslandskapet.

5. *Utvecklad rådgivning*

Rådgivningen både kan och borde utvecklas med insikten av att vi kan göra miljöarbetet bättre. Det handlar väldigt mycket om att öka precisionen i våra råd, genom att inkludera både företags- och nationalekonomiska beräkningar som komplement till konsekvensanalyserna för miljön.

Vi föreslår därför att man utreder hur de nordiska länderna kan uppmuntra och finansiera ett effektivt miljö- och vattenvårdande arbete i det intensiva odlingslandskapet. Se nedan under politisk uppföljning.

Rådgivning som bygger på konceptet *On farm research*, och som syftar till att demonstrera olika odlings- och managementstrategier, utgör ett effektivt sätt att utveckla rådgivningen till lantbrukarna.

Vi föreslår ett nordiskt (nordeuropeiskt) pilotprojekt (se punkt 4) där gemensamma strategier för att minska växtnärläckaget testas och utvärderas på en noga utvald skara potatis- och grönsaksproducenter.

Forskarnas meriteringskrav innebär idag att man är tvungen att meritera sig genom att publicera sina arbeten i internationellt erkända tidskrifter för att få fortsatta anslag. Det är idag ingen merit att vända sig till produktionen för att lösa de problem som den har.

Vi föreslår att man ser över universitetens och högskolornas sociala villkor och samhälliga uppdrag och i samband härmed granskar de meriteringsregler som gäller för forskare idag, så att det skapas bättre möjligheter att omsätta forsknings-

resultat till praktiska lösningar. Fertilisation strategies for improving nutrient utilisation in field-grown potatoes and vegetables 14

Förslag till politisk uppföljning

1. Första förslaget

Det viktigaste uppdraget inom jordbruket är att stärka skyddet kring våra vatten i det intensiva odlingslandskapet.

Politisk åtgärd. Lämna ett nordiskt utredningsuppdrag att i samband med revision av de olika nationella åtgärdsprogrammen finna ett samlat nordiskt koncept för att stärka skyddet av vatten (grundvatten, vattendrag, sjöar och slutrecipienten havet) i intensiva odlingslandskap i samband med potatisodling och fältmässig produktion av grönsaker.

2. Andra förslaget

Senast år 2010 skall medlemsländerna i EU ha en utarbetad prispolitik för vatten, och en sådan prispolitik kan innebära att lantbrukarnas vattenuttag avgiftsbeläggs eller beskattas.

Politisk åtgärd. Lämna ett nordiskt utredningsuppdrag för att genomföra förslaget i enlighet med den fullständiga texten i förslaget under punkt "1.3. Proposals for Nordic strategies".

Följdprojekt

Ett flertal följdprojekt har utvecklats som en följd av de initiativ som tagits sedan projektet startades 2004. De flesta av dessa projekt har fortsättningsvis initierats och finansierats av det svenska Jordbruksverket. Jordbruksverket i Sverige vill på detta sätt ta ansvar för att processen inte avstannar. Flera av dessa initiativ har emellertid haft sitt ursprung i de presentationer och idéer som framkommit under workshopen 2004 och de resultat som presenterades under NJF-seminariet 2005.

Samtliga föreläsningar som genomförts under både workshopen 2004 och NJF-seminariet 2005 samt diskussioner som förts under workshopen är underlag till de bedömningar som gjorts ovan. Det gäller förslag till nya strategier såväl som till förslag till politiska åtgärder.

Program och samtliga presentationer och föredrag som genomförts i detta projekt finns presenterade på projektets hemsida www.Improved.com.

1. Implementation and results of the project

1.1 Application

In compliance with the initial funding application, a working party (scientific committee) of Nordic researchers was convened to implement the project. The following steps were carried out in accordance with stated intentions:

- Step 1 (2004): Inventory of problems ahead of the first workshops. These workshops were held at Tune Agricultural College near Copenhagen on 3 November and 1 December 2004.
- Step 2 (2004): Formulation of a programme based on the standpoints and problems presented above.
- Step 3 (2004): Execution and documentation of the workshops over two days.
- Step 4 (2005): Preparation of preliminary report (Status report 2005–02–01), as a basis for planning the subsequent NJF-seminar.
- Step 5 (2005): NJF seminar held on 12–13 October 2005.
- Step 6: Preparation of preliminary report (Status report 2006–01–18).
- Step 7: Preparation of final report to the Nordic Council of Ministers (NCM) (Status report 2006–08–24); plus preparation of this final report Fertilisation strategies for improving plant nutrient utilisation in field-grown potatoes and vegetables.
- Step 8: Publication
Publication of Fertilisation strategies for improving plant nutrient utilisation in field-grown potatoes and vegetables is the final step in completion of the project. Scientific articles about the project have been published in Danish and Swedish journals. Popular science articles on the results obtained remain to be written and published. An internet website has been created where it is possible to follow the progress of the initial project at www.ImprovedNP.com and the follow-up project at www.Improved.se.

1.2 Five strategies improving nutrient utilisation.

The five strategies for improving nutrient utilisation that formed the basis for the approach adopted in the project are presented below.

A general observation is that great differences exist between the Nordic countries as regards fertilisation recommendations for various field crops. Equally great differences are apparent in comparisons with fertilisation strategies in England, the Netherlands or other parts of Europe. At the NJF seminar on 12–13 October 2005, many of the standpoints reported to the NCM, Nordic Council of Ministers in Status report 2005–02–01 were verified and expanded upon. These are summarised below. All presentations are published on the project website www.ImprovedNP.com.

1.2.1 New improved crop rotations

New crop rotations must be developed on the basis of the knowledge available at present regarding when and how nutrient leaching occurs and how it can be prevented. At the same time, research must be increased in several areas and a holistic approach must be adopted to synthesise new and old knowledge into new crop production expertise and cropping systems.

The most important factor in this context is to increase knowledge of the different characteristics of maincrop plants and catch crop plants regarding their capacity to utilise nutrients, harbour disease and prevent nutrient leaching. The potential to develop new crop production knowledge in this area is very great. For example, N-efficient varieties can be used to a much greater extent, while catch crops can be used for various purposes in new crop rotations.

Crop rotations and fertilisation strategies must take into account the fact that catch crops can reduce leaching, but also the fact that catch crops can influence soil structure and the spread and propagation of plant diseases. Soil structure and plant diseases are also very important in efficient nutrient utilisation. The potential exists to develop new crop production expertise in this area.

It is important to keep crop cultures healthy in order to increase crop utilisation of the nutrients available, both applied and mineralised. There is great potential in this area to reduce the use of crop protection chemicals and thus leaching of chemical residues.

We therefore propose a combined Nordic/Northern European pilot project focusing on the effects of potato and vegetable crop rotations on leaching of plant nutrients and crop protection chemicals, using the knowledge we have today and implementing new tools as EU-Rotate_N (see point 1.2.2).

It is important to be able to predict mineralisation and nutrient leaching from the soil, as well as leaching of chemicals. In this regard, it appears essential to be able to use forecasting and decision support tools developed in recent years, such as EU-rotate_N, irrigation forecasting and other weather-based forecasting instruments for controlling the spread of diseases and limiting their effects. Development of a forecasting instru-

ment that could predict the mineralisation in a given crop rotation would also be very valuable.

1.2.2 Risk analysis with respect to nutrient deficiency

Using more fertiliser than necessary is often regarded as a risk premium by potato and vegetable growers. In high-value crops, the increased cost of this practice is not particularly significant. Can we contribute to altering this perspective and thereby obtaining environmental gains?

Fertilisation recommendations for a particular crop vary extremely widely in the Nordic countries and throughout northern Europe. It will be difficult to reach agreement on fertilisation recommendations for different potato and vegetable cultures, since conditions are so different in the Nordic countries. We believe therefore that this is not a productive approach. Considering this issue objectively, we believe it is important to move away from general fertilisation recommendations and instead concentrate on methods and strategies that take into account site-specific conditions (rainfall, crop rotation, soil mineral N, applications of organic manure, water availability, etc.).

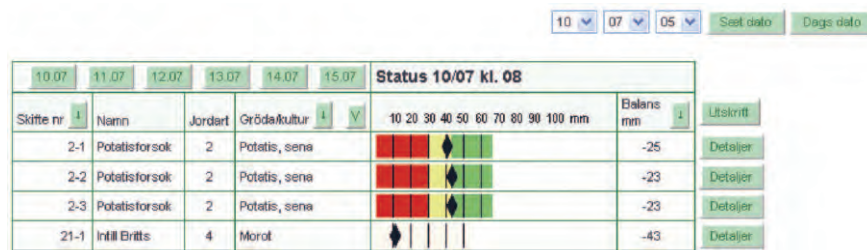
We propose that EU-Rotate_N will be developed for Nordic conditions.

EU-Rotate_N is a computer-based decision support tool that can be used to increase the reliability of fertilisation decisions that advisors and growers have to make in potato and vegetable crop rotations. EU-Rotate_N is funded by the EU and is available for all countries to develop further. The NJF seminar concluded that it would be strength if we could devote our combined resources to supporting the continued development of EU-Rotate_N to include a user application for the Nordic countries or northern Europe with national adaptations.

1.2.3 Forecasting irrigation

Good forecasts are very important for irrigation. It is easy to make mistakes in irrigation, so that either the grower uses too much water, often unfortunately in conjunction with rainfall, or else too little irrigation is applied due to lack of time or capacity in dry periods

In both cases the risk of leaching and nutrient deficiency is increased for more susceptible cultures, thereby increasing the need for crop protection chemicals and decreasing yield levels and nutrient use efficiency. Irrigation forecasting is therefore a good instrument for optimising cropping. An internet-based decision support system has been developed in Denmark and would be a suitable subject for Nordic collaboration. Irrigation forecasting is based on climate data, i.e. the same basic resource required for crop protection forecasting. Here too, there is great scope for Nordic collaboration.



Display from the irrigation programme Pl@nteinfo. The black shapes show the water status of the soil. When the black shape is in the green area, access to water is relatively good, but when the black reaches the yellow area it is time to irrigate. Irrigation must be carried out before the black reaches the red area. The column on the right shows the actual water balance of the fields, which varies from -23 mm for maincrop potatoes to -43 mm for carrots.

An application with the aim of developing an internet-based decision support system has already been submitted to The Nordic Joint Committee for Agricultural Research (NJC). The title of the proposed project was *Decision support for supply of irrigation water and fertiliser nitrogen to high-value crops with respect to yield, quality and environmental effects*. This application was rejected in December 2006.

We therefore propose that the use of decision support systems for forecasting irrigation needs should be obligatory connected to the authorisation to irrigate.

1.2.4 Increased protection of watercourses in arable areas

Field production of potatoes and vegetables is often carried out near water in vulnerable areas with light soils and with high inputs of fertilisers and crop protection chemicals. A careful assessment of the existing risks and the countermeasures necessary to combat these risks is essential for the credibility and future survival of potato and vegetable production. Potato and vegetable production is often the point source of large emissions of pollutants, nitrogen, phosphorus and chemicals in particular. The issue here is *Co-operation, Precision, Control and Monitoring*. Growers must be motivated to become active participants in environmental protection in a considerably more tangible way than previously, and must be encouraged to co-operate with the authorities and all other water interests to achieve improvements in the environment. This must be done in the spirit of the new EU water legislation, the Water Framework Directive, and may include the following plan of action:

- Identify the critical production areas in a catchment area.
- Find the important point sources of pollution.
- Engage the landowners who are affected and who are capable of action.
- Agree on the most important measures.
- Work on farm-specific measures to achieve the overall goals.
- Concentrate efforts on measures that are financially profitable for businesses, through advice and economic stimulation.
- Finance socio-economically profitable investment in consultation with users and their organisations.

We therefore propose a pilot project, preferably on a Nordic/Northern European basis, to implement and evaluate known and new measures to reduce the risks to the environment arising in the intensively cultivated landscape.

1.2.5 Improved advisory services

The advisory services both can and should be improved with the insight that we can improve our environmental protection work. This is to a very great extent a matter of increasing the precision of advice by including both business and national economic calculations as a complement to environmental risk analyses.

Funding of environmental protection work

To motivate farmers to participate more actively in environmental protection work, they should be allowed to work in a goal-orientated way according to remediation plans approved by the authorities and to actively invest in the environment. This is in contrast to imposing additional fees or taxes on farmers. Such an approach would motivate and stimulate farmers and all water interests concerned and produce immediate and concrete results in production and in the environment.

It is very important to strengthen co-operation and collaboration between research, advisory services and crop production by increased contacts, in which respect for successful environmental protection and the competitive power of crop production can both be employed. This can be achieved by improving the opportunities for advisors to work with individual landowners, so that together they can agree on the most important countermeasures and identify farm-specific solutions that can form part of a remediation and management plan, e.g. for a watercourse in a cultivated area.

We propose an investigation into how the Nordic countries can find incentives to and fund (see point 1.2.4 above) effective environmental and water protection activities in the cultivated landscape.

