Systems Innovations in Agriculture in the Netherlands

Examples of innovation projects in the development towards a more sustainable agriculture

WAGENINGEN UR
For quality of life

Colophon

The innovation projects described in this publication are part of the research programme Systems Innovations Plant Production Systems. Wageningen UR conducted this programme upon commission of the Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I). The programme started in 2004 and was completed early 2010.

Up-to-date information and backgrounds of systems innovation research can be found on www.syscope.nl and www.kennisonline.nl

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Foreword

In recent years scientists of Wageningen UR (University & Research centre) dedicated much effort to systems innovations in agriculture and horticulture. Complex and persistent environmental problems require new approaches, new so-called proof of principles that should offer farmers and growers of the future new perspectives in a development course towards more sustainable farm management systems.
And this course was – and still is - characterised by intensive cooperation with a large number of stakeholders: farmers and growers and their representatives, businesses in various links of the chain, regional organisations, service industries and knowledge institutions, societal organisations and authorities. This is because development and implementation of sustainable farming requires the development of new techniques as well as – at the same time - acquiring support for the implementation of such changes among all stakeholders. This is why communication and knowledge transfer were playing such an important role in the systems innovation programmes.

The innovation projects for the field crops sectors were started in 2004 and ended in 2009. Early 2010 the 'Systems Innovations Programme for the Field Crops Sectors' was concluded by presenting the results of the innovation projects to the Netherlands Ministry of Agriculture, Nature and Food Quality.

This report presents the four innovation projects and their results, together with a short description of the embedding of these projects in the future explorations that have been conducted together with stakeholders.

Ben Meijer,
Programme Manager for the Field Crop Sectors

From Exploring the Future to Innovation projects [1]

Agriculture is strongly influenced by macroeconomic and societal developments such as liberalisation of world trade and the accession of Eastern European countries to the EU. Farmers and growers in North-West Europe are reacting differently to these macro-trends. One group specifically focuses on maintaining its competitive position on the world market, in particular by cost price reductions, while another group wishes to strengthen participation in chains or is trying to find niche markets. Yet another group is searching for new, often local, economic activities to strengthen the basis of their holdings.
The Dutch government pursues goal-oriented policies to stimulate the transition into sustainable economic sectors. For agriculture and horticulture this involves stimulation of systems innovations (see box) that make agriculture more sustainable, together with
an improved embedding in society and an increased economic competitive strength. The Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I) has asked Wageningen UR to support this process by developing and executing systems innovation programmes for joint transition and innovation with stakeholders.

Two transition paths

The systems innovation programmes follow two complementary paths for initiating and strengthening the desired transitions and innovations in agriculture and horticulture (see Figure 1). The first path runs from the future to current practice. From the future as wished and supported by the stakeholders we first identify apparently unsolvable bottlenecks, i.e., transition points that are impeding the road to the future. Where possible we subsequently develop innovation projects to tackle the bottlenecks. This should make the road to future perspectives accessible in the medium term.
The second transition path leads from practice to the future. This path fully focuses on innovation. We do not only use innovations of pioneers as inspiration source, we also help where innovations are faltering, or where parties are unable to find each other to pull off innovations. We are also supporting the application of innovations in broad commercial agriculture via so-called farmer networks.
By simultaneously being active in all these fields we are strengthening innovations and their application in practice; essential for the development of agricultural and horticultural holdings for the future.

Path 1: from future to practice

Exploring the future, trends and wishes

How would agriculture and horticulture need to look like in 2030 and which steps would be required? These were the central questions when exploring the future together with a large number of stakeholders in and around agriculture and horticulture and several representatives of interest groups. These explorations yielded interesting pictures: pictures of the future that enable policy and research to focus on the desired future and the bottlenecks that need to be eliminated to pave the road to the future.

Background

The future explorations drawn up in the systems innovation programmes are based on the

[1] *Source: Syscope, Quarterly Magazine of Systems Innovation Programmes (In Dutch), no. 6, Wageningen UR, 2005.*

assumption that agriculture and horticulture of the future are sustainable, ecologically (in relation to nature and environment) as well as economically and socially (as regards income, the way they can be fitted into the landscape, and acceptance by socieity). The formulated future explorations visualise such a future.
But however good our explorations of the future, we will never arrive at such a future without public support. This means that exploring the future comprises more than simply extrapolating trends. This is about ideals of people and interest groups, pictures of agriculture and horticulture with sufficient support. This is why many stakeholders in and around agriculture helped thinking about agriculture and horticulture one generation from now.

Paradoxes in Exploring the Future?
The initial phase of Exploring the Future – the interviews with stakeholders – soon revealed strongly differing views on the future. A number of the interviewees favoured the economic line of efficiency improvement, scaling up, high-technology applications, internationally oriented and market-driven chains with integrated quality warranting and excellent logistic performances. Others on the other hand see a future in a regional embedding of agriculture and horticulture: small-scale, locally oriented chains, fulfilling more functions than agricultural production. These two differing views on the future seem to present a paradox but later workshops with stakeholders precisely showed a combination of both concepts to be an important source of inspiration for representing the future. In other words: how do we combine an efficient and effective, economically viable and competitive agriculture and horticulture with small-scale

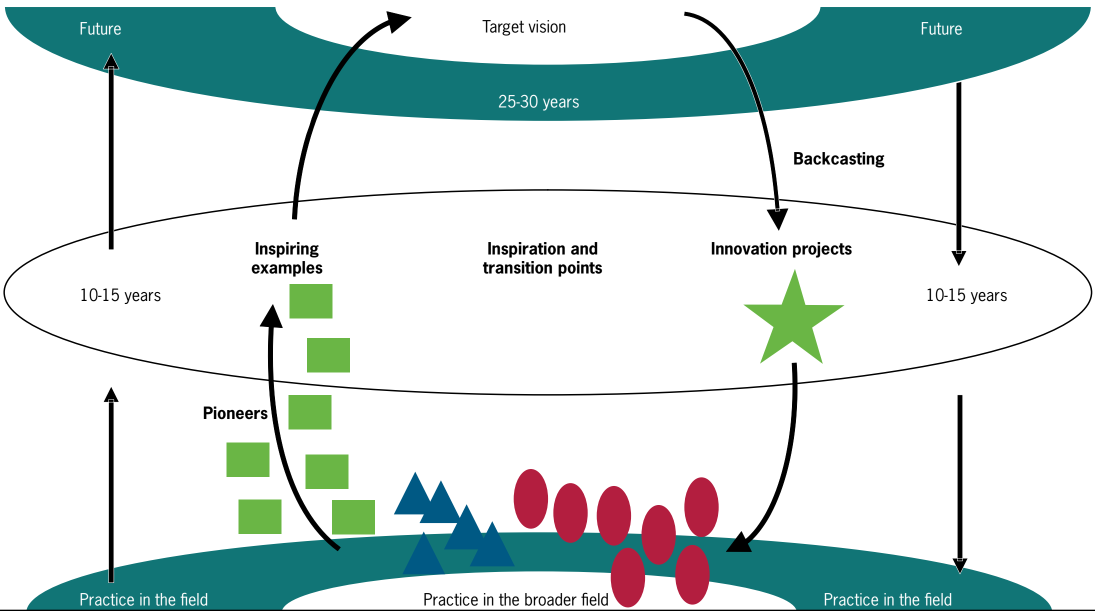

Figure 1. Schematic representation of the two transition paths: from future to practice (right) and from practice to future (left). The right-hand path illustrates how innovation projects are working towards overcoming transition points. The left-hand path shows how pioneering farmers and growers and their partners are developing practicable roads to the future. Considered from the current broad practice both developments are important for the medium term. Linking innovators and innovation projects in a learning network combines all available expertise and experience. This enables accelerated and more goal-oriented stimulation of innovation for the transition into a sustainable agriculture.

Agriculture and horticulture around cities

In 2030, agriculture and horticulture will not have disappeared from urban areas but will have been integrated. In the 'rings' around the city of diminishing urban density agriculture will be fulfilling several functions. The inner rings will be focussing on perception: dairy farming, and agriculture and horticulture in combination with care, day nurseries, education, pick & pay orchards, meeting centres under glass, architectonic greenhouses, etc. These are new forms of management with a partly different function for agriculture in which production will no longer be the most important or only motive for acquiring income and management. The outer rings have room for production specifically aimed at the urban area, fresh special products (dairy) and large-scale production for markets elsewhere (international). This is how agriculture and horticulture can provide for various needs of society. And this is where it performs the function of 'shop window', bringing production and consumption together; this also increases the social awareness of food. The quality of living improves considerably (green) and, finally, agriculture fulfils a role in care, education, recreation (water), and energy.