On-farm research

Advisory work based on the concept of On-farm research, and that aims to demonstrate various cropping and management strategies on farms in different arable districts represents an efficient way of improving the advisory services supplied to farmers. This creates the potential to take advantage of grower knowledge, while at the same time acting as part of the advisory process in convincing growers of the value of altering their fertilisation and production strategies.

We therefore propose a Nordic/Northern European pilot project (see point 1.2.4 above) in which joint strategies for reducing nutrient leaching are tested and evaluated on a carefully selected group of potato and vegetable producers

Meritition requirements for researchers

An important part of the potential to develop the advisory service is an investigation into how the operating terms imposed by society on universities and colleges affect the range of knowledge offered. Meritation requirements for researchers currently mean that they are obliged to acquire merit by publishing their work in internationally recognised journals in order to obtain continued funding. There is currently no merit to be acquired in solving the problems that exist within production. We believe that this must change. A model could be the scheme established at certain universities in the USA, which has the title 'Extension Service'.

We therefore propose that the societal terms and public commissions imposed on universities and colleges be reviewed, and that this review examine the meritation requirements currently applied to researchers, meaning that better possibilities should be provided for researchers to implement their findings.

Universities and colleges should receive meritation for taking sectoral responsibility and for their researchers contributing to solving the serious problems facing society and agricultural production.

There should also be an investigation into whether it is possible to establish combined research and advisory services that are directed at production.

1.3 Proposals for Nordic strategies

The challenge for politicians and authorities consists of co-operating with farmers and other actors in the catchment area to maintain competitive agriculture in harmony with nature, regardless of site. Good water and environmental status must thus be combined with good farm status. See the report *Vattendirektivet och jordbruket: Aspekter på relationen mellan god vattenstatus och god lantbruksstatus* by Dr. Helena Krantz, Tema Vatten, Linköping University (included as an appendix to the present report).

1.3.1 First proposal

The most important task within agriculture is to improve the protection of waters in the cultivated landscape (particularly in intensive arable areas) to reduce the loads on groundwater, lakes, watercourses and the final recipient, the sea, as regards phosphorus, nitrogen and chemicals. Measures will vary in different arable districts both with regard to the waters to be protected and the intensity of cultivation. This will be a question of prioritisation.

For this to be successful the most vulnerable areas in the cultivated landscape must be identified and strategies and prioritised measures that reduce the environmental load considerably compared with the current situation must be implemented. The key concepts are *Co-operation, Precision, Control and Monitoring*. Growers must be motivated to become active participants in environmental protection in a considerably more tangible way than previously, and must be encouraged to co-operate with the authorities and all other water interests to achieve improvements in our environment. This must be with the new EU water legislation, the Water Framework Directive, at the centre. Such a strategy could include the following plan of action:

- Identify the most important watercourses.
- Identify the critical production areas in the catchment area.
- Find the main point sources of pollution.
- Engage the landowners who are affected and who are capable of action.
- Agree on the most important measures.
- Work on farm-specific measures to achieve the overall goals.
- Concentrate efforts on the most profitable measures in the first instance.

Political measure. Commission a Nordic study, in conjunction with revision of the various national programmes, to devise a collective concept for strengthening protection of waters (groundwater, watercourses, lakes and the final recipient, the sea) in intense agricultural landscapes in connection with potato and field vegetable production.

Measures along watercourses and relating to drinking water resource (groundwater and surface waters) should be prioritised. Watercourses, rivers and streams transport large quantities of nitrogen, phosphorus, chemicals and sediment to the final recipients and should be paid particular attention. Within the national programmes, there are possibilities to fund subsidisation and investment measures, which can complement farmers' own investment in compliance with the *Second Proposal* presented below.

Governments should also consider their own responsibilities and contribute direct subsidies to high-cost investment along watercourses undertaken in compliance with this First Proposal.

Such investments could involve large-scale reconstruction projects in conjunction with drainage systems, which are currently significant point sources of pollutants to watercourses, or other measures to re-use or infiltrate drainage water in the cultivated landscape.

1.3.2 Second proposal

By 2010 at the latest, EU member states must have a viable pricing policy for water, and such a pricing policy may involve imposing fees or taxes on water withdrawals by farmers.

Such a future pricing policy must also take into account the national and international competition climate. In conjunction with this, allocation of the responsibility for environmental loads arising as a result of food production between consumer and producer must be investigated (separate investigation).

An interesting alternative to water fees or further taxation could be a combination of catchment area-specific and internal business water environment funds. This would provide a resource for use by farm businesses within a catchment area. These funds would be administered preferably by the water council in a catchment area on the one hand and the farmers themselves on the other. The water council and farmers would submit proposals for remediation plans and management plans and agree in consultation with the water authority on the measures to be adopted. The water authorities would approve the remediation and management plans devised by the farmers within a catchment area.

To motivate farmers to participate more actively in environmental protection, which is absolutely essential, this possibility should therefore be investigated. There is no other single measure as important as stimulating farmers to increased engagement. Actively allowing farm businesses to work in a focused and purposeful manner on remediation plans approved by the authorities and facilitating environmental investment would drastically change the perceptions and significance of environmental protection work. This is in contrast to imposing additional fees or taxes on farmers. Such an approach should be able to stimulate both farmers and all other water interests concerned and provide immediate and concrete results on water quality and more environmentally friendly production.

Political measure. Commission a Nordic investigation in order to implement this possibility in accordance with the text under “1.3. Proposals for Nordic strategies”.

1.4. Supplementary projects

A number of supplementary projects have been developed as a result of the initiatives taken since the start of this project in 2004. Most of these projects have been initiated and funded by the Swedish Board of Agriculture, which aims in this way to take responsibility for ensuring that the process does not stagnate. However, a number of these initiatives have originated from the ideas and presentations that emerged during the workshops in 2004 and the results presented during the NJF seminar in 2005.

1.4.1 Networks

One such project has been to develop and maintain networks of growers, advisors, researchers and representatives of authorities in co-operation with each other within and across national boundaries in target-orientated environmental protection work. The aim is that the networks will form part of a long-term conscious process that will lead to optimised nutrient utilisation and a better environment in intensive arable landscapes. The networks that were created as a result of this project comprise around 100 people and continue to be developed as a result of constant new initiatives.

1.4.2 ISHS symposium

The networks described above have also taken the initiative to hold an international symposium under the auspices of the ISHS and entitled *Fourth International Symposium on Ecologically Sound Fertilisation Strategies for Field Vegetable Production*. This symposium will take place on 22–29 September 2008 at Alnarp in Sweden.

1.4.3 The Water Directive and Agriculture

A further project consists of holding ‘water days’. The first water days took the form of the conference Vattendirektivet och Jordbruket - Samverkan, styrning och uppföljning för en framtida god vattenkvalitet [The Water Directive and Agriculture – Co-operation, Control and Monitoring for Good Water Quality in the Future]. This was held at Kristianstad, Sweden on 22–23 November 2005. The conference website www.ImprovedH2O.com contains all lectures and other results published. The results from this conference were also published in a separate report by Dr. Helena Krantz, Tema Vatten, Linköping University, entitled *Vattendirektivet och Jordbruket - Aspekter på relationen mellan god vattenstatus och god lantbruksstatus* [The Water Directive and Agriculture – Aspects of the Relationship Between Good Water Status and Good Agriculture Status]. The Swedish Board of Agriculture, other Swedish au-

thorities and organisations/projects, authorities and conference delegates funded the conference.

The objective of the Water Conference was to highlight the importance of the relationship between all water interests and concrete measures in the cultivated landscape in achieving good water quality for the future. It also resulted in the start of collaboration between growers, advisors, researchers and representative of authorities, which was documented e.g. at a subsequent water conference in Vara, Sweden, under the title *Från Mark til Vatten – Vattendirektivet och Jordbruket* [From Soil to Water - The Water Directive and Agriculture]. This documentation is available on the same website www.ImprovedH2O.com.

1.4.4 University course for advisors

A university course for advisors also constituted one of the supplementary projects originating from the present project. This university course was first provided in 2006 and is available on www.Improved.se under the heading *Improved Education*. The course has been offered on a Nordic basis but in its first year only Swedish delegates applied. Eleven advisors and lecturer at agricultural colleges are expected to complete the course. The course is based on the knowledge collected and published in the project, see the publications below. Undergraduate projects will also eventually be published on the website under *Improved Education*, which is the special course website within the domain www.Improved.se.

1.4.5 Nordic irrigation forecasting

A Swedish webbased irrigation forecasting program www.planteinfo.dk/se is under development, hopefully as a first step towards a Nordic web-based irrigation forecasting program. Collaboration with the Danish Agricultural Research Institute (DJF) has led to this Swedish irrigation forecasting service, which is founded on the internet-based decision support system developed by DJF and available on www.planteinfo.dk. A similar initiative has now also been taken in Norway to develop this irrigation forecasting service for the rest of the Nordic market. A proposal for the Swedish irrigation forecasting service was developed and evaluated during 2005 and the outcome has been very successful. A Swedish forecast is being test-marketed at present (2006). The funding for the irrigation forecasting service was a joint venture by DJF, Swedish Board of Agriculture, Svenska Lantmännen, SMHI, the Swedish SL-Foundation Lyckeby Stärkelsen. An application was submitted in 2006 to the Nordic Joint Committee for Agricultural Research for funding to continue development of this forecasting instrument. A number of Nordic research groups were involved in this application, which was unfortunately turned down in December 2006.



This picture was taken on the Bjäre peninsula in Sweden. Irrigation forecasting has begun to be used in several areas of the world. We have the opportunity to develop a Nordic forecast. [Photo Håkan Sandin 2005].

1.4.6 Publications

A teaching folder including e.g. four new articles is being prepared. These articles are directed at advisors and interested farmers. Three of them have been published already, one in both Swedish and English. The three published articles are entitled:

1. Kväveutnyttjande i potatis och grönsaksodling [Nitrogen utilisation in potato and vegetable growing] (the present project funded translation into English).
2. Miljöekonomi i potatis och grönsaker [Environmental economics in potatoes and vegetables].
3. Bevattning och växtnäringsutnyttjande [Irrigation and nutrient utilisation].

The fourth article will deal with Sound potato cultures and will be published in spring, 2007.

These articles are available on www.Improved.com under *Literature*. They will be used as a basis for a teaching folder directed at advisors and interested farmers in coming years. The three published articles are also available as individual papers under the title *Praktiska Råd* [Practical Advice] and as submissions in the Swedish trade periodicals *Potatis och Grönsaker* and *Viola*. The Swedish Board of Agriculture funded the production of all publications.

2. Scientific committee

All the lectures presented both during the workshop in 2004 and at the NJF seminar in 2005 and the discussions carried out during these events formed the basis for the proposals for new strategies and political measures presented above.

The scientific committee that formulated these proposals comprised the following people:



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3. Workshop in Denmark 2004

Programme, abstracts and Power Point presentations

Internet link to the programme

www.improved.se/workshop/pdf/20041102_Program_HS_corr.pdf

3.1 Why a workshop of fertilisation strategies?

This presentation can be found on the following website

www.improved.se/workshop/pdf/ppt_workshop_hsandin_20041207.pdf



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3.2 Nitrogen, phosphorous and pesticide losses from vegetable areas in Norway.

This presentation can be found on the following website

www.improved.se/workshop/pdf/ppt_workshop_mbechmann_20041207.pdf

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3.2.1 Introduction

In the early 1990s, a comprehensive monitoring programme for agricultural pollution in Norway was initiated. The objectives of this National Environmental Monitoring Programme (JOVA) in Norway was to get an overview of nutrient losses from different agricultural areas with different production systems and geological conditions, to look at trends in losses of nutrients and suspended solids and to evaluate the effect of measures

introduced to reduce losses. The JOVA programme consists of a number of agricultural dominated catchments, each of them representing different production systems, soils and soil management strategies. One of these catchments (Vasshaglona), located in the most southern part of Norway, is dominated by vegetable and potato production.

3.2.2 Methods

A monitoring station for each catchment measures flow through a fixed profile at the outlet of the catchments and flow-proportional composite water samples are taken for analysis of nutrients, suspended sediments and pesticides. To describe catchment characteristics, data on soils (NI-JOS), precipitation and temperatures (DNMI) are collected. Information on agricultural production is collected from farmers at field scale and includes crops, nutrient application rates and methods, soil management methods and time and use of pesticides. A detailed description of monitoring methods and results is given in Vandsemb et al. (2004).

3.2.3 Results and conclusions

Highest losses of total nitrogen (N) and total phosphorus (P) were measured from the Vasshaglona (vegetable/potato) catchment, compared with all other catchments included in the JOVA monitoring programme. The losses of N from catchments varied from 20 kg ha⁻¹ from a catchment dominated by grassland production to 98 kg ha⁻¹ from the Vasshaglona catchment, dominated by vegetable and potato production. Runoff from this Vasshaglona catchment was also higher (1250 mm) than from the other catchments and was partly responsible for the high losses of nitrogen, since nutrient losses and runoff have been shown to be closely related. Phosphorus losses varied from 0.3 kg ha⁻¹ from a grassland catchment to 6.7 kg ha⁻¹ from the Vasshaglona catchment. The mean N and P application rates in the Vasshaglona catchment are 180 kg ha⁻¹ and 43 kg ha⁻¹, respectively. Land use in the Vasshaglona catchment consists of vegetables (38%), potatoes (52%) and cereal production. The losses of P are closely related to transport of suspended sediments. Open uncovered soil, plant residues and high nutrient surplus may be causes of high nutrient losses.

These results confirm that areas of vegetable/potato production may be hotspots regarding nutrient losses from agriculture. A focus on improved management of nutrient sources (fertiliser and manure) and soils used for vegetable and potato production is a prerequisite for a successful mitigation strategy for reduced nutrient losses from agriculture.

References

www.jordforsk.no/fagarealavr/jova.htm
www.jordforsk.no/fagarealavr/vansjo-vanemfjorden.htm

3.3 Keynote Speech

- *Fertilisation strategies and additional measures necessary to comply with (the future) EU standards for groundwater and surface waters.*

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_alsmit_bert_20041221.pdf



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In the Netherlands, specialist vegetable farms are characterised by intensive (high input) cropping systems with increased risk of N leaching to groundwater on dry sandy soils. To comply with the EC Water Framework Directive and Dutch legislation, farmers will need new strategies. The current Dutch legislation (the mineral accounting system MINAS) is based on nutrient balances with default values for crop nutrient export. The system is based on the principle that reduction of surpluses will reduce emission of pollutants to the environment.

In 2000–2003 a group of 33 (arable, horticultural, bulbs, trees/shrubs) practical farms were participating in the project *Farming for the future* in which strict goals were formulated with respect to farm nutrient surpluses, N-min harvest and N-min autumn.

The project was supported by a desk study focusing on the development of cost-effective packages of measures to improve nutrient utilisation. It was done by designing various model farms which are considered to be representative for certain sectors.

3.3.1 Material and methods

Practical Farms

For the nine practical vegetable farms located in the southeast and southwest of the country a complete nutrient balance (including deposition) was calculated, based on the registration data, for the period 2000–2003. In the summer of 2002 and 2003 nitrate concentration in the upper 1 m of the groundwater was also measured on each farm.

Model Farms

Several vegetable model farms were designed, as representative for groups of vegetable farms in a specific region. For each model farm, a reference fertilisation strategy was conducted assuming ‘good agricultural

practice', which included the following recommendations. In the reference strategy, two packages of measures were designed to reduce surplus levels of nutrients. A 'moderate' package comprised measures such as reducing pig manure rate, employing N side-dressing systems, growing catch crops etc. A 'less acceptable' package consisted of the removal of crop residues from the fields to reduce further the surplus of nutrients.

3.3.2 Results and conclusions

Practical Farms

Although farms more or less followed current recommendations, on most of the vegetable farms the N-input was high in relation to the nutrient export with harvested products. At almost all farms, the 50 ppm nitrate concentration was exceeded. However, the direct relationship between nitrate concentration in groundwater and N-surplus turned out to be weak. On some farms a concern about maintaining or even increasing organic matter content of the soil by applying compost increased the surpluses considerably.

Model Farms

'Good agricultural practice' resulted in some model farms having N-surpluses of more than 180 kg N/ha. With 'acceptable' measures this surplus could be diminished by 40–50 kg N/ha, but removal of crop residues was needed to arrive at the target surplus of 90 kg N/ha. However, this measure strongly increased cost (up to 1500 €/ha), in such a way that it would not be viable under today's conditions.

3.4 Phosphorus strategies for future production of field vegetables

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_goswinh_20041207.pdf



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Phosphorus (P) loss from agricultural land to water has become the critical factor controlling the ecological quality of many freshwaters, inlets and coastal waters in the Nordic region. In the light of the EU Water Fra-

mework Directive (WFD) it is essential to establish targeted measures for the control of phosphorus losses from agricultural land.

In the soil-plant system inorganic and organic P forms are dynamically redistributed between different P pools. Biological processes recycle P by means of mineralisation and immobilisation reactions. With organic matter approaching steady state conditions in arable soils, organic P is generally not a significant sink for fertiliser P. Phosphorus concentrations in the soil solution are typically low as P is strongly retained by mineral constituents. A minor fraction of the soil P is readily exchangeable with the soil solution and plant-available. From an agronomic perspective it was reasonable to increase the pool of plant-available P by applying more phosphorus than plants removed. Over the past decades this has led to over 90% of agricultural soils in Denmark now being tested as sufficiently or excessively supplied with P. With increasing contents of plant-available P, however, the risk of P loss to water principally increases, too. There are no existing data regarding the P status of horticultural soils in Denmark. However, due to low efficiency of P uptake, crops such as onions, leeks and carrots typically have received large inputs of fertiliser P to secure economic yields.

Phosphorus loss is a complex function of climate, topography, soil type and land management and varies greatly both temporally and spatially within agricultural landscapes. Critical source areas for P loss are those where an effective transport process links an area with large contents of potentially mobile P with a watercourse. Intensive field vegetable production in Denmark is thought to be associated with sandy or peaty soils, high groundwater levels and frequently field drainage or irrigation. Together with the likelihood of high soil P status, these soils may pose a particular risk for P loss, which ought to be investigated.

Measures to reduce P loss can target the P input, the soil P status or the transport processes (Rapport fra Fosforgruppen, 2003). In terms of sustainability it is desirable to adjust the soil P status to the lowest level compatible with economic yields. In practice on many amply supplied horticultural soils this corresponds to P inputs below crop P offtake. The placement of P fertiliser close to plant roots is viewed an important strategy reducing fertiliser requirements considerably. However, lowering the P status takes many years and even adjusted P contents may remain problematic in terms of P loss. Amending soils to increase to binding capacity for P is untested in the Nordic countries and agronomically questionable. Therefore, targeting especially the transport processes in critical source areas will be more efficient. A catalogue of measures is available for reducing surface runoff, including reduced tillage, sufficient soil cover during winter and avoidance of winter cereals. Buffer zones are effectively preventing the delivery of P to streams. Controlled drainage retains P-enriched particles in the soil system and facilitates denitrification,

while riparian areas can be utilised to trap sediment and P through controlled flooding and irrigation with drainage water.

References

Rapport fra Fosforgruppen, 2003. Fosfor I dansk landbrug. Danmarks JordbrugsForskning.
(www.vmp3.dk/)

3.5 Fertiliser application methods to improve N efficiency

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_tsalo_20041207.pdf



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3.5.1 Application methods

It is possible to classify at least seven different methods of application. Broadcast application is an even distribution over the field surface, after which the fertiliser is usually mixed into the topsoil. Injection and band placement involve subsurface placement of liquid or solid fertiliser before or during planting. In-row application places the fertiliser directly in the seed row. Side dressing is applied beside the plant row after crop establishment. Top dressing is a broadcast application over the top of the growing crop. Foliar fertilisation means spraying of fertiliser solution directly onto the plant foliage.

3.5.2 Broadcast application

Broadcast application is probably the most common application method as it needs relatively small labour inputs and heavy N rates can be applied. With pneumatic applicators it is also possible to spread several single-nutrient fertilisers relatively quickly. The problems are mostly related to non-uniform distribution, location of fertiliser in too dry soil layers or too far from roots of small plants.

3.5.3 Subsurface placement

Vegetable yields have increased in several experiments with band placement but research has not shown a clear advantage for band application in comparison with broadcast application. Studies in England have shown that side dressing with a small amount of NP fertiliser might hasten plant development and increase plant yield. Beneficial effects of placement are likely to be greatest with crops having a large distance between plants, crops having a short growing period and in soils with low fertility. Use of fertigation has increased in areas that have a shortage of irrigation water and with crops that are valuable enough to compensate for the costs of fertigation equipment.

3.5.4 Split application

Split applications are usually given as top dressings. Side dressing is a possible split application method but fertiliser should be applied far enough from the plant to avoid root injury. Small amounts of N can also be applied by foliar fertilisation. Split applications should be used as a safety measure against leaching of N caused by high rainfall early in the growing season. Split applications should maintain a sufficient soil inorganic N content until harvest.

The rate of plant N uptake during the growing season is important for determining the timing of top dressings.

3.5.5 Slow-release fertilisers

Nitrogen in slow-release fertiliser is released at a slower rate throughout the season, and plants are able to take up most of the nutrients without waste by leaching. A slow-release fertiliser is more convenient, since ideally only one application is required. On the other hand, slow-release fertilisers are usually more expensive than soluble types and their rate of N release does not necessarily match crop N demand.

3.5.6 N use efficiency

It is not likely that any application method of fertilisers alone would greatly improve N use efficiency. Application methods can be seen as selection of tools that can be used based on other knowledge of crop N environment.

3.6 Keynote Speech

– *Systems for precise fertilisation in field vegetable production*

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_thartz_vers2.pdf

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3.6.1 *Systems for precise fertilisation in field vegetable production.*

Intensive vegetable production has been implicated in nutrient pollution of both surface and groundwater in many areas of the world; in California the main vegetable production areas have elevated NO₃-N concentration in groundwater, and high N and P concentration in surface water. Vegetable growers often apply fertiliser based on habit or experience, without reference to field-specific diagnostic tests. In California an extensive effort has been made over the last decade to evaluate and refine diagnostic tools to improve fertiliser management. The validity of bicarbonate extractable P (P_{bc}, the standard agronomic test for soil P availability) as a predictor of P bioavailability was confirmed in both laboratory and field experiments. In the laboratory, P_{bc} of 30 soils in long-term vegetable rotations was highly correlated ($r = 0.89$) with P bioavailability as measured by an anion resin technique purported to simulate root P uptake. In a series of commercial field trials P fertilisation was found to be unnecessary to maximise lettuce yield in fields with P_{bc} > 50 mg kg⁻¹. Vegetable rotations are often characterised by high levels of residual soil NO₃-N. A series of 25 commercial field trials was conducted to evaluate the use of pre-sidedress soil nitrate testing (PSNT) to determine sidedress N requirements of lettuce. PSNT reduced seasonal N application by an average of > 40% with no loss of yield or product quality. In these trials tissue N concentration (NO₃-N in midribs, or total N in whole leaves) was not correlated with concurrently measured soil NO₃-N, suggesting that tissue analysis was an insensitive measure of future fertiliser need. Field-specific factors (cultivar, temperature and light conditions, soil moisture status, etc.) confound the relationship between tissue N status and soil NO₃-N. These results have been confirmed by other research conducted in the western U.S. The establishment of heavily fertilised plots within a field can provide a 'reference' of known N sufficiency against which to evaluate the crop N status of the rest of the field; delaying or minimising fertiliser application to the field as long as tissue nutrient status (petiole

NO₃-N, leaf N, or leaf reflectance value) of the field is near that of the reference plots provides another method to minimise wasteful fertilisation. In a series of 16 commercial field trials the use of in-field reference plots allowed growers to reduce seasonal N application approximately 30% from their typical fertiliser usage rates. By choosing the right tools for their soil and crop, the farmers can certainly improve N use efficiency. The task of researchers and advisors is to develop at least conceptual models that assist farmers to choose most efficient applications methods for their crops.

3.7 Keynote Speech

– The use of computer decision support systems such as Well-N and EU-Rotate_Nin in optimising N use in field vegetable rotations

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_cliver_20041207.pdf



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3.8 Cropping systems and crop rotations in field vegetables.

The significance of root growth and catch crops for N-use efficiency

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_kthorup_20041207.pdf



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3.9 Influence of nitrogen fertilisation strategies on quality of field vegetables

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_rsejlasen_20041207.pdf



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Nitrogen is considered to be one of the most important factors involved in growth and yield of vegetables. However, less attention has been paid to the effects of nitrogen on physical, chemical and sensory quality of vegetables. In this review a short presentation is given of results from research work within this area.

One of the most discussed quality reducing factors of vegetables affected by nitrogen fertilisation is nitrate accumulation. Nitrate levels in vegetables are restricted to be below standard limits to prevent carcinogenic nitrosamines in human body and interruption of oxygen transport in infants. Accumulation of nitrate in plants is positively correlated to nitrogen levels in fertiliser. The accumulation is also higher with nitrate fertiliser compared with ammonium fertiliser. Nitrate increases in cases with uneven soil moisture, e.g. when heavy rainfall follows a dry period and causes a sudden and high release of nitrogen to the plants. Nitrate in plants also increases with increasing temperature and reduced light intensity (e.g. less space between plants). The crop species most associated with nitrate accumulation are plants from the families *Chenopodiaceae* (spinach, beets), *Asteraceae* (lettuce) and *Brassicaceae* (cabbage and rape).