Agriculture and horticulture in rural areas

In 2030, rural areas will have large-scale agricultural and horticultural holdings that are producing high-quality products for various markets. On (clusters of) such holdings large-scale, intensive

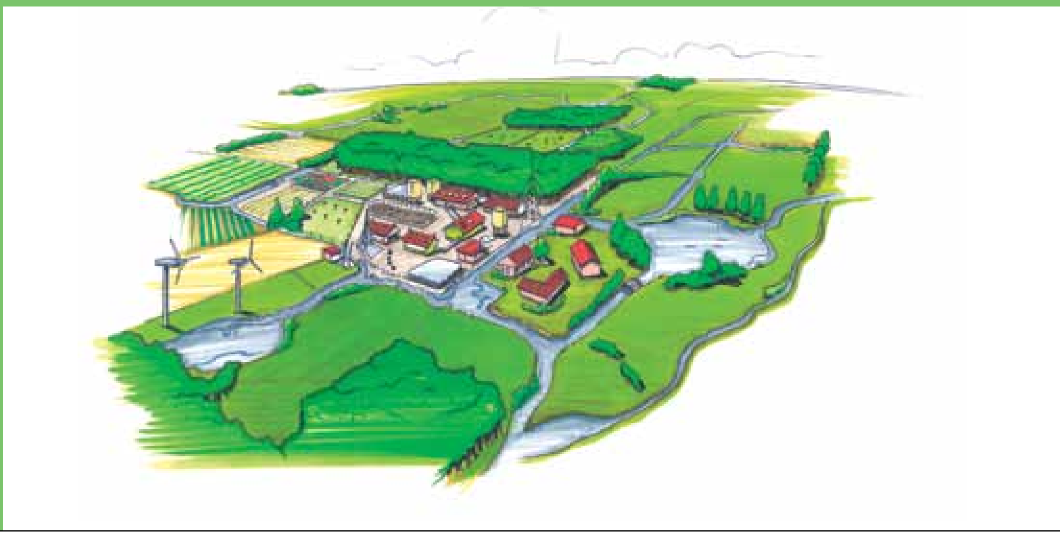

Figure 2-3: Pictures of the future 2030

production (plant and animal) is contributing to financing parts of holdings with economically weaker functions, such as extensive agriculture, nature and water management, recreation, etc. Individual farmers and growers are cooperating in such clusters and their specialisation is an illustration of the concept multifunctionality.
On the ‘region farm’ a quarter of the soil is intended for (intensive) production and three quarters for (extensive) nature farming. The production part is knowledge-intensive; food crops are grown as well as crops that supply ingredients for, e.g., medicines and stimulants.
Rural areas have different types of animal husbandries. Production-oriented holdings are characterised by their large-scale and high production. On nature-oriented holdings, near pools and rivers, nature and landscape management form the heart of the farm. Landscape holdings are providing for social needs such as an attractive landscape.
In this picture agriculture and horticulture fulfil several functions by providing economic vitality of the countryside via high-quality agricultural products and raw materials for new products with a high added value. And agriculture and horticulture also have an important function in nature and landscape care, offers recreational possibilities, and fulfils a role in energy production and water storage.

production systems closer to citizens and townspeople that can fulfil several functions? An important underlying question was how agriculture and horticulture can meet the demands of market and society, all embedded and shaped in the relatively small-scale and largely urbanised Netherlands landscape.

The discussions during the workshops about future perspectives gradually yielded a picture of the future for agriculture and horticulture interwoven in the urban area and a picture for agriculture and horticulture in rural areas. The very question is whether agriculture and horticulture will ever correspond with those pictures of the future. Yet, the pictures represent basic development lines for which public support exists.

Transition points

Backcasting of the main transition points was the first step on the road from exploration of the future to current practice. Transition points are technical, socio-economic, cultural and institutional obstacles that are seriously impeding realisation of the perspective of the future. Solution of these transition points requires action in various fields. Technical points often require experimental work. Socio-economic aspects, e.g., require finding payment mechanisms for new services and functions of agriculture. Institutional points may concern new regulations and legislation, and changing roles of organisations in the innovation process. Technical transition points can often only be solved by finding new principles because existing knowledge and mechanisms are inadequate. This requires renewal of the specialist disciplines that can contribute to solving the problem. This first requires ‘proof’ that the new principles are working. Such research often is high-risk experimental work with a time horizon of 5 to 15 years. The technologies that need to be developed often are still so far away from application on commercial scale in practice that market parties are not yet investing, making government support indispensable. And when such new principles are working, much “optimisation work” is required for development into in economically profitable applications.

Innovation projects

Three innovation projects have been set up on basis of the most important future-impeding bottlenecks – the transition points – in open cultivations:

- *Nutrients waterproof.* The boundaries of field cropping with minimal nutrient emission were explored in this project. Nutrients Waterproof was conducted on the sandy soil of PPO’s Vredepeel site in the south-east of the Netherlands;
- *A Taste of Tomorrow.* This project focussed on field cropping and quality production without, or only restricted, pesticides use. Research was carried out on a number of sites: for the field crops on the Prof. Broekemahoeve of PPO in Lelystad and for fruit cultivation on PPO’s Randwijk site and in three commercial orchards;
- *Topsoil+.* This research focussed on optimisation of soil quality, in particular soil health, for the cultivation of ornamental crops on dune sand.

In these innovation projects scientists were – right from the beginning – intensively cooperating with various stakeholders, via brainstorming groups or via active participation. The solutions that were found are in the end contributing to overcoming obstacles for innovation and this gives them a pioneering and stimulating function in current practice. In the following chapters we are describing the setup and results of these innovation projects.

Path 2: from practice to future

Pioneers: inspiration for transition

Influenced by the expected developments and trends, farmers and growers are continually balancing chances and threats. This forms the basis of their development decisions. Innovations that can make agriculture more sustainable are accomplished in practice (inspiring examples, see Figure 1). Good lessons can be learned from the successful innovations. Scaling up of the innovations can be achieved by removing bottlenecks and by making promising innovations and development strategies available to others. Several of these inspiring examples have been systematically traced in the systems innovation programmes; these provided the basis for further project development.

Facilitating innovations

Many innovations require changes that can only be implemented at a farm-exceeding scale or through joint tackling by several holdings and/or stakeholders. The systems innovation programmes yielded experience with various work forms to bring parties together and to stimulate and facilitate innovations. Stakeholders around certain themes have been brought together in networks and new coalitions have been formed. Also here, the long-term perspective (the shared future perspective) is the connecting link that may in turn result in totally new initiatives. In the systems innovation programme for the field cropping sectors, e.g., the problems around scaling-up and cooperation, precision farming and chain development were tackled.

Supporting innovations for wide application in practice

On the road to sustainability and broadening of agriculture and horticulture it is important that commercial farming is making the best possible use of the latest knowledge and experience from research, advisory bodies, and colleague-farmers (pioneers). In so-called Praktijk-netwerken (Practical Networks, a collaboration of farmers/growers, Wageningen UR, advisory bodies, and other stakeholders) we are supporting such processes by making our knowledge available and linking this with the innovative strength of the participating growers and farmers. The targets of the Practical Networks are often based on the EL&I policy dossiers on specific themes. The Practical Network ‘Growing for the Future’, e.g., works on the dossier Crop Protection and Fertilisation while ‘Nature Wide’ works on nature development, and the various organic networks are working on the organic agriculture dossier. The networks are yielding much experience with the application of new knowledge and innovations. From the networks this knowledge and experience is disseminated to broad application in practice, where cooperation with advisory bodies and chain parties that are active “on the farm” is essential.

Prototype for recognition and non-chemical control of in-row weeds.

Linking path 1 and 2

Learning networks

The innovation projects as well as innovating farmers and growers are contributing to a "collective" pool of experience and knowledge with chances and threats for transition and innovation. We therefore consider it essential that all initiatives that are focussing on the medium-term (10-15 years) are linked in a network. This stimulates the exchange of technical and process knowledge and can accelerate the transition process, not only at pioneer level but also in broad commercial practice. As yet, there is relatively little experience with this "linking". The best work forms still need to be found.
Linking this collective knowledge and experience pool with knowledge and educational institutes can result in a learning network, providing an inspiring learning environment for farmers and growers and other stakeholders. The first innovative forms of such networks are already active (academies, innovation networks etc.).

Systems innovations

Systems innovations are changes that exceed the individual farm level. They are needed in the transition of agriculture and horticulture into socially desirable sustainable production systems. Systems innovations can only take shape and succeed in larger contexts and with cooperation of all stakeholders: farmers, growers, farmers' unions, national and regional governments, as well as chain parties and societal organisations. Together with these parties Wageningen UR is working on the realisation of new future-oriented farming concepts and integrated strategies for sustainable and broader forms of agriculture for the primary holding and its first links in the chain.

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Innovation project A Taste of Tomorrow [2]

Target, setup and execution

Target of 'A Taste of Tomorrow' was to realise an innovative agricultural system with minimum pesticides use while maintaining quality production. The project focussed on organic and integrated farming. Work on integrated farming focussed on methods to reduce pesticides use while work in organic farming focussed on improvement of product quality and quantity. Two agricultural systems have been developed for both cultivation systems: high-quality production agriculture and urban agriculture.

- *High-quality production agriculture* is aiming at the cultivation of constituents for the processing industry and the production of high-quality propagation material (seed potatoes, sugar beet, spring-sown onions) with high yields of good quality. These crops should be able to compete on the world market as regards quality as well as cost-price.

- *Urban agriculture* is locally oriented and produces leafy vegetables, special luxury products and soft fruit for the (local) fresh market. Interweaving production and perception (nature, shape & colour, education) are important in the urban context. This gives perception of farming sites a place in designing agricultural systems. The agricultural systems have been converted into a cropping plan (Table 1). Research has been conducted on the Prof. Broekemahoeve in Lelystad.

The programme counted five spearheads (Table 2). The most promising developments for each spearhead were identified for incorporation into the four agricultural systems. The choice has been tightened in the course of the project and has been restricted to two spearheads: robotisation & automation, and functional agrobiodiversity. The results described below are therefore in particular dealing with these two spearheads.

Table 1. Cropping plan of the four agricultural systems of A Taste of Tomorrow on the Broekemahoeve in Lelystad.