The physical quality defect 'tip-burn' in leafy vegetables (lettuce and cabbage) is also influenced by nitrogen fertilisation. Tip-burn is the common name for this necrosis on leaf borders caused by calcium deficiency in cases with low transpiration flow. This is mainly caused by long periods of high humidity and low transpiration in plants. Deterioration of the conditions occurs in cases with uneven growth caused by fluctuating availability of nitrogen and water. This is explained by a sudden increase in the need of calcium.

Hollow stem in broccoli is another physiological quality deficiency affected by nitrogen fertilisation. Uneven growth due to dry periods followed by wet periods and high release of nitrogen from soil also seems to be the main reason in this case. Increasing levels of nitrogen fertilisation generally increase the degree of hollow stem.

Moderate levels of nitrogen are required for optimal quality of potatoes as regards tuber gravity, tuber shape and crisp colour. Rising levels

of nitrogen increase the tendency for bruising of tubers and browning of tubers after cutting.

Interestingly, nitrogen fertilisation also affects the flavour of vegetables. Increasing levels decrease sugar content and sweet taste and increase bitterness in carrots. In a similar manner flavour compounds of onions tend to decrease with high levels of nitrogen.

More knowledge is required about nitrogen effects on chemical and sensory quality of carrots. In Norway there is an ongoing project focusing on the effects of nitrogen and other different pre-harvest factors on flavour and chemical compounds (e.g. flavour compounds and antioxidants). All in all, the nitrogen effects have to be valued together with other pre-harvest factors to design cultivation strategies for optimum quality.

3.10 Irrigation schedules and water stress

– influence on nutrient uptake and quality

This presentation can be found on the following website

www.improved.se/workshop/pdf/ppt_workshop_jnygaard_20041207.pdf



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3.10.1 Irrigation requirements

Field vegetable crops need approximately 200–800 L m⁻² of water to develop into acceptable yields in temperate climate conditions. This amount is supplied through rainfall and applied irrigation water. Water is necessary for transpiration and the total water use is mainly determined by the crop duration.

The need for water uptake varies during the crop development. Therefore, field vegetable crops are irrigated due to their developmental stage, rooting depth, soil type, and the method of plant establishment.

The irrigation need is determined either according to direct measurements of soil moisture or to calculations based on potential evapotranspiration. Direct measurements have to be related to the soil's water holding capacity. Deficit calculations require corrections of the potential to the actual evapo-transpiration.

3.10.2 Irrigation equipment

During irrigation, some water is lost due to evaporation. It is possible to increase the water use efficiency by using more efficient equipment. Compared with long-range sprinklers, equipments with nozzles mounted on a bar are more efficient. The water use efficiency can be further increased by use of trickle irrigation. Compared with rainguns and similar equipment, the investment in drip irrigation is higher, but the labour costs are usually lower.

Drought stress may occur even in irrigated fields. During dry periods, plants may be short of water due to limitations in the use of irrigation water and more often limitations in the capacity of irrigation equipment.

3.10.3 Nutrient use efficiency and risk of leaching

In dry soil, plant growth and nutrient uptake are reduced. A reduced uptake results in reduced nutrient use efficiency and an increased risk of nutrient leaching due to the higher content of unused fertiliser. A surplus supply of irrigation water or rainfall just after irrigation may harm plant growth and also reduce nutrient uptake. More seriously, a surplus supply of water results in nutrient leaching.

3.10.4 Quality of vegetable produce

Drought stress usually reduces total plant production, and the yield of marketable produce is often reduced proportionally. However, drought stress may reduce the yield even further due to an increased development of disorders like tip-burn in e.g. lettuce. In contrast, some disorders like hollow stem in broccoli or growth splitting in carrots may develop less seriously in dry soil resulting in an increased yield of marketable produce.

Due to an increased dry matter content, the concentration of minerals and some organic constituents may slightly increase. The concentration of nitrate may increase even further due to osmoregulation. In some cases, the concentration of minerals may decrease due to a decreased bioavailability in the soil.

3.11 How to implement research and development in practice

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_ullag_20050111.pdf



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3.11.1 Background

The different actors connected with the production of vegetables have their own interests and aims. Society wants to have production that is environmentally safe and sustainable, while farmers have their main focus on profit. Profit is also important for retail organisations, as well as products that increase their reputation. From the consumer point of view safe and inexpensive food has the highest priority. This must be kept in mind when new production methods are suggested.

In a book about sustainable agriculture, Rölöf and Wagemarks (1998) raise the question whether it is immoral to be concerned about the health of natural resources. The reason is that the number of people and their needs and 'wants' are growing. The conclusion is that we need to change the attitudes and the agricultural practices, since human survival depends on natural resources. According to Rölöf and Wagemarks this process requires that farmers become experts instead of users, receivers or adopters of other specialists' wisdom and technologies. The management of a farm places great demands on knowledge and experience in a wide range of topics. Therefore the management of many successful vegetable-producing farms is shared between two persons with different responsibilities. In Sweden, the growers' organisations point out that growers want to change their production methods but need support to do this in an appropriate way concerning the environment without taking too large risks.

Agricultural scientists want to perform good science that creates mobile and immutable knowledge. However, in agriculture a lot of 'immobile mutables' are involved (Flora, 1992). Thus knowledge of the local conditions and of the specific farm is important. On one hand the growers need to evaluate the practical benefits of research, and on the other hand most research results are wholly inaccessible to non-scientists (Edwards-Jones, 2001). It is obvious that growers need help if society wants them to implement new methods in their production.

Society can force the growers to change their practices by legislation. An alternative is to give the growers recommendations through specialists. Another possibility is to facilitate the growers to participate in the process. These methods need to be combined in a strategic manner if fast progress towards more environmentally friendly fertilisation strategies is to be reached.

Farmers who are able to make new choices have self-confidence. They also need knowledge based on insight, experiments and comprehension. The help available to them in this process is mainly through agricultural advisors. Andersen (2004) describes three different potentials of the local agricultural advisor: The specialist, the reflective specialist and the reflective listener. The specialist has the focus on methods and the contact with the farmer might result in technical adjustments to which the farmer is not personally committed. The reflective specialist responds to the personal information given by the farmer and both are involved in a learning process. Their relationship will mainly result in adaptive changes, personally embedded in the farmer. The reflective listener is rare, but when this kind of relationship is established between the advisor and the farmer both will gain through deep learning and understanding. The action eventually caused by their conversation is not predictable, but probably based on new insights.

The growers need help to meet their new needs, concerning new production strategies, by deeper understanding of the processes leading to environmental problems. One way is to encourage a greater degree of farmer participation in the research process. Two methods, participatory research (PR) and participatory learning and action (PLA) have been used in developing countries during the last 15 years and the interest to undertake PR in developed countries is increasing. The methods are well described by Eksvärd (2003) and the outcome, concerning both the process and the new knowledge, from a successful project has been presented (Eksvärd et al., 2001). Edward-Jones (2001) mentions two barriers to the use of PR in developed countries: 1) availability of funding, and 2) attitudes of agricultural researchers and their evaluators. According to Coupal (1997), beneficiaries are in the driving seat in participatory evaluation. In the case of changed fertilisation strategies, both farmers and society benefit if the environment is less influenced. Therefore society ought to support the required learning process.

3.11.2 Conclusions

It is important to:

- Use the farmer's knowledge
- Develop new method for advisors with the focus on reflective listening rather than specialist advice
- Have active advisors willing to adopt new environmental approaches
- Integrate extension and research

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3.12 Constructed ponds and wetlands for phosphorous and nitrogen retention.

– *Experiences from the Nordic countries*

This presentation can be found on the following website
www.improved.se/workshop/pdf/ppt_workshop_bbraskerud_20041207.pdf



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3.12.1 Introduction

Loss of phosphorus (P) and nitrogen (N) from agricultural fields may harm our watercourses and surface waters, even though we implement best management practice (BMP) at field level. Construction of ponds and wetlands (CWs) is a possible supplement to BMP to mitigate nutrient losses.

3.12.2 Materials and methods

Results from 15 intensively studied wetlands from the Nordic countries and USA (3 CWs) are presented. A total of 72 yrs of investigation provided in papers, reports or as personal communications by A.-G. Blankenberg (NO), J. Koskiahio (FIN), D.A. Kovacic (USA) B. Ulén (SE), B. Wedding (SE) and myself (NO), are used as input data. Lack of space permits full references. Pond and CW surface areas varied from 340–10000 m², or 0.007–6% of the catchment area. The hydraulic loading rates (HLR) varied from 0.02 – 11.4 m³ runoff m⁻² surface area day⁻¹ (median 0.8 m d⁻¹). Seven to 100% of P was dissolved, while nitrate dominated the N fraction. Data were analysed with multiple statistical methods to evaluate the factors important for N and P-retention.

3.12.3 Results and conclusions

Phosphorus retention

Results showed that the average total-P retention varied from -26% to 62%, measured as the difference between inlet and outlet. Sedimentation was the most important P-retention process in wetlands and ponds. Increased soluble part of P influences the retention negatively. Soluble P withdraws from settling unless biota or chemical reactions adsorb it in some way. Still several of the wetlands have shown good soluble P retention (36%). Retention increases as the surface area of the pond or wetland increases compared with the catchment area. In addition we have a negative effect of increased hydraulic load, because the retention time decreases as runoff increases. The negative effect of increased HLR is, however, compensated for by increased erosion in the catchment, giving more particles with high settling velocity.

Nitrogen retention

Results showed that the average total-N retention varied from -6% to 43%. Increased pond and CW *surface area* were the most important factors for increased N-retention. In addition, retention increased as the N-*concentration* increased. Increased *runoff* was negative as for the *P-retention*.

Shallow, vegetated wetlands appeared to be more efficient than deeper ponds with respect to P and N retention. The importance of identifying factors affecting the P-retention in the individual catchments is needed. As a result, wetlands can be used selectively in order to improve water quality in eutrophic water bodies. In catchments with some erosion or high N concentrations, the specific retention can be large; 57 g P and 230 g N m⁻² surface area yr⁻¹.

4. NJF seminar in Sweden 2005

Programme, abstracts and Power Point presentations.

Internet link to the programme

www.improved.se/njf/pdf/20051006_Program_NJF_programmeonly.pdf

4.1 Background and aims of the project

This presentation can be found on the following website

www.improved.se/njf/documentation/20051020_Hakan_Sandin_Background.pdf



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4.2 Nitrogen budgets and losses in lettuce and potato fields

This presentation can be found on the following website

www.improved.se/njf/documentation/20051020_Gunnar_Torstensson&Hakan_Sandin_Nitrogen_budgets.pdf

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4.3 The WFD and its influence on agricultural production

This presentation can be found on the following website
www.improved.se/njf/documentation/20051020_Hans_Thyssen_WFD.pdf



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4.4 Danish plans for the aquatic environment - effects and costs

This presentation can be found on the following website
www.improved.se/njf/documentation/20051020_Brian_Jacobson_Vandmiljo.pdf

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4.4.1 Introduction

An analysis of the implementation of the Nitrate Directive in the EU indicates that relative few countries have implemented the directive satisfactorily. Some of these countries are the Nordic countries, but other countries are in the process of getting their implementation accepted or rejected.

In Denmark the Nitrate Directive has been fulfilled with the implementation of the Plan for the Aquatic Environment II (1998–2003). The aim of this plan was to reduce the nitrogen (N) leaching by 37,000 tonnes N so that the total reduction in N-leaching since the mid 1980s would be 100,000 tonnes N in 2003. This aim was achieved in 2003 with the additions to the plan made in 2001.

4.4.2 Measures

The measures were divided into area- and farm-related measures. The area-related measures consists of measures like taking land out of production in environmental sensitive areas, wetlands, forest and organic farming.

The farm-related measures include changes in feeding, better utilisation of N in animal manure, catch crops, lower stocking rate and reductions in fertiliser norms.

4.4.3 Results

The total costs for the Danish Plan for the Aquatic Environment II have been estimated at 70 million € or 2.0 € per kg N in reduced leaching. There exists only few analyses in Europe where the actual costs have been compared with expected costs. The analysis shows that the expected and the actual cost effectiveness are almost the same. Farmers have paid 60% of the total costs. The lesson is that it takes longer to achieve the environmental goals than expected. All in all, the cheapest measures are wetlands, better utilisation of N in animal manure and changes in feeding.

The Action Plan for the Aquatic Environment III was decided in April 2004 and will help to fulfil the Water Framework Implementation in Denmark although it in itself is not enough. Possible analyses at the regional level were also presented. The analysis shows that the geographical positioning of the measures is very important in achieving cost-effective nutrient reduction.

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|---|--|

4.5 Introduction of EU-Rotate_N.

An instrument to optimise fertilisation for potato and field vegetable production

This presentation can be found on the following website
www.improved.se/njf/documentation/20051020_Matthias_Fink_EU-rotate.pdf

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The objectives of the project have been described in the projects newsletter (Issue no. 1, www.hri.ac.uk/eurotate) as follows: The aim of this project is to develop, and then evaluate, a model-based decision support system to optimise nitrogen use in both conventional and organic vegetable rotations across Europe. This will help Member States to:

- Minimise hazards to the environment by adopting consistent approaches to improved efficiency of nitrogen use for different production systems and climatic regions of Europe,
- Optimise production of quality horticultural crops while enhancing the economic sustainability of horticultural production within the EU.

Most vegetables within Europe are produced in intensive rotations, which rely heavily on large inputs of nitrogen from fertiliser or organic sources to maintain the yield and quality of produce. Unfortunately, many field vegetable crops use nitrogen inefficiently and often leave large amounts of nitrogen (either as unused fertiliser or crop debris) in the soil after harvest, potentially this can cause pollution to soil, water and aerial environments. Recent research has shown that the environmental impact can be reduced, without loss of yield or quality, by improved the design of rotations and by more closely matching nitrogen supply to the demands of individual crops. This project will exploit these new techniques to develop a flexible integrated decision support tool, based on models and databases, for nitrogen management and rotational planning in conventional, organic and other low input production systems. This support tool will then be used to compare the effects of different crop sequences and fertiliser rates and other cultural practices on the cycling of nitrogen within rotations, for widely different production systems and climatic conditions across Europe. It will be used to:

- Recommend protocols of Good Agricultural Practice, including nitrogen use in vegetable and mixed vegetable and arable crop rotations through-out Europe
- Provide a basis for choices between economic and environmental constraints to production. The decision support system will be used to identify crop management strategies that lead to reductions in nitrate leaching. These will be tested together with existing Codes of Good Agricultural Practice developed in accordance with the EU Nitrate Directive (91/676/EEC). The results will be used to develop 'rules' that will allow crops to be grown using environmentally sound practices as required in the reformed Fruit and Vegetable regime EC 2200/96, as part of the Common Agricultural Policy. Such work will help Member States satisfy the Community need for quality field vegetables while minimising the risk of nitrate leaching into ground-water and surface and coastal waters. EU-Rotate_N builds on work

completed by a previous European project, ENVEG. The project website is www.hri.ac.uk/eurotate.

4.6 Where is my nitrogen? Let the computer be your spade and help you use “lost” nitrogen

This presentation can be found on the following website
www.improved.se/njf/documentation/20051020_Anders_Pedersen_Where_is_my_nitrogen.pdf



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4.7 Organic farming - a measure to minimise leaching risks

This presentation can be found on the following website
www.improved.se/njf/documentation/20051024_Lennartsson_for_PDF.pdf



Margi Lennartsson

Francis Ryans

www.HDRA.org.UK/research

4.8 Soil and plant analyses in organic vegetable production

- evaluation of grower use of analytical data in a documentation project

This presentation can be found on the following website

www.improved.se/njf/documentation/20051020_Margareta_magnusson_asa_Rolin_Soil_Analysis.pdf



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4.8.1 Nutrition balances

Ten farms with long experience in organic farming were documented 1999–2005. The content of nitrogen in cabbage and especially in carrot differed remarkably from the recommended reference values which are used in the computer software STANK. Maybe there is a need to review the reference values used in STANK, at least for organically grown vegetables.

Surplus of nitrogen in nutrition field balances was on average 33 kg ha⁻¹. The utilisation of nitrogen was on average 56%. Most crop rotation included legumes. The surplus of phosphorus (P) was on average 10 kg ha⁻¹. The utilisation of P was on average 45%. In 63% of cases, the P surplus was higher than the value recommended by the National Board of Agriculture. Organic fertilisers based on farmyard manure have proportionally higher amount of phosphorus than needed for vegetables. Several fields in the study were naturally poor in nutrients and there was a need for potassium.

4.8.2 Analyses

From the beginning of 1999, the standard analyses for soil mapping in Swedish agriculture (extraction of P, K, Ca and Mg by ammonium lactate, extraction of P, K and Cu by HCl and extraction of B with hot water) have been performed each year in the cabbage and carrot fields. The edible products have been analysed at harvest for the total content in DM of C, N, K, P, S, Ca, Mg, Na, Fe, B, Mn, Zn, Cu, Si, Al, Ni, Mo and Cd. From 2002 the soil was also analysed during the season by the modified Spurway Lawton method (soil pH and Ec, extraction of NO₃-N, NH₄-N, P, K, Mg, S, Ca, Na, Cl, Mn and B by HAc) and the plant sap was analysed on the same occasions for the concentration of NO₃-N, NH₄-N, P,

K, Mg, S, Ca, Na, Cl, Mn, B, Cu, Fe, Zn, Mo, Al, and pH and Ec. The aim of these analyses was to calculate balances for addition and removal of nutrients but also to discover nutrient imbalances that might reduce yield and quality of the products.

In the yearly evaluations the advisors found several interesting tendencies in the data, e.g. deficiency of manganese has strongly been suspected to limit yield and thereby decrease the utilisation of other nutrients. Potassium and sulphur were probably deficient in some fields. Attention was drawn to the need for boron additions.

A major problem in the evaluation of analyses is the absence of reliable reference values for organic growing. The statistical evaluation of all data by multivariate methods has confirmed some of the previous conclusions. The major one is manganese deficiency in cabbage, which is caused by high soil pH and high Ca and Mg in the soil.

According to the farmers, the analyses in the project have provided valuable information, and influenced changes in their fertilising strategies. With better reference values, the plant sap and Spurway analyses have the potential to become an important tool in improving the utilisation of fertilisers in organic growing.

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4.9 Optimising farm economics and N use - the economic module within EU-Rotate_N

This presentation can be found on the following website
www.improved.se/njf/documentation/20051020_Schmutz_Firth_Economics_inEU-Rotate_N.pdf



Ulrich Schmutz
 Chris Firth
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4.9.1 Introduction

EU-Rotate_N is a 4-year, EU funded research project, which is developing a model-based decision support system to optimise nitrogen use in horticultural crop rotations across Europe. The EU-Rotate_N project builds on an existing, well-established soil and plant nitrogen model (N-Able). To enhance its power, various sub-modules and more field scale vegetable and arable crops including fertility building crops from all European climates have been added. Among the new-programmed sub-modules are a root module, a water movement & irrigation module, a mineralisation module, a snow & frost module and finally an economic sub-module. EU-Rotate_N also looks at the rotational level and not only specific crops to understand the agronomic, environmental and economic interactions of rotational strategies. This paper only introduces the economic module; further information on the other sub-modules, including three annual newsletters, can be found at www.hri.ac.uk/eurotate.

4.9.2 The economic sub-module

At present soil and plant models rarely contain economic components, because natural and social sciences often use different approaches to modelling. In the EU-Rotate_N model we did not attempt to build a separate economic model, rather integrated the economics into a sub-module so that EU-Rotate_N can run with or without the economic part (Schmutz et al., 2004).

The main entry into the economic module is the total dry matter yield produced by the current agronomic model. However, this parameter does not give an indication of the aboveground dry matter or fresh matter, nor is there an indication of size or shape of the marketable vegetable parts. Therefore, one of the challenges is to find appropriate algorithms to calculate a marketable yield, which is a major input in any farm economics model. This gives also a figure of dry matter removed and the remaining residues, post-harvest, are used as an input for the mineralisation sub-module following crop in the rotation (EU Rotate_N DL5, 2004).

4.9.3 Conversion of total dry matter into marketable yield

Marketable yields are not fixed: the percentage of total yield marketable depends on 'soft' or social factors. Among those are market channels, production systems (organic or conventional), eating cultures (e.g. some countries prefer small, other large vegetables, a full-flavoured taste in one may be considered bitter in another). Only a few 'hard' figures can be used as the EU trade classification, which makes certain vegetables un-marketable if below or above the specifications.

Considering these, two approaches were developed - one more empirical, the other more theoretical. For the empirical conversion our own research, published and un-published field research data were collected where both total dry matter and marketable yield were measured across Europe. From this an algorithm was derived converting total dry matter into marketable yield at any given N supply level including sub-optimal and supraoptimal supply. A unified algorithm with different crop specific parameters is used for each annual vegetable with a single harvest. There are three main types of vegetable crops: some with a simple constant relationship at all available N levels, some with linear increasing or decreasing relationship depending on available N. Some are more complicated with a non-linear relationship. Other vegetable crops are perennial, like artichokes, or with multiple harvests and need different algorithms than annual single harvest crops.

In a second approach, the single plant fresh weight is calculated. This is done using the harvest index to calculate the dry weight of the harvested parts. Then, with the dry matter content and the plant population, an average single plant fresh weight is produced. Assuming a normal distribution of plant fresh weights and a coefficient of variation of e.g. 20% a lower and upper limit of marketable plant fresh weight can be set (e.g., the EU trade specifications). With this information, an average fresh weight of marketable plants within these specifications is calculated. Using the plant population again, the marketable yield and the residues left post-harvest are calculated.

4.9.4 Prices, variable cost and gross margin database

These calculations are not done within the core model (Figure 1). They are hosted in the model framework because prices differ for each country, market channel and growing system. The countries considered in the database are Norway, Denmark, Germany, UK, Italy and Spain. The market channels considered are pre-pack for supermarket, wholesale, direct marketing and processing. The growing systems considered are conventional and organic.

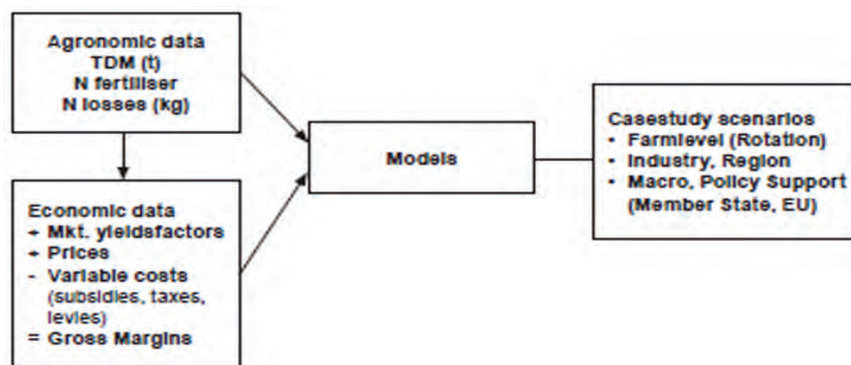


Figure 1. Model overview.

The database holds about 300 crop entries of all relevant horticultural crops, including fertility-building crops, across Europe. The data are current prices and standardised variable cost data published in each country for conventional and organic farming systems (e.g. Lampkin *et al.*, 2004; Nix, 2004; Agro Business Consultants Ltd., 2005). The level of data availability and the depth of detail vary among countries.

4.9.5 How to use the model on different decision-making levels?

As a decision support tool, the model aims at different decision-making levels. One is the farmer and advisor level, making decisions on crop management and rotational planning.

Farmer and advisor level

For this level, the model will be made freely available on the internet in a reduced version. It will have a graphical user interface (GUI), where the user can calculate his rotations with default values (soil, plant and economic data) or overwrite those with his own specific data (Figure 2).

Regional, national and EU levels

The other levels are regional (e.g. water authorities planning in a catchment), national and EU (policy makers planning legislation). For those, more scientific inputs in terms of statistical data, GIS analysis and additional programming are needed and it is therefore likely to be only used in ongoing research projects, where only a basic research-GUI is required to control the various complex model runs.

Economic output screen

Crop	Carrots	Cabbage	Cereal	Average
Marketable yield		36	30 000	4
Price		200	0.3	165
Output		7 200	9 000	963
Variable costs		3 058	5 850	144
(of which N related variable costs)	500	500	50	350
Subsidies (organic, low input)	0	0	0	0
Gross margin	4 142	3 150	819	2 704
Environmental economics kg N /ha			cumulative (average)	
N use (mineral, organic) kg N /ha	100	400	100	600 (200)
N leaching	50	250	0	300 (100)

Figure 2. Example of an economic output screen

4.9.6 Test of management strategies to optimise N use in horticultural crop rotations

Within the EU-Rotate_N project itself, the main work is on developing and validating the model. Only one possible use of the tool as a research-tool is investigated in detail: It will be used to test a set of management strategies at the national level of all six participating countries (Norway,

Denmark, Germany, UK, Italy and Spain) and the EU level. It will assess a set of management strategies to support policy decision-making on GAP (Good Agricultural Practice) development in member states and on the EU Organic Standard (organic-GAP). In order to assess different set of management strategies on a national level, a ‘virtual’ picture of the horticultural land use in a country (e.g. the United Kingdom, EU Rotate_N DL14-UK, 2005) has been created. It is based on the total area of each crop grown. Then a regional breakdown depending on soil type and climate data follows. It results in a set of model rotations or model farms, which represent a large part (> 75%) of the whole member state.

These typical and representative rotations are then used as a baseline for model runs of the EU-Rotate_N model. With this method, detailed tests and sensitivity analyses of management strategies are possible. The agronomic, environmental and economic implications can be shown with sufficient detail on a national and a EU level. The optimisation approach of economic and environmental factors is discussed in detail in the project report DL9 (EU-Rotate_N DL9, 2004).