1. Integrated production agriculture	**2. Integrated urban agriculture**
1. Spring-sown onions / winter carrots	1. Tulip
2. Seed potatoes	2. Ware potatoes
3. Sugar beet / oilseed rape	3. Flax
4. Winter wheat / grain maize	4. Brussels sprouts
	5. Lettuce / strawberries
	6. Winter wheat
3. Organic production agriculture	**4. Organic urban agriculture**
1. Spring wheat	1. Tulip / spring-sown onions
2. Seed potatoes	2. Ware potatoes
3. Grass / clover	3. Grass / clover
4. Spring-sown onions / headed cabbage	4. Headed cabbage
5. Spring wheat	5. Leafy crops
6. Winter carrots	6. Spring wheat

[2] *Source: Stilma, E.S.C. and J.E. Jansma. Smaak van Morgen; Op zoek naar teeltsystemen met minder gewasbeschermingsmiddelen (A Taste of Tomorrow; searching for cropping systems with less plant protection products). Wageningen UR PPO, 2010.*

Table 2. The five spearheads of A Taste of Tomorrow.

Spearhead	Objective
Societal issue	Provide insight in consumer views on urban agriculture
Functional agrobiodiversity	Design and development of aboveground systems giving maximum suppression of pests and diseases
Soil management	Design optimum soil management giving maximum suppression of pests and diseases
Robotisation & automation	Investigating the possible contribution of robotisation and automation to the control of crop threats (with specific attention for weeds)
Post harvest	Investigate how post-harvest treatments can contribute to the preservation of post-harvest product quality

Societal issue
Urban agriculture tries to open the interface with the city. People perceiving agriculture in a different way will change their wishes regarding cultivations. In the touristic/recreative sector, e.g., flowers, colour and variation are important in choosing a crop. Marketing of perception products focuses on freshness, origin, and seasonality of products. But the future handling of pesticides in urban areas may also require amendment.
A Taste of Tomorrow has designed an integrated and organic farming system meeting the demands of urban agriculture. A crop rotation has been chosen with the least possible pesticides use in the integrated system and crops that are meeting people's expectations about agriculture in an urban area.

Functional agrobiodiversity
Functional agrobiodiversity provides for such diversity in the agricultural landscape that it helps to suppress or even prevent pests and diseases in crops. This is a step further than agrobiodiversity, where mainly borders of fields are sown with flower-rich mixtures to suppress the development of pests and diseases in the crops.
A Taste of Tomorrow made a step towards functional agrobiodiversity by applying mixed cropping or polycultivation in cabbage crops in addition to the flower-rich borders of fields. Mixed cropping involves alternating cultivation of two different varieties or crops in rows. Polycultivation is the cultivation of various crops in alternating strips. Biodiversity within a field is further strengthened by herb strips. Modern precision techniques with crop recognition contributed to setting up mixed cultivation in practice.

Soil management
Soil management in A Taste of Tomorrow focused on the control of weeds, soil pests and diseases. A good crop rotation gave maximum assurance that pests and diseases could not accumulate. Furthermore, varieties that were resistant as well as marketable were always chosen. The effect of compost on the structure of clay soil has been tested as well as the

added value of mycorrhiza's in a number of crops. During the project, physical aspects of the soil acquired increasing attention, in particular soil structure, in view of workability and crop growth and health. This resulted, amongst others, in the demoday Soil 2008 and the BASIS project (see follow-up projects).

Robotisation & automation

Robotisation and cropping automation help growers in the early detection and identification of weeds, pests and diseases, the automatic control of weeds, pests and diseases, and precision application of the correct dose of plant protection products. Several techniques have been developed and tested in cooperation with other institutes and market parties. Other techniques had already been developed but A Taste of Tomorrow was the programme where these were first applied and further developed.

Post harvest

Post harvest product quality preservation is an important aspect. Much is to be gained by post-harvest product selection and creation of the right storage conditions. A Taste of Tomorrow also included some limited work on carrot storage and the prevention of black spot disease.

Results of the integrated agricultural systems

Environmental effect water and soil

The environmental effect of the two integrated agricultural systems on surface water was compared with that of (average) conventional agriculture in the Netherlands (Figure 4). It has also been investigated how the integrated agricultural systems have attained their policy goals. Goal of the Netherlands policy paper Sustainable Crop Protection is a reduction of the environmental impact on surface water by 95 per cent in 2010 in comparison with 1998. A reduction of 86 per cent had been achieved in 2005. This means that in comparison with 2005 another 64 per cent reduction will have to be attained to meet the target for 2010.
Expressed in environmental indicator points (MIP's) both integrated agricultural systems attained over 70 per cent reduction in comparison with the environmental impact of surface water in conventional agricultural systems in the Netherlands. This means that both agricultural systems did in one go meet the surface water goals in 2010. The impact on soil and groundwater has been calculated on the basis of environmental impact points (MBP's). Integrated urban farming was found to almost double the environmental impact on the soil in comparison with conventional agriculture (Figure 4).

Production agriculture versus urban agriculture

Environmental targets were easier achieved in the integrated production farming system than in the integrated urban farming system. This had all to do with crop choice. In particular Brussels sprouts and ware potatoes contributed to the poorer environmental score in the urban farming system. This was in particular caused by the use of spinosad (Tracer) in Brussels sprouts and the high use of diquat dibromide (Reglone) in ware potatoes. This had a very heavy impact on soil life. Seed potatoes were grown in the production farming system. Unlike in ware potatoes, haulm desiccation in seed potatoes does not depend on the use of Reglone. The largest bottleneck in urban farming was the cultivation of small crops. These crops must meet high quality demands and sufficient integrated (alternative) crop protection measures to safeguard the quality for the consumer are not always available for these crops. This means that conventional methods and techniques must be applied.

Successful innovations

Innovative measures and methods for production agriculture and urban agriculture (functional agrobiodiversity) have been developed around the spearhead robotisation & automation. Measures and methods already used in practice have been applied, such as decision support systems (DSS) for integrated agriculture. All sprays in integrated cultivations were carried out on the basis of a DSS. The products were selected on basis of CLM's (Centre for Agriculture and Environment) environmental impact chart. Resistant varieties were sought as well. Small weeds were controlled in early spring with a low herbicide dose (LDS). Potato ridges were earthed up more frequently to suppress weed germination. Sticking agents were added to the sprayed products. Surface active agents ensured a better spreading of the products over the leaf. Where possible, low-drift nozzles were used in combination with air support; this restricted drift to a level lower than legally required.

Product saving with SensiSpray

A technique has been developed for integrated control in (ware) potatoes in which crop sensors are used to adjust the amount of product to the amount of vital foliage mass: the SensiSpray technique. Calculations show that SensiSpray is cost-effective in a cropping plan with ware potato, sugar beet, winter wheat, spring-sown onion, winter carrot and tulip at a farm size from 60 hectares.

Savings on fungicides in this farming system amount to 15 to 30 per cent and savings on haulm desiccants are 30 to 50 per cent. Savings on residual herbicides can also be achieved with SensiSpray. This requires soil maps with parameters such as soil texture, pH, phosphate and potassium. SensiSpray can enter these soil maps into the board computer. These soil maps enable location-specific dosing

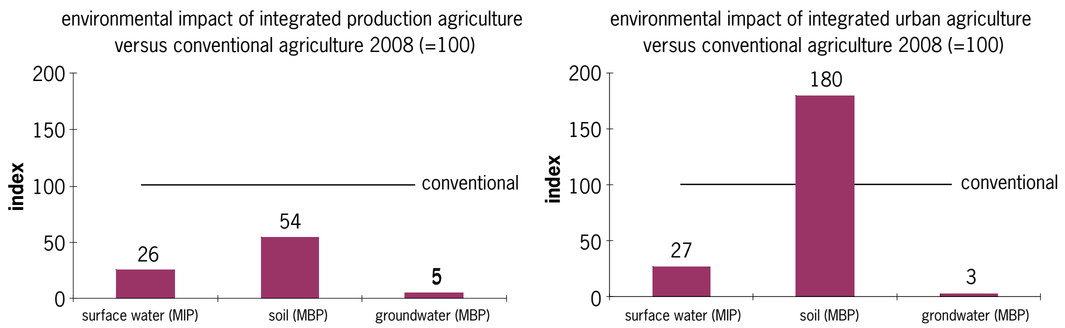

Figure 4. Index of the environmental impact of surface water (environmental indicator points, MIP), soil life (environmental impact points, MBP) and groundwater (environmental impact points, MBP) of integrated production agriculture and urban agriculture compared to conventional farm management systems in the Netherlands with standard spraying in 2008 (standard). Figure a represents the environmental impact under integrated production agriculture and Figure b shows the impact under integrated urban agriculture.

of residual herbicides; this may result in a product saving of 25 per cent.
The SensiSpray calculates the required amount of product on basis of crop development.
A calculation model must be tested, and if necessary adjusted, for each product. But more research into the application of fungicides and herbicides will further expand the possibilities for application of SensiSpray and this will make the technique economically more attractive.