4.9.7 Requirements for other countries

For other European countries to participate in this process no additional crop parameters are required, because all main European climate are covered in the model. However, additional socio-economic data are needed. The main categories are:

At farm level.

A standardised economic data set of vegetables, cereals and green manure crops with:

- Total yields, marketable yields, market channels
- Prices, subsidies
- Variable costs (seed, fertiliser, pest & weed control, casual labour, transport, etc....)

At national level

- Detailed statistics on country and regional level
- Typical rotations in major vegetable producing regions
- Typical management practices, nitrogen levels
- Spatial data (GIS) on horticultural land use, if available, can be used

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4.10 Plant analysis to monitor nutrient status in vegetable crops

This presentation can be found on the following website
www.improved.se/njf/documentation/20051024_Goran_Ekbladh_Plant_Analysis.pdf

Göran Ekbladh
 Ernst Witter
 SLU, Dept. of Soil Science
 Tom Ericson
 SLU, Dept. of Landscape Planning

A more careful adjustment of N fertilisation in relation to crop N demand and N supply from the soil is needed in order to minimise the pollution caused by N applied in excess. As a consequence, the safety margin for N fertilisation to avoid deficiency will be less than it is today. In such a scenario, tools to assess the plant nitrogen status will be valuable in the evaluation of fertiliser strategies. Although cumbersome, one of the most robust such tools is one based on analysis of the total nitrogen content of the plant.

However, relevant reference data that define the lowest plant nitrogen content for optimal growth and that take account of the dynamics of the development of crops are not always available. These problems were

addressed by several authors in the 1990s and theories were proposed which relate the dynamics of the nitrogen content in the crop during the growth period to leaf area – growth relations (Caloin & Yu, 1984; Greenwood et al., 1991; Lemaire & Gastal; 1997; Grindley, 2000).

We applied these theories to data on cabbage as a representative of a row-grown crop with a high nitrogen demand. The data sets were collected from experiments in the field as well as in growth chambers.

The data confirmed that, also for row-grown crops, the decline in the plant nitrogen concentration is closely related to the decline in the leaf area ratio (leaf area divided by biomass dry weight). As a result, the nitrogen concentration of individual leaves expressed on the basis of the leaf area, rather than weight, remained at a constant level. Sampling of individual leaves therefore seems a promising tool for assessment of the plant nitrogen status in vegetable production.

With thanks to FORMAS, Stiftelsen Lantbruksforskning (SLF) and Stiftelsen Svensk Växtnäringsforskning (SV) for financial support.

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4.11 Optimisation of nitrogen to early potatoes

Anders Nilsson

Swedish University of Agricultural Sciences.

This presentation was made at a preliminary stage of that project and results will be presented during 2007.

4.12 Fertigation as a measure to improve precision in fertilisation for vegetables

This presentation can be found on the following website
www.improved.se/njf/documentation/20051029_Tapio_Salo_Fertigation.pdf



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4.13 Fertiliser recommendations for agricultural and horticultural crops (RB209)

This presentation can be found on the following website
www.improved.se/njf/documentation/20051028_I_G_Burns_RB209.pdf



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Reference Book 209 (RB209) provides a comprehensive system of fertiliser recommendations for a wide range of crops in different commodity groups, including arable, vegetable, fruit and grass grown by conventional (non-organic) methods in the UK. The recommendations deal primarily with N, P and K fertilisers, but also include other nutrients (*eg* Mg, Na, B) where appropriate, in addition to recommendations for animal manures. All are based on the adoption of sound principles of nutrient management and fertiliser use to optimise production and quality, and maximise farm profits, whilst avoiding nutrient pollution. This is achieved by balancing the supply of N, P and K from the soil to the known requirements of individual crops.

Soil N, P and K supply is categorised into separate sets of seven indices from 0 (low nutrient status) to 6 (high nutrient status) in each case. For P and K, these indices are estimated from soil analysis of the top 15 cm of soil after extraction with sodium bicarbonate (pH 8.5) and ammonium nitrate respectively (MAFF, 1986). The soil analysis only needs to be repeated once every three or four years, because the P and K status of the soil does not change rapidly. The Soil Nitrogen Supply (SNS) index

can also be estimated from a mineral N analysis of the top 90 cm of soil, after adjustment for the expected amount of N released by mineralization (and for any N already in a growing crop). However, because of the dynamics of N in the soil, the soil sample must be taken close to the anticipated time of N fertiliser application every year, and this can become expensive where several fields and/or planting dates are used. An alternative method is therefore provided based on simple information on the previous crop grown at the site, the category of excess winter rainfall (low, medium or high) and the soil type to estimate the expected proportion of residual mineral N remaining in the soil for a spring planting. Further adjustments can be made for a second crop grown in the same year. Once the nutrient index has been estimated, the fertiliser recommendation is read off from a look-up table for each crop.

Although developed for soils and crops in the UK, RB209 is equally applicable to other northern European countries with similar amounts of excess winter rainfall, provided the same methods of soil P and K analysis are followed. RB209 can be purchased as a book, or can be accessed (free of charge) on www.defra.gov.uk/enviro/pollute/rb209.

Reference

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4.14 How can the fertiliser industry help minimise environmental risks in conjunction with potato and field vegetable production!

This presentation can be found on the following website
www.improved.se/njf/documentation/2005-1023_AKW_The_fertilizer_industry.pdf

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<http://fert.yara.de/de>

4.15 Fertiliser placement to improve efficiency of nutrient use for wide row crops

This presentation can be found on the following website
www.improved.se/njf/documentation/20051028_I_G_Burns-Fertiliser_placement.pdf



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Low recoveries from conventional broadcast fertiliser applications on wide row crops can create large nutrient residues which may increase the risk of nutrient pollution by leaching or erosion. Targeting fertiliser applications using placement techniques offers the potential to help protect the environment by reducing the total amounts of nutrient applied, increasing their overall recovery and minimising their accumulation in the soil. However, to maximise growth, a continuing supply of nutrients must be maintained around the developing roots of young seedlings or transplants to sustain uptake at a time when high concentrations of nutrients are needed in their tissues. The principles of successful fertiliser placement are therefore to meet early crop demand with targeted applications of fertiliser in the seedbed, whilst ensuring there are enough nutrients available to satisfy later demand at a time when roots are better able to exploit the soil more effectively. This can be achieved using banding or starter fertiliser techniques.

Banded fertiliser. Studies of root development in the early growth stages of different wide-row crops showed that their root systems expand laterally to exploit only about half of the inter-row width within 4 to 8 weeks of planting. Crops planted with the optimum rate of N base dressing recovered most of the N in this rooted zone within 8 weeks, whilst little or no N was recovered from outside the zone. Subsequent measurements of crop response using split dressings of N in which the base was applied either in a band (spanning the crop row but restricted to only 50% of the soil surface) or broadcast to the whole soil surface, produced equivalent yields of cauliflower, leeks and maize with a 25% overall saving in N fertiliser. There were also substantial reductions in residual N remaining in the soil at harvest.

Starter fertiliser. The injection small volumes of nutrient solution (usually ammonium phosphate) at high concentration about 25 mm below the seed at drilling or below a new transplant can enhance the early growth of a range of different vegetable crops and, when used in combi-

nation with a supplementary base or top dressing of N, can produce equivalent yields with smaller total amounts of fertiliser. With other crops (notably lettuce, onion, carrots, parsnips, and some arable crops), the promotion of vigorous root growth using starter fertiliser encourages young plants to exploit the soil resources even more effectively, allowing them to reach a higher final yield than can be achieved with conventional applications. Crop response studies have shown that nutrient recoveries can be enhanced by up to 50%, reducing the levels of residual N and P in the soil at harvest. There is also evidence that starter fertiliser can be particularly effective early in the season, when uptake of P from conventional dressings in cold soil can be low.

Advice on these placement techniques are now included in the UK Fertiliser Recommendations (RB209), and are increasingly being used by growers.

4.16 Assessment of critical source areas for nutrient losses – How to measure risks of nutrient losses

This presentation can be found on the following website
www.improved.se/njf/documentation/20051023_Bechmann_Assesment.pdf

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4.17 Vegetable production creates nitrogen leaching risk – How catch crops and rotation planning can help reduce this problem

This presentation can be found on the following website
www.improved.se/njf/documentation/20051023_Kristian_Thorup-Kristensen_CC_and_rotation.pdf



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4.18 'Focus on Nutrients'

- How can we change our ways of working to become more efficient in achieving our environmental goals?

This presentation can be found on the following website
www.improved.se/njf/documentation/20051013_Hakan_Sandin_FocusonNutrients.pdf



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4.19 Economic and environmental aspects of adopting precision farming

This presentation can be found on the following website
www.improved.se/njf/documentation/20051023_Marcus_Pedersen_Economical&environmental.pdf



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4.20 Management in vegetable production with mobile internet

This presentation can be found on the following website
www.improved.se/njf/documentation/20051109_Iver_Thysen_pres.pdf



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Allan Leck Jensen and Margrethe B. Høstgaard

An online ICT system for management in the fruit and vegetable sector with PC and mobile phones is being developed and tested by Danish producers. The primary objective is to develop an attractive and efficient management system for primary producers. A further objective is ICT support of food product documentation, certification and collaboration throughout the supply chain. The system is developed in collaboration with Danish fruit and vegetable producers, wholesalers and retailers.

4.20.1 Introduction

In many countries, including Denmark, there is an increasing demand among consumers, retailers, wholesale dealers and authorities that producers of food must be able to document their products being produced under certain quality standards. Some wholesale dealers demand access to documentation for the use of pesticides in the production and authorities may be concerned about the possibility to track and trace a particular batch of products. There are internationally recognised certification criteria, such as EurepGAP, which a producer can decide to comply with and thereby obtain a competitive edge.

A survey of five of the largest producers of fruit and vegetables in Denmark showed that on one hand, that the farms are very specialised in cultures, with many employees, special machinery and large turnover. On the other hand the use of ICT in the farms was very limited, and it was recognised as a serious problem to maintain the necessary documentation and to make efficient planning and management of the production.

The increasing competition in the European market for fruit and vegetables and the increasing negotiating power of larger and larger supermarket chains forces producers and retailers to be more efficient. A hitherto only slightly explored route is to improve efficiency by better use of advanced ICT.

These problems are the background for the Danish project “Fruit and vegetable ICT” with participation of groups from several relevant sectors: Research, advice, wholesale, primary production and authorities. Web-based information and decision support systems as well as mobile internet applications are rapidly gaining a status of common-day technology (Jensen et al., 2000; Jensen and Thysen, 2004). These technologies provide excellent possibilities for sharing information across the fruit and vegetable supply chain, which is major advantage in future business organisation.

4.20.2 Objectives and developments

The objectives of the project are twofold: Firstly, to build an efficient and attractive system for the daily management of primary producers of fruit and vegetables and at the same time to ensure the recording of the neces-

sary data for the documentation of the products, and, secondly, to develop and test pilot applications for net-based collaboration between producers and retailers.

The system is developed over two years of which the first year was dedicated to prototyping, initial user tests and programming of the first production version. The second year is dedicated to full scale implementation and testing by 15 fruit and vegetable farmers during the growing season, and to the development of a final version after the growing season. The system will thereafter be available for fruit and vegetable growers on a commercial basis; it is expected that the system will be self-financing after a two year period.

The system is entirely web-based with server software written in Active Server Pages deployed in Microsoft Information Server; the database is in Microsoft SQL Server. Client applications for accessing the system are web browsers, also in mobile phones, as newer models are equipped with web browsers (Opera in phones on the Symbian platform or MS Explorer in phones running on MS CE). Web pages intended for mobile phones are customized to the smaller screens. Mobile phones connect to the Internet by GPRS.

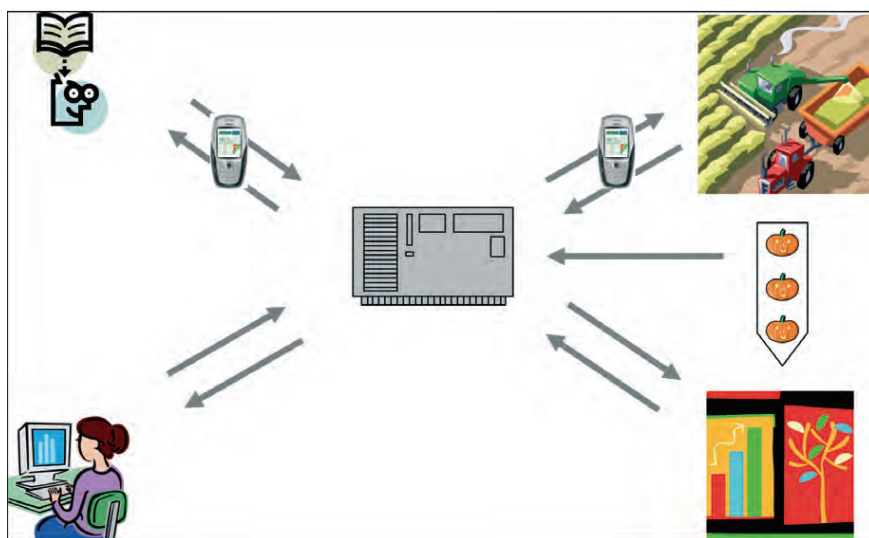


Fig 1. Fruit and Vegetable ICT system.

4.20.3 System overview

The main actors in the fruit and vegetable system are shown in Fig. 1. The *primary producer* (lower left corner) uses the system for scheduling the daily work in the operation of the farm. For this purpose, s/he defines the tasks of the day. Each task is assigned with the required information for the field workers to perform the tasks as well as the required information for future documentation. The tasks are stored in the online database.

The *field workers* (upper right corner) are provided with their personal task list (or work sheet), which often will be as a print-out. They have the possibility to access the online from the field by mobile phones to acquire further information and to record starting and ending time of tasks being done (possibly with modifications to the planned task). Data collected during field work, e.g. quantity and quality of harvests, can also be recorded directly to the online database.

The *advisor* (upper left corner) accesses the online database by mobile phone during field inspections for acquisition of crop data and for recording his/her observations. S/he has the possibility to store advices in the online database the form of recommended tasks. These are immediately available for the primary producer, who can include these tasks in the work plans (possibly with modifications).

The last actor in the system is the *wholesaler* (lower right corner). While all other connections in Fig. 1 symbolise transfer of information via the online server, there is a transport of physical goods from the primary producer to the retailer. In the field the products are identified by the location of the crop (e.g. a field number); during harvest and transport to the retailer, the products are labelled with a new identification, which is stored in the database together with the location identification. This new identification is maintained all the way to the end user. This method enables traceability throughout the food supply chain.

4.20.4 Facilities

Work scheduling in primary production

The purpose of this facility is to allow the farm manager to define and store work tasks in the online database for use by the farm workers and for documentation of the production methods. This may seem rather simple, but the requirement of a full documentation of the work turns out to add considerable complexity to the definition of a work tasks. The categories of data used in the system to define a work task are given in Table 1. The status of the task defines a collaboration framework for the different actors. An advisor will store his/her advice as recommended tasks, which are readily available for the farm manager to transform to a planned task. The farm workers will store tasks as fulfilled, when the work is done, and finally the farm manager can release the task, meaning that retailer gets access to the task. Modifications can be made at each step. Each state of a task is stored in the database, which is important for certification schemes requiring the causes for certain crop treatments.

Subject, methods and materials (Table 1) are data attributes giving an exact definition of tasks. In this context, it is imperative to use common data definitions and vocabulary. This system links to a data definition database at the Danish Agricultural Advisory Centre, which holds data for all farm activities, crops and varieties, pesticides including chemical

compounds, etc. Data are always entered by selection forms created from farm specific subsets of the data definitions in order to keep the selections small and relevant. A special attribute in the farm subsets is a short name suited for the small screen on mobile phones. The online database need only hold the id from the global data definition database, being sufficient to include the detailed information when necessary.

Table 1. Data categories for work tasks

Data category	Description (examples)
Status	Recommended, planned, fulfilled, released
Subject	Soil preparation, fertilization, sowing, etc.
Methods	Machine types, operation types, etc.
Materials	Fertilizers, pesticides, etc.
Areas	Fields, parcels, greenhouses, etc.
Persons	Workers

Defining the area for a task can be tedious in horticulture, where the crops often are grown in a large number of small parcels. Sometimes a task is attributed to all parcels in a whole field and sometimes only to one parcel or some of the rows in a parcel. An efficient method for entering the area attribute to a task has been developed by using a conceptual graphical representation of the area hierarchy (e.g., fields, parcels and rows) as shown in Fig. 2. Areas are symbolised by boxes, which are clickable in a web page; a mouse click on a box switches its state between selected and deselected, visualised by green and red. States are inherited to lower levels in the hierarchy. This utility enables selection of all possible combinations of areas with a few mouse clicks.

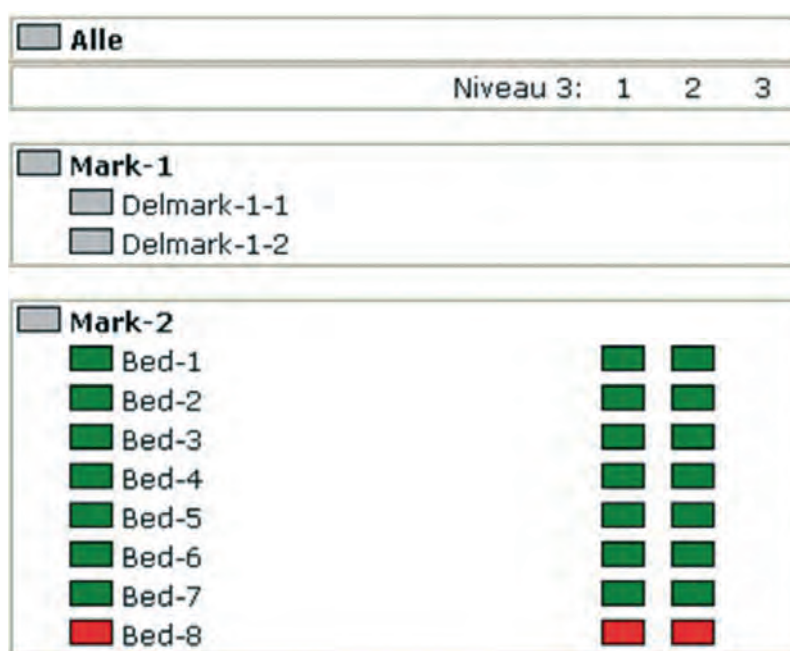


Fig 2. Web page for selecting areas in defining tasks

Persons are selected from farm workers defined in the database. The identity of persons involved at different stages of a task is required by some certification schemes, for example EurepGAP.

There is a risk that the amount of information needed for a task will be an obstacle for the daily use of the system. Much effort has been made to make the data entrance as user-friendly as possible. A further utility not implemented at the time of writing is a set of standard tasks providing the details of common tasks in the farm. This will establish an operational production manual, which may also be used for documentation of the farm's production methods to external bodies.

Using mobile phones from the field

The suitability of using mobile phones to access the system from the field was examined by the fruit and vegetable growers participating in the project in summer 2004 on prototype versions of selected facilities. The experiences were that the connections often are too slow, partly due to poorer mobile coverage in the countryside. This was in particular a problem when the user should navigate through several pages, for example to find a specific parcel. Another problem was caused by too long text strings from data definitions designed for the PC.

The conclusion was that the use of mobile phones is feasible, but for the time being it must be restricted to very specific operations. Navigation should

in particular be kept to very few pages. Intended use of mobile phones for the operational version of the system in 2005 are recording of the time for starting and ending tasks (much appreciated by farm managers as an easy way to get data for paying workers).

Reporting advice from the field by mobile phones

Advisors specialising in fruit and vegetable production are often used quite extensively by Danish growers; it is not unusual the advisor has a weekly inspection of the crops during the growing season, and his recommendations are in general applied by the farm manager. It is, furthermore, implemented in the Danish Integrated Production scheme that treatments for certain pests and diseases may only be applied when an advisor has identified the problem. The purpose of this facility is to make the communication between the advisor and the farm manager easy and unambiguous.

An example of this is treatment for Carrot Fly, which is only allowed after trap catches of flies has passed a given threshold. Fig. 3 shows a series of web pages designed for the mobile phone for recording, checking and visualising trap catches of carrot flies in relation to the threshold. The pages contain links that direct the user to a page for supplying a treatment recommendation.

Harvest prediction

A web-based system to forecast the harvest time of cauliflower has been developed and is being tested (Jensen and Grevsen, 2005). The system combines a deterministic growth model of cauliflower with an online weather database and the online production database for fruit and vegetable growers. The system enables growers to retrieve an updated harvest forecast of a particular planting from the field with an advanced mobile telephone. From the office PC, the grower can follow the growth of all cauliflower crops to obtain an early warning if the growth differs from the scheduled, thus distorting the delivery plan. The system also gives wholesale dealers access to aggregated results from their associated growers, showing the expected number of delivered curds from each grower each week.



Fig. 3 Web-pages for recording and evaluating carrot fly trap catches

The web page for the grower's evaluation of the forecasted harvest date for a cauliflower crop is shown in Fig. 4.

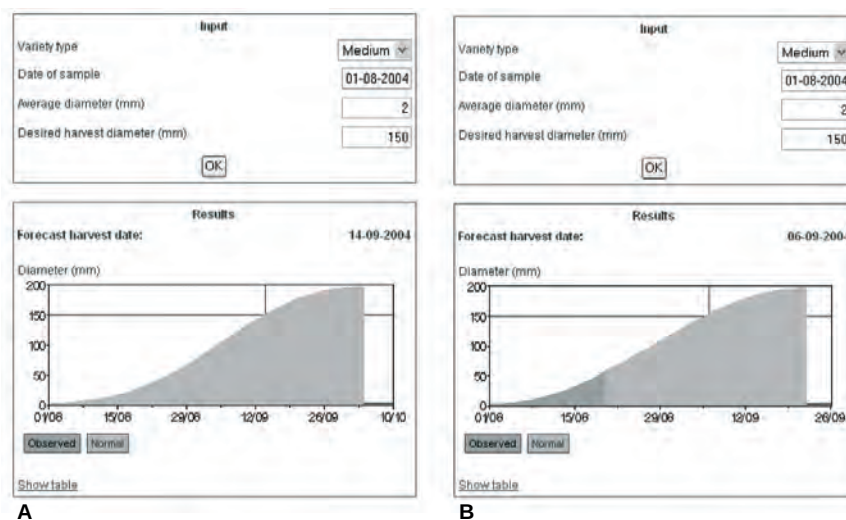


Fig. 4. User interface for the regular grower. Based on input about the crop and the location the model predicts the harvest date. a: On the sample date, 01-08-04, the harvest date is forecasted to 14-09-04. b: On 20-08-04 the forecast harvest date has been updated to 06-09-04, due to the observed weather.

4.20.5 Discussion

Fruit and vegetable ICT is a web-based system with an online database. This has several advantages: The necessary installation and maintenance is minimal for the producer since only a web browser is required, the system can be used by several persons of the farm simultaneously, and it is possible to access the system from multiple technological platforms. The technological platforms include traditional pc and handheld devices with wireless internet access, like PDA's or smartphones. The entire user interface is programmed with standard web technology (xhtml), so it is platform independent. However, the applications are optimised for the different screen sizes of the platforms.

The possibility to access the system from the field with an advanced mobile telephone removes the need to bring task descriptions on paper and to write field recordings on paper for later database entry. This will be timesaving and reduce the risk of erroneous data recordings. Tests with a prototype system in the summer 2004 showed, however, that the currently available mobile internet connections are too slow in practice. There is little doubt that the bandwidth of mobile internet will improve dramatically in the near future, e.g. by the implementation of a nation-wide 3G network.

Fruit and vegetable ICT is designed to support a web-based collaboration between the producer and the next links in the food chain 'from field to fork'. It is part of the project to demonstrate the possibilities for collaboration through examples. Producers can give wholesale dealers authorisation to retrieve certain production data of relevance, e.g. a list of applied pesticides in a given crop. There will be an application to give a harvest forecast of cauliflower and lettuce, which is a powerful tool for the producer as well as the wholesale dealer to predict the variation of the supply of these vegetables, due to the weather.

The system is at the time of writing in a development phase including tests by fruit and vegetable producers and wholesalers. Provided these tests are successful, further research and development will be initiated, for example on the following subjects:

- General applicability and user friendliness, especially on use of mobile client hardware.
- Work planning tools to automatically generate daily work plans. These should be generated from general tactics specified by the farm manager, and the current situation concerning crop conditions, weather conditions and production demands. Optimisation should be employed by integrated decision support systems.
- Business intelligence applications for analysis of production efficiency, cost-benefit, etc., and for optimisation of land allocation and crop selection.

- Harvest forecasts (harvesting time, quality and quantity) on more products. Danish data are available for estimation of forecasting models for some varieties of apples and pears.
- Supply chain wide traceability: Further development of ensuring traceability over the gap between the crop growth phase (area related data) and the product distribution phase (product batch related data), including bar codes and RFID tags.
- Context and location aware applications. Mobile equipment with GSM to detect where the user is; intelligent software to suggest what the user wants to do.
- Speech recognition applications used in combination with context and location awareness. Recommendations and decisions made during field inspection is to be extracted from plain speech and stored in the database.
- Food industry company applications for managing contract grower relations. Inclusion of company crop growing politics in generating work plans, crop and work monitoring, communication between company and farmers, harvest forecasting, harvest logistics, etc.
- International collaboration. Development of a generic version, which can be adapted to different countries or regions, data exchange between several sites.