Mechanical weed control in field crops
Mechanical weed control with finger weeders is quite well possible in sufficiently developed field crops such as onions, carrots, perennials and summer flowers. This technique has already for years been in use in organic agriculture whereas the possibilities in integrated agriculture have hardly been utilised. Most growers already have a weeder and would only need to buy finger weeders and mount these on the machine.
Finger weeding causes an average plant loss of 2.5 per cent but this caused no yield loss in the experiments. Average product savings by finger weeding in the field experiments amounted to 37.5 per cent. Finger weeding is economically interesting from a farm size of about 60 hectares with a crop rotation of ware potato, sugar beet, winter wheat, spring-sown onion, winter carrot and tulip, where finger weeding

The SensySpray enables savings on fungicides, even in tulips

was carried out in sugar beet, spring-sown onions and winter carrots.
Covering seed with compost suppresses the emergence of weeds early in the season. This makes mechanical weed control later in the season more effective. A machine for simultaneous onion sowing and compost application and spreading has successfully been developed. In 2008 a 2 cm compost layer resulted in a weed reduction of over 75 per cent, increasing to 80 percent under a 4 cm layer, without effects on onion plantlet emergence. Sowing underneath compost strips is not yet widely applied in practice. It is very laborious, a large amount of compost is required, and the capacity (ha sown per hour) is 5 times lower than in a conventional system.
Later in the season the rows were weeded with a finger weeder. Use of RTK-GPS showed that more accurate weeding would be possible. This also improved the results of the finger weeder. Adaptation of the cultivation method, such as sowing onions in clusters, simplifies mechanical weed control in the row. For sowing in clusters, five to seven seeds are combined in a pill and are sown simultaneously. Weed between the clusters can then be followed by using a camera system for plant location determination followed by control by means of an actuator. An actuator is a weeder or burner capable of weeding in the crop row between the plants.

The finger weeder controls weed in the crop row

Product saving with Weed IT

Weed IT is the trade mark of a sensor-controlled sprayer that detects plants by using a fluorescence technique. Each nozzle is controlled by a sensor observing a 10-cm wide area. A prototype with a working width of six crop rows (3 metres) has been built for the study.
The Weed IT has once been tested for haulm killing in ware potatoes. This resulted in a more than 50 per cent saving on the haulm desiccant Spotlight Plus. A clear saving on fungicides was also found to be possible in an early potato crop stage.
Weed IT has also been tested for the detection of volunteer potatoes in sugar beet cultivation. The idea is that this will result in a saving on the number of working hours for the manual removal of volunteer potatoes. The sensors properly detected the volunteer potatoes between the crop rows but the crop suffered too much damage caused by the spraying technique used.
In a further development the Weed IT will have to be given a larger working width and the purchasing price (€ 15.000) will have to come down, but even then it remains a considerably more expensive machine than, e.g., the SensiSpray. Meanwhile, a prototype with cameras and a new spraying system, capable of successfully removing volunteer potatoes in sugar beet crop rows, has been built elsewhere.

Precision operations with RTK-GPS
Very precise – down to 2 cm from the plant – field operations at a driving speed of appr. 6 km/hour can be carried out by using RTK-GPS. A system costs € 25 000.- but maximum utilisation of the benefits requires additional investments for adjustment of machinery for sowing and planting, fertilisation, and spraying. Such a complete system, however, makes it possible to attain larger financial benefits. Crop yields can be increased by a more efficient utilisation of fertilisers. Spots that would with a normal fertiliser dose get insufficient nutrients will be given an extra dose with RTK-GPS in combination with soil maps. In addition, costs can be saved on, e.g., propagation material, labour, fuel, fertiliser, and plant protection products. This is because the RTK-GPS is operating according to a fixed driving path system, which avoids overlapping treatments. RTK-GPS and adaptation of machinery is cost-effective at a farm size from 60 hectares.

More applications for RTK-GPS can be envisaged. A combination of RTK-GPS with inter-row weeding in onions, e.g., is under development. Precision crop protection also holds perspectives. The manufacturer of Hardi sprayers has bought the Greenseeker crop sensor that has been developed for the SensiSpray. The combination has been tested for precision crop protection in A Taste of Tomorrow. A lower

The Weed IT uses fluorescence sensors to control potato volunteers between the sugar beet rows

amount of crop protection product was sufficient when less leaf mass was present.
RTK-GPS is also quite suitable for small-scale urban agriculture. The technique has been used to set up so-called 'Mondriaan fields'; a combination of attractive crops in a variable patchwork pattern. RTK-GPS can in the future also be used for crop diversification. Crop recognition enables easy sowing and harvesting of different crop types or varieties (for functional agrobiodiversity). A Taste of Tomorrow was among the first to apply RTK-GPS. Meanwhile the system is used by over a thousand farmers and growers.

Healthy crops with functional agrobiodiversity

Functional agrobiodiversity fits well within the objectives of urban agriculture in view of the variation in crops in and around the field and the variation in (flying) insects. And future location-specific cultivation automation (GPS) can make functional agrobiodiversity applicable in practice. Experiments with functional agrobiodiversity have shown that success depends on the type of diversity. A mixed hedge in combination with a grass strip, e.g., did have the desired effect whereas intercropping with grass-clover did not. The experiments contributed to knowledge development but more knowledge is required for goal-oriented utilisation of functional agrobiodiversity.

Innovations – Areas for special attention

Scale and implementation of the measures

The success of a measure may be dependent

RTK-GPS was used to set up so-called Mondriaan fields in urban farming experiments on farm size. The use of decision support systems (DSS) is more difficult on large farms than on small farms. A spraying round on a large farm takes several days which makes day-to-day following of the spraying advice impossible. Mechanical weed control can be too labour-intensive for large holdings. On the other hand, larger holdings can sooner invest in RTK-GPS and the SensiSpray technique. The high purchasing price is partly compensated by a higher efficiency, cost savings on inputs, higher yields, and wider applications.

Product choice with the environmental impact chart

The environmental impact chart is a rather simple instrument. A disadvantage, however, is that the environmental impact points (MBP's) and exposure risk indexes (BRI's) are re-calculated annually. This may change the status of a product: from high environmental impact to a lower impact and vice versa. And then there is a new calculation method, the environmental indicator points (MIP's) used in the Dutch environmental policy. The results of both methods do not always correspond. Doubt about the environmental impact of a product makes it difficult for farmers to know which product they should select.
Use of the environmental impact chart may also be difficult for technical reasons: each product has its advantages and disadvantages; this sometimes complicates the choice of different products. In practice, the price of a product has a strong influence on the choice of the product.

Scetch of a possible appearance of an urban faming district in Almere East

Phythophtora control in potatoes
Resistant potato varieties in combination with decision support systems can reduce the number of sprays. In the future, SensiSpray can also reduce the amount of product per spray. Product choice based on the environmental impact chart can further reduce environmental impact. This total package of measures decreases the environmental impact but the problem has not yet disappeared. Complete phythophtora control methods without spraying do not exist.

Product use in onion
Successful onion cultivation is based on intensive weed and disease control. In A Taste of Tomorrow chemical weed control was found to be interchangeable with mechanical techniques used in organic farming.
Current fungicides against downy mildew in spring-sown onions are only effective if applied preventively. Warm water treatment (1 hour at 40 °C) is an alternative for second-year onion sets. This effectively reduces the spreading of downy mildew. Treatment on farm-sale is still difficult. There are only few resistant varieties. True breakthroughs against downy mildew have not yet been achieved.

Follow-up projects
A number of the sub-projects of A Taste of Tomorrow have grown into autonomous projects: Bioveldag (Bio field day), Agromere, and BASIS.

Tractor with adjusted wheel distance (3.15 m) for BASIS

Bioveldag

Biovelddag is an annual organic agriulture meeting event for scientists, growers, advisors, industries, and associations. Information about experiments is given, the latest technologies and equipment are presented, and lectures and workshops are organised. And there are business markets. Over the years, the number of visitors increased from 200 to 650. A Taste of Tomorrow as project has been ended but the Biovelddag, held annually on the Prof. Broekemahoeve in Lelystad, remains.

Agromere

For the case Urban Agriculture in Almere cooperation has been sought with societal organisations and a network has been established. Participating partners were thinking along and participated in new sustainable farming concepts in the urban periphery. The possibilities of urban agriculture were investigated in an exploratory study with stakeholders in which the wishes of city-dwellers, the role of the municipality, province Flevoland, the Ministry of Agriculture, Nature and Food Quality and project developers were identified, together with the view of farmers on broadened agriculture. This resulted in the virtual urban agriculture district Agromere where agriculture, rural living, recreation and working are combined. Urban Agriculture has been included in the Concept Structural Vision Almere and has been presented to the Netherlands government.

BASIS

Soil tillage receives a lot of attention in conventional as well as in organic agriculture. This is because ploughing is time and fuel consuming, contributes to the emission of greenhouse gases and has a negative effect on soil life and organic matter build-up in the soil. Abolishing ploughing can also contribute to decrease leaching and erosion and to improvement of the suppressiveness and water permeability of the soil. Some organic farmers made the step towards reduced, or even no, ploughing, whether or not in combination with a tram line system. On the Prof. Broekemahoeve, where A Taste of Tomorrow experiments were carried out, the effect of reduced tillage on weed pressure, cultivation of root crops and green manure crops, organic-matter build-up and soil life is investigated in the BASIS (Broekemahoeve Applied Soil Systems) project.

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Allergic patient eating Santana, a hypoallergenic apple

Innovation project A Taste of Tomorrow / section Fruit [3]

Target, objective and execution

Current fruit growing still is a long way from the desired sustainability. This is mainly caused by the use of pesticides, where despite all sorts of measures the emission of products has decreased insufficiently. Good fruit production with minimal pesticides emission is a live topic, not only for the future but also now. Under regulations such as the EU Water Framework Directive, government policy is focussing on improvement of the quality of groundwater and surface water. New solutions are required to achieve such improvements to arrive at the desired sustainable future. The activities in the innovation project A Taste of Tomorrow/section Fruit were aimed at developing such solutions. Innovations signifying a step forward in the reduction of pesticides use and emission as well as in marketing or cost price have been developed. These last aspects are important because innovations for environmental improvement do usually lead to a higher cost price but not to a higher selling price for the grower.

The project comprised three sub-projects:

- *Clean Ditch.* This innovation route focussed on the future perspective of large-scale production agriculture. A Waterboard Authority, parties from the supply chain, as well as the societal organisation Foundation Food Allergy were involved in this project.
- *Open Orchard.* An innovation route for the future perspective of large-scale production agriculture but then in a situation of small-scale areas with tourism. This project was conducted together with a local authority and the (fruit) sector.
- *Fruit cultivation and perception.* This innovation route focussed on the future perspective of small scale urban agriculture. Activities were aimed at developing a new relationship between producer and consumer.

Innovation route Clean Ditch

Clean Ditch was aimed at making a big step forward in the reduction of pesticides use, reduction of production costs, and the creation of new market perspectives. This resulted in:

a. development of the farm systems innovation concept Clean Ditch;
b. preparation of a marketing plan and setting up of a distribution channel for the hypoallergenic (less allergenic) and scab-resistant apple variety Santana from the Clean Ditch systems innovation;
c. selection of new disease and/or pest resistant apple and pear varieties with market potential.

a. Systems innovation Clean Ditch

Sustainable cultivation in fruit growing areas with many ditches and narrow orchards without windbreaks is difficult. This project focussed on realising profitable fruit cultivation adjacent to waterways without windbreaks, with spraying remaining below the toxicity criterion for surface water according to the CLM environmental yardstick. This systems innovation consisted of the combination of emission-restricting measures (3 metres crop-free zone between the last fruit tree row and the ditch; spraying the last row from one side; use of a venturi nozzle for the last four rows), omitting plant protection products (such as Pirimor, Thiram, Delan and Dimilin) and sustainable crop

[3] *Source: Maas, R.P. van der. Smaak van Morgen /onderdeel Fruit; Systeeminnovaties met winst voor environment en markt (A Taste of Tomorrow/section Fruit; Systems Innovations with profit for environment and market). Wageningen–UR PPO, 2010.*

protection (scab-resistant apple variety Santana, use of earwigs against woolly apple aphids, and sanitary measures against mildew and fruit tree cancer).

This systems innovation has been designed and further developed on three fruit farms in the province South-Holland. The results as regards environmental impact, the occurrence of pests and diseases, and financial performance were assessed annually. The most important annual amendment was the use of new plant protection products with a sufficiently low environmental impact.

The number of product applications was 66 per cent lower than in an average apple orchard bordering a ditch (Table 3). The annual environmental impact on surface water and the environmental impact per product application were reduced by 98 and 93 per cent, respectively. In addition, the holdings did not, or no more than one time per year, exceed the CLM environmental surface water criterion. These exceedances were relatively small and were caused by Captan sprays.

There were no insurmountable pest and disease problems. Cultivation of Santana with a gross margin of 3402 euro/ha/year is much more profitable than cultivation of Elstar with 893 euro/ha/year (Table 4). The calculations for Santana are based on the results of the last two experimental years, which is somewhat restricted. The costs of crop protection, pruning and picking of Santana are distinctly lower.

Selling of the apples produced in the study progressed reasonably successfully as result of the publicity for Santana as hypoallergenic apple and the low annual volume of 30 to 40 tonnes. Sales of larger volumes were clearly less successful.

The perspectives of a wide application of this systems innovation depend on price and sales development of Santana. Currently, small-scale cultivation for, e.g., on-farm sales shows most growth. The sales perspectives of large-scale cultivation of Santana are not favourable. This is mainly caused by the lack of promotion by stakeholders towards consumers, e.g., as hypoallergenic product.

Table 3. Environmental impact on surface water according to the CLM environmental yardstick.

	Systems innovation Clean Ditch 2006 - 2008	**Average apple orchard in 2006 with the same emission restriction as in Clean Ditch**
Number of product applications/year	16	47
Environmental impact on surface water (number of environmental impact points/year)	57	2616
Average environmental impact surface water/ product application; (number of environmental impact points/year)	4	56

But a substantial reduction of the environmental impact on surface water does not really require a large sales volume. Very substantial environmental gains are already made when Santana is grown in areas with many ditches and few windbreaks. Four to six rows of Santana along ditches is sufficient. The usual variety can then be grown in the remaining part of the orchard.

b. Santana for people with apple allergy
The finding that Santana is hypoallergenic, i.e., less allergenic, gave Santana a new selling point. Three quarters of some 350 000 people in the Netherlands with apple allergy can eat this apple. But how can Santana be marketed in a sound way, medically, legally, qualitatively, organisationally and commercially? A protocol has been developed and tested and (a) distribution channel(s) have been set up in a project.

The protocol consists of instructions for pollution, picking time, storage, grading, and packing. Most prominent is the sticker on the apple packs with the text "Suitable for persons with a mild apple allergy; read leaflet first" and a leaflet with the necessary information, including a user test. A consumer survey showed that the protocol works: some 78 per cent of the consumers with a mild apple allergy – the target group – were content. Most consumers with a stronger apple allergy were content as well (Table 5).

Table 4. Gross margin, including own labour, of the systems innovation Clean Ditch with a Santana and an Elstar orchard based on KWIN values.*

	Systems Innovation Clean Ditch with Santana	**Elstar orchard calculated with KWIN values**
Yield		
Harvested product (kg/ha)	38,422	40,740
Sold product (kg/ha)	37,312	39,110
Yield price (€/ha)	0.40 (realised)	0.40 (from KWIN)
Total returns (€/ha)	14,925	15,644
Variable costs (€/ha)		
Crop protection	475	1,053
Materials, fertiliser, hail insurance, delivery costs	3,139	3,329
Permanent (€25/h) and temporary labour (€10/h):	7,652	10,080
Interest running capital	257	289
Gross margin (€/ha)	**3,402**	**893**

* KWIN – Quantitative Information System (for agriculture and horticulture)

Table 5. Appreciation of Santana by 295 consumers with apple allergy.

Allergic reaction to Santana	Consumer appreciation Santana[1]	Level of apple allergy Mild (%)	Moderate (%)	Strong (%)
No	1–4	0	0	0
No	5–7	52	35	32
Yes	1–4	22	17	16
Yes	5–7	26	48	52
Total	1–4	22	17	16
Total	5–7	78	83	84

1 Scale 1 to 7: 1 = not content at all, 7 = very content

Large and structural distribution channels for Santana have not developed; permanent, smaller markets did. Sales of conventionally grown Santana via the C1000 supermarket chain and via on-farm sales by Santana growers are most structural. Santanas produced in the Netherlands are meanwhile also exported to Germany. And there are several channels for organic hypoallergenic Santana sales, of which Albert Heijn is best known.
Promotion is an important key in increasing sales. Financial reasons only allowed consumer approach via the media in this project.

c. New disease-resistant varieties with market potential

The environmental impact is substantially reduced by the cultivation of pest and disease resistant fruit varieties. Scab resistance in particular is important because this disease requires the largest number of sprays. Resistances or decreased susceptibility to mildew and fruit tree cancer are relevant as well. Such varieties with an added market value result in a win-win situation for environment and market.
This project included testing of the most interesting apple and pear varieties from breeding programmes throughout the world for:

- suitability for cultivation in the Netherlands;
- market potential;
- pest and disease susceptibility.

In 2009 121 apple varieties were under investigation. About 20 to 30 per cent is probably scab-resistant while another 10 per cent is probably less scab susceptible. And 43 pear varieties were being investigated. Some of these are probably resistant to fire blight.
In 2009 five new promising apple varieties were qualified as promising, four of which are most probably resistant against scab and one pear variety is characterised as promising. Generally, the chance of finding suitable varieties with good market potential as well as resistance against scab is increasing. In addition, more varieties with combinations of disease resistance or lower susceptibilities are being tested.

Innovation route Open Orchard

Objective of the Open Orchard project was strengthening of fruit growing in touristic areas and increasing the contribution of orchards to landscape perception and tourism. This would result in a win-win situation for tourism and for fruit growers.

The project was situated in Buren, a municipality in the Betuwe, a fruit producing area in the Netherlands. The municipality wishes to expand the number of walking and cycling routes.
But some orchard hedgerows are disturbing landscape perception, e.g., high conifer hedges and hedges alongside cycling and walking paths. These are restricting the view on the orchards. The main reason for fruit growers to have such hedges is emission restriction which allows the application of certain products. The development of an innovative sprayer that achieves such an emission reduction that many hedges can be removed is interesting for growers as well as local authorities.

The Fruit Cultivation Study Group Maurik selected a new three-row low-emission sprayer to be developed by KWH. The single-row sprayer of this manufacturer has already shown a very high emission reduction through a combination of venturi nozzles – designed to keep the spray mist close to the spray booms – with variable air support.
The emission reduction would still be higher for a three-row sprayer because fruit trees are simultaneously sprayed from both sides. In addition, pest and disease control are more efficient, which results in environmental gains and cost savings. This is the result of the fact that less time is required for one spraying round on the holding; this enables the grower earlier anticipation to the development of a pest or disease and to better utilisation of good weather conditions for spraying. In addition, a three-row sprayer would result in some 60 per cent labour saving in comparison with a single-row sprayer while fuel consumption would be lower as well.