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Jensen, A.L. & Thysen, I., 2004. Agricultural information and decision support on smartphone. AFITA/WCCA 2004 Conference, Bangkok, Thailand. ISBN 974–229–639–1, p. 704–709.

Jensen, A.L., Boll and Grevsen, K.. 2005. Web-based harvest forecast of cauliflower for the agri-food chain. The third international symposium on: Applications of Modelling as an Innovative Technology in the Agri-Food Chain. May 29 – June 2, 2005, Leuven, Belgium. 4.21 The importance of On-farm Research in achieving environmental goals

4.21 The importance of On-farm Research in achieving environmental goals

This presentation can be found on the following website
www.improved.se/njf/documentation/20051031_Lars_Wiik_Staygreen.pdf



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4.21.1 *Stay green 2003–2005. The importance of healthy potato crops*

The project *Stay green* was carried out on starch potatoes in the period 2003–2005. The emphasis was within the areas of plant nutrient proportions and growth data, and soil science and crop protection science studies.

Research leader Lars Wiik, SLU, Collaborating SLU researchers: Olof Hellgren, Abraham Joel, Hans Larsson, Anders Nilsson, Tomas Rydberg, Urban Svantesson.

4.21.2 *Objective*

The main objective was to identify measures giving rise to increased harvest quantity and quality while at the same time decreasing negative effects on the environment through improved exploitation of the growing period, so-called *stay green*. To achieve this objective, we attempted to create an overall perspective on potato cultivation, to use water resources optimally, to quantify yield-limiting factors, to adapt and optimise crop protection inputs to specific requirements and to increase knowledge of potato development and the factors controlling growth.

4.21.3 *Background*

Stay green has been established as a term for genetic characteristics that delay leaf senescence and support photosynthesis for longer. However, the ability of a crop to stay green depends primarily on water and nutrient availability and the absence of disease. In recent years, the stay green concept has been discussed for a range of different crops, although we have not found any references to potatoes. We believe *stay green* to be extremely suitable for this crop. Plotting crop growth productivity against time in a graph often produces an asymmetrical bell-shaped curve. However, if the crop can be established more rapidly and reach full growth and maintain maximum productivity until the end of the growing season,

a more rectangular growth curve is obtained. Our approach in this project is very similar to that of *stay green*, in that a potato crop should rapidly reach its maximum productivity and then maintain it for longer than normal before rapidly senescing (Thomas & Howarth, 2000).

On many good potato soils, the penetrative ability of the roots is often limited to the loosened and tilled topsoil. The reason is that these soils lack aggregate structure, which means that the subsoil becomes too compact for roots to penetrate. If we loosen to approx. 50 cm we should be able to create the conditions necessary for potato roots to grow to depth. If the roots are irrigated optimally, they will utilise the loosened layer (Harry Linnér, pers. comm. 2002). Increased rooting depth normally improves the buffering capacity of a crop against a range of different stress situations, not least water stress. Sojka et al. (1993) reported increased potato yields in Idaho (USA) after partial subsoiling under the rows.

Cultivation practices are very important for nitrogen leaching potato production. Continuously meeting the crop requirements for water and nitrogen and keeping the crop healthy are some of the keys to high yield and efficient nutrient utilisation. Measures that lead to high and uniform yield generally also lead to improved nitrogen use efficiency and thus decreased leaching. In studies where good cultivation practices are employed, uptake of nitrogen by the potato crop is consistently greater than that supplied by fertilisation, and residual N amounts are modest (Linnér, 2002).

It is well known that pests such as leafhoppers and aphids and plant pathogenic fungi such as leaf blight, stem canker and early blight restrict the growth of potato plants, which is not only a disadvantage for harvest quantity but also for its quality. When these pests and diseases become established in a crop, they are difficult to control. With better precision, i.e. targeting crop protection measures in potato crops to time and need, very large yield increases can be obtained (Larsson, 2003; Wiik, 2004). However, these yield increases can probably be even higher if the cultivation practices are adapted to the ability of the crop to stay green for longer. Potato crops that are carefully protected from pests and diseases can remain green for several weeks longer than untreated crops. Precise application of nutrients and water is probably required in this case, while the untreated crop that grows and develops poorly does not utilise nutrients optimally.

4.21.4 Methods

Intensive paired investigations were carried out on high yield and average yield farms. On one or several of the average farms, field trials were established to study the importance of individual factors.

4.21.5 Results

Our investigations revealed best yields of around 60 tonnes per hectare but the difference between neighbouring growers and fields were great despite external conditions being relatively similar. The stay green effect was clearly apparent on the high yield farms. Large differences with respect to tuber yield, starch content and starch yield were found between the farms included in the investigations. On average, the high yield farms had approx. 30 tonnes greater tuber yield per hectare than the average farms in 2003, while the difference was approx. 10 tonnes per hectare in 2004. On the high yield farms, the relative growth of the potato plants was higher both early and late in the season, although this effect was most pronounced in 2003. The difference was due to e.g. the crop protection measures employed and the timing of such measures. The incidence of pests differed markedly between the farms, with the growers on the high yield farms being most successful at controlling pests even though the number of measures used was not significantly different from that on average farms. When weeds were counted and weighed, it was found that the number of species and their weight was greater on the average yield farms.

Soil permeability differed between the different farms, which may contribute to explaining the yield differences observed.

Despite the fact that all the fields in these investigations were fertilised with approximately the same amount of nitrogen, yield differed widely between farms. Large losses of plant nutrients can therefore be expected on the farms with low yields.

The data produced in the project were analysed by correlation analysis. Some examples of relationships with high correlation coefficients (Pearson correlation coefficient > 0.600 and ** significance, 0.01) are given below. However these correlations must be interpreted with great caution since they are only based on two years of results.

Starch yield and: tuber yield (0.962), starch concentration (0.755), stem canker (-0.628), damping-off (-0.642), senescence (-0.737) and aphids (-0.894).

Tubers < 42 mm and: tubers 42-55 mm (0.914), tubers 55-65 mm (0.653), tubers > 65 mm (- 0.920), starch concentration (-0.647), number of plants (0.702), damping-off (0.665), senescence (0.690) and aphids (0.652).

As mentioned above, the results from these years are just the beginning of essential data collection, which after another few years will allow for a constructive statistical analysis, particularly as regards studying the different interactions. We have therefore applied for continued funding for a further two years.

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4.22 An action plan for protecting the drinking water in a vegetable growing area of Nordsamsø, Denmark

This presentation can be found on the following website
www.improved.se/njf/documentation/20051023_Karin_Hvidtberg_Nilsson_An_Action_Plan.pdf

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In collaboration with Samsø Municipality and the local waterworks, Aarhus County is drawing up an action plan for protecting the drinking water resource on northern Samsø. As is the case elsewhere in Denmark, the drinking water there derives almost solely from groundwater. Such action plans largely contain the same elements as the groundwater part of river basin management plans that have to be drawn up pursuant to the Water Framework Directive. The action plan for northern Samsø is an example of how to plan local protection of the groundwater in an area with intensive vegetable production.

4.21.1 Environmental objective

The groundwater resource on northern Samsø is very scarce and vulnerable to nitrate contamination. The risk of seawater infiltration is high, and the amount of nitrate leaching from the agricultural land is considerable. Groundwater conditions have therefore been charted very thoroughly. Taking into account the current abstraction conditions the environmental objective has been set at 50 mg NO₃ per litre (drinking water quality standard). Compliance with this objective necessitates that total leaching

of nitrate in the waterworks catchment area does not exceed 2,088 kg N per year. Protection to that level can be compensated for financially.

4.21.2 Nitrogen loading from agriculture

Nitrate leaching from the root zone under current agricultural practices has been calculated in detail at field level using the crop/soil simulation model Daisy. As the dominant land use in the area is vegetable growing, the crop modules have been supplemented with a number of vegetable modules and have been calibrated to local yields. Comparison with suction cup measurements made in a field within the area reveals good agreement between the modelling results and the measurements. Total leaching within the waterworks catchment area (140 ha) is calculated to be 4,610 kg N per year.

4.21.3 Reduction requirements

When nitrogen loading from agriculture exceeds the environmental objective, it is necessary to reduce leaching. In the present case the reduction requirement is 2,522 kg N per year for the waterworks catchment area as a whole. Quantifying the reduction target in this way makes it possible to focus the efforts to reduce leaching. At the same time, it allows the agricultural sector the possibility to decide what measures to implement provided that the resultant overall reduction in leaching is adequate. Good contact between the agricultural sector, the waterworks and the County is important to ensure consensus about the results and mutual understanding of the necessity for further protection measures. All three parties are currently working very seriously with this.

4.21.4 Measures

Scenario simulations of possible measures to reduce leaching show that continued cultivation of the land will be difficult, but will be possible provided that measures are taken to reduce leaching. The scenarios have served as the foundation for the farmers' proposals for achieving the necessary reduction in leaching. This work is currently ongoing. Together with three other Counties, Aarhus County has established a Danish website on protection of the drinking water resource: www.beskyttditdrikkevand.dk. This provides waterworks, municipal authorities and farmers with inspiration for possible measures to reduce nitrate leaching and pesticide contamination from fields and farm properties, and describes the various types of land use agreement that can be implemented to protect the groundwater.

4.23 Local regulation of nitrogen and water in potato and vegetable production - a grower's experience

This presentation can be found on the following website
www.improved.se/njf/documentation/20051011_Jens_Kjeldahl_Growers_Experience.pdf



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4.24 Local planning in Sölvesborg municipality, Sweden, reduces the risk of leaching and enhances the possibilities of using drainage water for irrigation

This presentation can be found on the following website
www.improved.se/njf/pdf/solvesborg_irrigation.pdf

Sölvesborg is a small municipality in the South of Sweden. Sölvesborg forms a peninsula with a long coast to the Baltic Sea. A large area of Sölvesborg consists of farming areas specialising in growing crops such as potatoes, vegetables, strawberries, etc. There is also a huge livestock industry in Sölvesborg. Intensive farming requires a lot of water for irrigation and other purposes connected to farming. At the same time the community has to provide their inhabitants with enough drinking water of good quality. The Sölvesborg area has very few lakes, so it has to rely on access to groundwater. The peninsula of Sölvesborg is an extension of the aquasphere of Kristianstad, one of the main groundwater reservoirs in Sweden. The groundwater is found in the sedimentary layers at 10 to 70 m below the surface.

Together with the Geological Survey of Sweden (SGU) and farmers' organisations, Sölvesborg has created a digital model for calculating water balance. This groundwater model indicates an available volume of about 6 millions cubic metres a year. Sölvesborg needs about 2.5 million cubic metres a year for drinking water, while farmers indicate their needs to be of the same magnitude. Sölvesborg is facing a future problem – where to find enough water for all parties concerned? The municipality covers their need for water supply from 15 wells, driven down in the limestone. The water is distributed through a branched pipe net. The farmers cover their need through wells driven down into the same limestone layer. At least 150 major wells are known. Studies showed that the

farming area is covered by drainage systems and open ditches, ending in the Baltic.

Taking all these facts into consideration, we planned for a 'local investment project (LIP) and applied for subsidies from the government to solve two environmental problems in one solution. The project was based on constructing a number of irrigation ponds for recycling drainage water to:

- Reduce discharge of nitrogen and phosphorus into the Baltic from contaminated drainage water.
- Reduce the need of groundwater for irrigation by using collected drainage water.

The project was approved and the rate of subsidy was set to 70%. The ponds are mainly placed on flat ground in open farmland and constructed using existing soil as building material. Average water depth is 2–5 m. Most ponds are sealed using existing clay to avoid seepage. In some places there was no clay so we had to use a synthetic liner. Most of the ponds are provided with small lift pumps to capture drainage water during the winter season from nearby main drainage pipes.

The building project started in 2003 and finished in early spring 2006.

- We have built 33 irrigation ponds, placed all over the farming districts.
- The total volume of the irrigation ponds is estimated at 390 000 cubic metres.
- Total cost was 14.1 million SEK (1.6 million EU)
- What have we gained from the investment?
- We have reduced the use of drinking water for irrigation. If we estimate that each pond is refilled one and a half times a year, then the total amount of collected drainage water is about 585 000 cubic metres. This means 20% of the need of drinking water in Sölvesborg is saved every year.
- We have reduced the leaching of N and P from farming areas into the Baltic. For some years we have monitored the occurrence of nitrogen and phosphorus in drainage water. From these tests we can assume the concentration of nitrogen to be ~20 mg per litre and that of phosphorus to be ~0.4 mg per litre in drainage water. Theoretically, the reduction of nitrogen is about 9500 kg per year and of phosphorus about 200 kg per year.
- We have created new areas for plants and wildlife. Already experts have found new species in the area, nearby the ponds. The ponds cover roughly 12–15 hectares.

4.25 Field and catchment scale approaches for improving water quality (NP) under the EU Nitrate Directive and the Water Framework Directive

This presentation can be found on the following website
www.improved.se/njf/documentation/20051023_Martyn_Silgram_Field_Catchment.pdf

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