The first orchard-ready version of the three-row sprayer has been taken into use on two pilot holdings. The sprayer is designed in such a way that apple as well as pear orchards can be sprayed. If necessary, the sprayers will be used, tested and adjusted for about two years. PPO Randwijk is at the same time studying emissions. The three-row sprayer is expected to achieve about 95 per cent emission reduction in comparison with the standard spraying technique without windbreak. This leads to 0.35 per cent emission in 'full-leaf' situations and 0.85 per cent in 'no leaf' situations.

Local authorities are very interested in this innovation in view of the narrowing of the expensive 50 m wide spray-free zone between orchards and, e.g., residential areas. The development of the three-row low-emission sprayer also has a high potential value for other areas with many ditches. Emission in orchards along surface water should be reduced by at least 90 per cent in comparison with a standard orchard without windbreak to meet the Discharge Order. The highest possible emission reduction is a major factor in keeping authorisations of products.

Innovation route Fruit Cultivation and Perception

There is an increasing demand for perception among consumers. This is a particular chance for fruit growers around cities for adding a new function to their holding for generating income. But what is the outlook of a fruit holding focussing on 'perception marketing'? Together with a number of fruit-producing pioneers it has been established that permanent access and an all-season perception are the most important aspects. Permanent accessibility means a weather-independent accessibility, which automatically leads to a partial covering of the crop. Permanent accessibility also means unsprayed crops, if only to avoid restrictions by the re-entry time for people after spraying. Finally, a vital and productive crop is an important factor in perception.

An innovative cultivation protocol has been developed and implemented at the PPO research location Randwijk. This served as a *proof of principles* for urban horticulture and not as an economic optimisation. The protocol focussed on unsprayed cultivation of vital and productive crops.

Demonstration of the three-row low-emission KWH sprayer

The main strategic lines were the following:

- cultivation of varieties with the lowest susceptibility to pests and/or diseases (the pear varieties Concorde and Gieser Wildeman have a low scab susceptibility, the red currant variety Roodneus is less susceptible to pests such as blackcurrant aphids, currant root aphids and leafrollers);
- a cover to keep crops dry. This prevents most fungus diseases (but does not prevent pathogens such as mildew and pear rust);
- windbreak netting and anti-aphid netting alongside the field to inhibit insects to enter the field;
- stimulation of the presence and survival of natural enemies, e.g., by specifically planting annual or perennial herbs;
- goal-oriented utilisation of natural enemies (predatory bugs, ladybirds, predatory mites and ichneumon wasps) to control insect and mite infestations;
- cleaning crops through manual irrigation when necessary (e.g., against honeydew that may lead to sooty mould);
- manual removal of infested plant parts or insects when necessary (always as last option).

Some characteristics of the orchard:

- a combination of the red currant variety Roodneus, the pear variety Concorde and the pollinator Gieser Wildeman;
- pear and red currant rows alternated with low herb strips, creating room in the field;
- a meeting area in the centre of the field;
- fields totally covered, with rainwater collection for reuse in the orchard.

All crops were planted in spring 2004 and were grown for five years without any spraying.

Unsprayed cultivation of red currant was successful: pest and diseases were absent, or manageable, during the last years and the crop was vital, productive and attractive. Aphid and whitefly control, and thus sooty mould, could not be controlled fully effectively in one of the first years but adjustment of the protocol enabled prevention of sooty mould.
The unsprayed cultivation of pears was reasonably successful: pests and diseases were absent or manageable, the crop was vital but production was rather low. This was probably caused by the low amount of light resulting from the presence of the plastic cover.

The Olmenhorst estate is a fruit holding that has developed into an urban holding (see www.olmenhorst.nl). Following the model developed for urban agriculture, Olmenhorst wished to start cultivation of cherries on a field of 0.25 hectare. The main lines of a concept for field layout and cultivation protocol have been drawn up. The cherry trees were planted in September 2009. The cover will be placed as soon as permission has been granted.

Farmers and growers in urban horticulture know that the presentation of new or rare crops is particularly attractive. Offering a wide product range throughout the year is important as well. This was the background of a study into potentially new fruit varieties for cultivation in the Netherlands. This resulted in a list of crops/varieties that can probably be cultivated in the Netherlands. These species also meet the following criteria:

- acceptable storage/display;
- new to current Dutch cultivation (currently grown on <1 hectare);
- positively outstanding appearance and, if possible, positively outstanding internal fruit characteristics;
- good taste;
- edible without processing.

Forty five 'perception' crops and varieties are recommended: pip fruit, stone fruit, currants, raspberries and blackberries, strawberries, other fruits and nuts. The largest possible amount of information on each crop or variety has been included and recommendations are made for an ideal location, and the most suitable cultivation region. In most cases experience in practice or research will have to show the best possibilities for cultivation in the Netherlands.

Conclusions

Innovation route Clean Ditch for large-scale fruit cultivation in areas with ditches:

- 66 per cent reduction of the number of product applications;

Experiment with covered urban fruit cultivation on PPO Randwijk

- 98 per cent reduction of the environmental impact on surface water;
- no, or no more than one, exceedance of the CLM environmental criterion for surface water; and such an exceedance may only be relatively small.

The gain at farm level is a lower cost price of cultivation of the apple variety Santana and a market position on account of its hypoallergenic property. Sales volume, however, is low; this means that the impact of the systems innovation Clean Ditch is limited as well. On the other hand, this innovation illustrates that pest or disease resistant varieties, applied in systems innovations such as Clean Ditch, have a large potential for reducing environmental impact.

Innovation route Open Orchard for large-scale fruit cultivation in touristic areas:
- 95 per cent emission reduction in comparison with the standard spraying technique without windbreak (based on exploratory measurements), which leads to 0.35 per cent emission in the full-leaf situation and 0.85 per cent in the no-leaf situation;
- fewer sprays resulting from the increased effectiveness of the individual sprays as result of a shorter reaction time of the grower and a better accessibility of the orchard (not quantified).

The gain at farm level mainly consists of lower costs for the execution of the spraying operations and a more effective pest and disease control. In addition, some plant protection products can now be kept in the available product range, which improves pest and disease control. Tourism benefits from a better visibility of the fruit trees. The number of holdings with many ditches, for which this innovation is extremely suitable, is large.

Innovation route Fruit cultivation and small-scale urban agriculture:
- no more spraying, i.e., no more environmental impact caused by spraying.

The gain at farm level is: improved accessibility of the orchards for consumers who wish to experience urban agriculture. The number of holdings that will be applying this innovation will be low in view of the small number of fruit holdings focussing on perception.

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Innovation project Nutrients Waterproof [4]

Objective, setup and execution
Nutrient Waterproof had been set up for the development of farming systems with minimum emission of nutrients to groundwater and surface water so that the objectives of European and national policies can be met (Nitrate Directive, Water Framework Directive and manure legislation).

The project was carried out in the south-eastern sand area of the Netherlands, an area with high nitrogen leaching, with many leaching-sensitive crops, and with a large manure surplus. Research was conducted at farm level to reveal the interaction between separate measures and crops, such as the fact that some measures do indeed reduce nutrient emission but are increasing the use of plant protection products. The objective was to find the right set of measures and crops. Studying the full farming system also provides insight in the economic perspectives of sustainable farm management.

From 2005 - 2008 two farming systems were tested on the Vredepeel experimental farm of Wageningen UR: an integrated (conventional) farming system and an organic system (Table 1). The crops are representing the major crops on the south-eastern sandy soils. A large proportion of leaching-sensitive crops have deliberately been chosen in the integrated system (see Table 6).

The integrated system was split into two subsystems: *GI-High* with supply of organic manure to preserve mineralisation and soil fertility, and *GI-Low* without supply of organic manure to decrease the mineralisation level of the soil. Three solution pathways were formulated to tackle nutrient leaching. Each option consisted of a combination of new innovative as well as existing measures. Some measures such as the removal of sugar beet crop residues and drain water treatment were tested separately because they could not be tested at farm level. The solution pathways and the most important measures were:

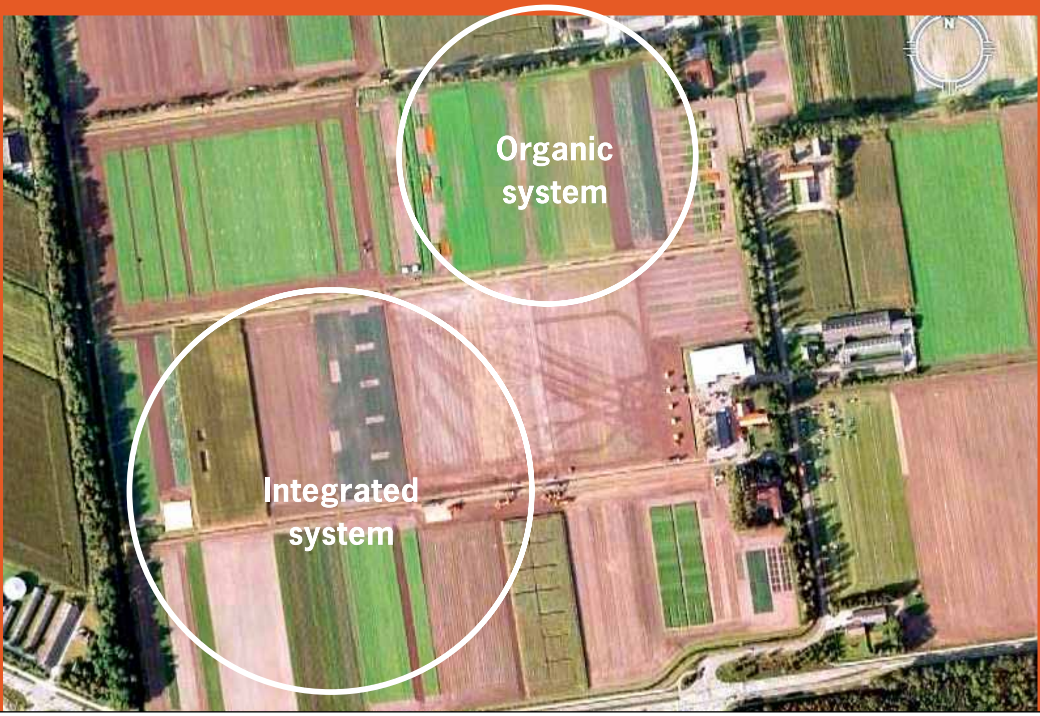
Increasing fertilisation efficiency by:
- minimising nitrogen mineralisation;
- new varieties and new crops (e.g. nitrogen fixation by leguminous crops in the organic system);
- matching spatial and temporal variation in nitrogen demand and supply.

Table 6: Cropping plan of the integrated and organic farming system.

Integrated farming system	Organic farming system
1. potato	1. potato followed by lucerne or grass/clover
1. triticale	2. lucerne or grass/clover (2nd year)
3. lily	3. lucerne/grass/clover until June, followed by autumn or winter leek
4. green pea followed by winter leek	4. broccoli and spring barley + green manure crop
5. forage maize – green manure	5. grain maize and 1st year tree and hedge planting stock
6. sugar beet	6. spring barley + green manure crop and 2nd year tree and hedge planting stock

[4] *Source: Haan, J.J. de and W.C.A. van Geel. Nutriënten Waterproof; Nitraatnorm op zand verdraagt geen intensieve landbouw (Nutrients Waterproof; Nitrate criterion on sand does not tolerate intensive farming). Wageningen-UR PPO, 2010.*

A fertiliser and cropping plan were annually made and followed for each system. A nitrogen balance method was used to determine nitrogen application rates, where nitrogen rates are calculated as crop nitrogen demand minus nitrogen supply from sources other than fertilisers (available mineral nitrogen in the soil before crop planting, nitrogen mineralisation and deposition, atmospheric nitrogen fixation). Nitrogen demand was determined on basis of target yield and nitrogen content of the crop and utilisation of available nitrogen by the crop. At the end of each season, the systems were evaluated and adjusted for the following season. Nitrate concentrations in groundwater and surface water for each system and crop were measured in winter. Sub-studies were conducted to gain more insight into the potential of measures. These included the effect of crop residues removal, nutrient value of digestates, testing of fertilisers and fertilisation systems, and effects of green manure crops. Communication focussed on acquiring grower support for the solutions, on finding cooperation to strengthen innovation, and on disseminating the research results.
An advisory board consisting of conventional and organic farmers and growers in the south-eastern part of the Netherlands (arable farming, vegetables, tree nursing, bulb cultivation) was formed. This board participated actively and critically in the development and execution of the studies and in assessing the significance of the results for application in farming practice.



Optimisation of the organic matter cycle by:

- removal and composting or fermentation of crop residues (sugar beet, broccoli, leek, green peas);
- matching organic manure type and composition with crop demand.

Re-use and/or treatment of leached nutrients:

- drain water treatment in constructed wetlands or wet buffer strip. The effectiveness of four different types of constructed wetlands was compared.

The solution pathways are schematically presented in Figure 5.

Results of the two farming systems

Nitrate directive

Both integrated farming systems did not meet the nitrate directive in any year. The nitrate concentration in the groundwater of *GI-High* was more than two times higher than the nitrate directiv (Figure 6). And although the nitrate concentration of *GI-Low* was ca. 20 mg/l lower than in *GI-High*, it was still well above the nitrate directive while nitrogen supply in both systems practically equalled the level of the 2009 application criteria of the Dutch manure legislation (Figure 8).

The accumulated fertilisation measures had insufficient effect on nitrate leaching. Nitrate

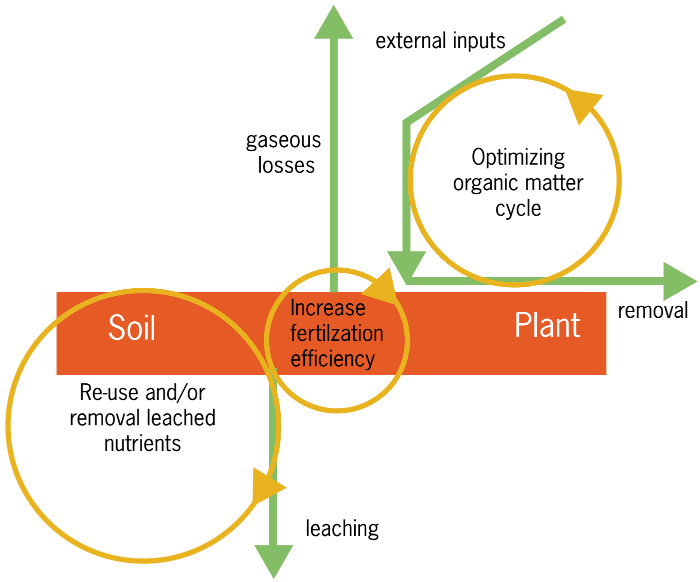


Figure 5. Nutrient management in crop production.

concentrations were highest after potatoes and lilies and lowest after sugar beet. A further reduction of the nitrate concentration is probably possible (Table 7) but this will still not result in the nitrate directive being met.

The organic system, however, did in all years meet the nitrate directive. Nitrate concentration was very low after second-year lucerne or second-year grass/clover and after second-year tree and hedge stock. The lower nitrate leaching in the organic system in comparison to the integrated system resulted from:

- *the more extensive cropping plan* with a lower proportion of leaching-sensitive crops and more (perennial) crops with a long nitrogen uptake period;
- *more room for early sown nitrogen catch crops* in the rotation (sown before 1 September). The integrated system left no room for early sowing of a green manure crop due to the late harvest of the main crops. A green manure crop could not even be sown after triticale due to the necessary soil disinfestation before lily as succeeding crop. The compulsory green manure crop after maize was sown late, remained small and absorbed little nitrogen (≤20 kg N/ha);
- *a lower supply of available nitrogen input from fertilizers and manure* (including nitrogen from mineralisation and deposition).

In all three systems only 62 per cent of the totally available nitrogen was taken up by the crops during the nitrogen uptake period (Figure 8). The amount of nitrogen not taken up by the crop amounted to more than 100 kg N/ha. This nitrogen is available for leaching if it is not taken up by a succeeding crop or green manure crop.

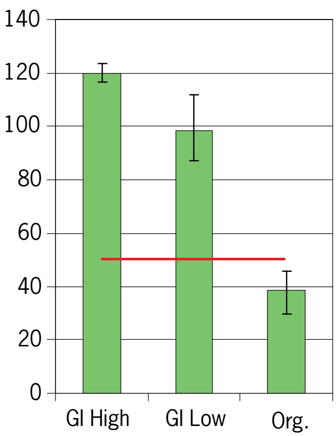


Figure 6. Average nitrate concentration in groundwater from 2005 -2008 in each system (mg/l NO3)

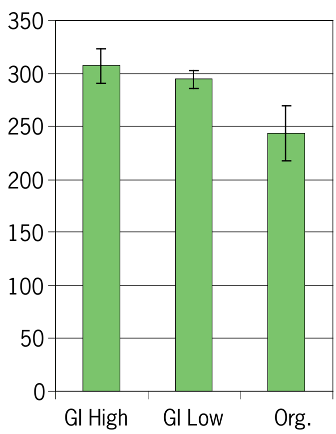


Figure 7. Calculated average total supply of available nitrogen for crop growth from 2005 -2008 in each system from fertilisers and other sources (kg N/ha)

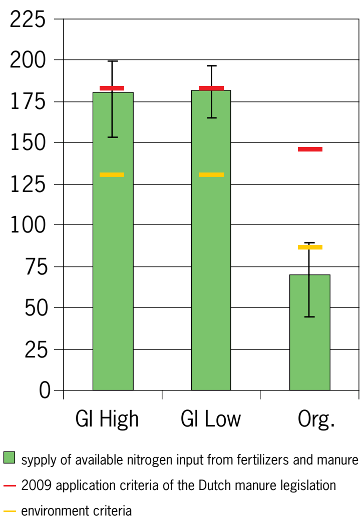


Figure 8. Average nitrogen supply from fertilisers from 2005 – 2008 from each system in comparison with the 2009 application criteria of the Dutch manure legislation (kg N/ha)

Table 7: *Additional measures in the integrated farming systems and their effect on reducing nitrate concentrations in groundwater.*

Measure	Effect on nitrate concentration (mg/l NO_3)	
	Crop level	Cropping plan level
Removal sugar beet tops after harvest:	-20	-3
Cultivation of a green manure crop after triticale:	-30 to -60	-5 to -10
Early maize harvest and earlier sowing of a green manure crop after maize:	-30	-5
Cultivation of early potato (early harvest) and sowing of a green manure crop:	-30	-5
Further optimisation of nitrogen fertilisation:	crop-dependent	0 tot -5

Gross margins

Average gross margins were over 25 per cent lower for *GI-Low* than for *GI-High*. Gross margins of *GI-High* and *GI-Low* were 20 per cent and over 40 per cent lower, respectively, than those of conventional agriculture. The substantially lower gross margins were caused by lower yields and higher fertilisation costs.
The fertilisation strategy in *GI-Low* led to poorer crop development and an average yield depression of 8 per cent in comparison with *GI-High*. Forage maize was the only crop without yield depression.
Average fertilisation costs in *GI-Low* were over 100 euro per hectare higher than in *GI-High*. This was because mineral fertiliser is more expensive than animal manure, in particular because farmers are even receiving money for accepting slurry. Less liquid manure was applied in *GI-High* than in current conventional agriculture. And the fertilisation strategy in Nutrients Waterproof entailed higher costs for Nmin measurements. This resulted in the fertilisation costs in *GI-High* being almost 200 euro per hectare higher than in conventional agriculture.

Results of the three solution pathways

Fertilisation strategies

Nitrogen or slurry application rates for maize can be reduced by 20 to 30 per cent by row fertilisation. The large acreages of maize grown on south-eastern sandy soils mean that this measure can make a substantial contribution to a reduction of the nitrate concentrations in groundwater. Row fertilisation with slurry has not yet taken root because simultaneous fertilisation and sowing is reducing sowing capacity and is causing logistic problems. It seems that this bottleneck can be solved by carrying out row fertilisation and sowing in two separate passes, making use of GPS for positioning manure and

Crop development sugar beet in June on Integrated (GI) High (left) and Low (right) seed at the correct mutual distance. This, however, requires further research and development. Application of digestate ((co)fermented slurry) could result in a nitrogen saving of 10-15 kg per hectare (in case of arable land injection).

Nitrogen efficiency of digestate in the succeeding crop is somewhat higher than that of unfermented slurry, and the residual effect of the organic fraction is lower. In Nutrient Waterproof nitrogen removal via harvested products was somewhat higher with digestate while the average nitrogen surplus was about 20 kg N/ha lower. Digestate is not (yet) available on a large scale.

Application of the (concentrated) liquid fraction of slurry after manure separation can also contribute to nitrogen saving and to a reduction of the nitrogen surplus. Use of this liquid fraction also means that hardly any phosphate is supplied; this makes this manure suitable for crops with a low phosphate demand and for supplementary nitrogen fertilisation.

It is important to keep the non-fertiliser nitrogen supply into account as much as possible, in particular nitrogen mineralisation from fresh organic material and soil-organic matter. Mineralisation, however, is difficult to predict. Extra research is required for finding suitable indicators for the prediction of mineralisation and for the further development and refinement of supplementary fertilisation systems.

Pulstec is a new fertilisation technique being investigated for injecting fertilisers into the soil under high pressure (50 – 150 bar)

Post-harvest measures

Green manure crops sown until mid September are taking up so much nitrogen that they can substantially reduce nitrate leaching. These green manure crops are incorporated into the soil in spring. The release of nitrogen means that less nitrogen is required in the succeeding crop. Green manure crops are also contributing to the organic matter build-up in the soil. The current, intensive cropping plan on south-eastern sand, however, leaves little room for timely sown green manure crops.
A disadvantage of the current green manure crops is that they can contribute to an increase in various harmful nematodes. Alternative green manure crops are required, such as Japanese oats.

Removal of nitrogen-rich crop residues in autumn can considerably reduce nitrate leaching. Waste of brassica and lettuce is easy to remove; where appropriate these can be composted and returned to the land. Collection and removal of sugar beet tops is impossible with the currently available sugar beet harvesters.
Crop residues removal has a number of major drawbacks: high costs, extra risk of soil structure damage in autumn caused by heavy tractors and machines, extra fuel consumption, and higher CO_2 emission. Addition of high-structure material is required for composting vegetable waste. This material must come from a source outside the holding. This is expensive or is restricted by regulations. Fermentation neither is a true option in view of the low total fermentation capacity in the Netherlands; alternative products with a much higher energy value are preferred.

Leached nutrients can be trapped and treated in constructed wetlands with water storage or wet buffer strip along the side of the field. Constructed wetlands and wet buffer strip have no effect on leaching to groundwater but they do have an effect on leaching to surface water. On PPO's Vredepeel site constructed wetlands with water storage removed 15 to 25 per cent of the leached nitrogen from the water. About 5 per cent could be removed with a wet buffer strip.

Amendment cultivation system or farm management

Meeting the nitrogen use criterion requires such a decrease in nitrogen fertilisation that yield depression becomes too high. This means that cost-effective crop cultivation is no longer possible.
A less intensive cropping plan with a higher proportion of crops with a lower leaching sensitivity, such as cereals, and more room for early sown green manure crops does also lead to a lower farm income and therefore is no alternative.

Soilless cropping systems may be an option for intensive field vegetable growers who are unable to meet the future use criteria. Crops are grown in closed recirculation systems in gullies, in pots or in trays. Production is easier to control and yields have a more consistent quality. Labour productivity and labour conditions are better. This increases the chance of a better market position, which is required to recover the higher costs.

Production increase by better soil management is an option for large-scale and lower-profit arable and vegetable crops. An integrated approach enables establishment of an optimal match between soil structure preservation and improvement, nutrient and water availability, and utilisation of biological processes. Profitable production systems that are meeting societal demands may probably be developed by combining a good and wide crop rotation with an integrated crop protection and fertilisation strategy. Integrated soil management still requires the development of much knowledge, which in turn requires close cooperation between various soil disciplines.

Discussion

Meeting the nitrate directive without yield depression is impossible in an intensive cropping plan with many leaching-sensitive crops. Various fertilisation measures to increase nitrogen efficiency had insufficient effect on nitrate leaching. Moreover, such measures had a cost-increasing effect, which decreased profitability.

Nitrate leaching was indeed reduced by no longer applying organic manure but this was insufficient to meet the nitrate directive. And this also led to lower crop yields and a considerable decease in farm income. This means that omission of organic manure holds little perspective for an environment-friendly and economically profitable agriculture and horticulture on sandy soil.

The organic farming system showed that increasing nitrogen mineralisation in the soil by increased organic manure does not by definition lead to higher nitrate leaching, for which fixation of the mineralised nitrogen by succeeding crops or green manure crops is a condition. A long continuous nitrogen uptake period through to the autumn plus a deep rooting seem at least equally – if not more – successful to reduce nitrate leaching than fertilisation measures.

The nitrate directive can be met by a less intensive cropping plan – more cereals, grass and timely sown green manure crops. This also leads to a reduction of farm income, a decreasing employment in agribusiness and loss of (international) market share of intensively grown agricultural and horticultural products. It is desirable to investigate the possibilities of extensivation and to (financially) support growers who wish to extensify.

The more extensive cropping plans and the

Returning composted crop residues to the field

Experiments with leek cultivation on water lower nitrogen input make it easier for organic farms to meet the nitrate directive. The market for organic products must also grow to make transition attractive. This requires active stimulation.

Row fertilisation in maize with slurry is a promising measure to reduce nitrate leaching on sandy soil. Application in practice still requires solution of technical bottlenecks. Digestate and the (concentrated) liquid fraction of slurry can slightly reduce nitrogen losses.

The perspectives of crop residues removal are doubtful. Removal of sugar beet tops does to some extent restrict nitrate leaching. Removal of the waste of a number of vegetable crops, in particular brassica, does substantially reduce nitrate leaching but the relatively small acreage means that the effect at regional level is restricted. Removal of crop residues must also be judged against the negative side effects such as a higher risk of soil structure damage, extra fuel consumption, higher CO_2 emission and higher costs.
Late harvesting is a good option for reducing nitrate leaching in sugar beet cultivation on sandy soil. This should be taken into account in the sugar beet processing campaign.
At regional level constructed wetlands can contribute to cleaner surface water (not groundwater). They can be laid out in the lower parts of a catchment area, including facilities for water buffering for a number of months. This can possibly be combined with other functions such as nature.
Soilless cropping systems present a solution pathway for intensive field vegetable cultivation. For the other field crops it is important to maintain the production capacity of the soil with integrated soil management and to improve nutrient utilisation. This still requires the development of much knowledge in close cooperation with various soil disciplines.

The south-eastern sand area of the Netherlands requires far-reaching measures to meet the nitrate directive. These measures will change the structure of agriculture and horticulture. Farmers and growers, authorities, and other stakeholders are facing an enormous challenge to shape this in such a way that a profitable agricultural and horticultural sector remains while preserving the agricultural landscape.

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Innovation project Topsoil+ [5]

Objective, setup and execution

Topsoil+ has been set up to develop socially acceptable and economically and environmentally sustainable farm management systems (people, planet, profit) with an optimum soil quality for intensive ornamental cultivation on dune sands in an urban environment.

Applied Plant Research (PPO) in Lisse, in the centre of the Dune and Bulb Area (see Figure 9), has been chosen as location. Its location in a densely populated area, the specific soil conditions, and the high groundwater level made the experimental site very suitable for the project. As well as elsewhere in the Bulb and Dune Area, the PPO site is facing soil quality problems. Organic matter is decomposing rapidly on dune sand and there are high nitrogen losses, phosphate saturation, soil structure deterioration, and soil-related diseases. The possibilities for chemical control of soil diseases are restricted and will in the future probably be non-existent due to a further tightening of the regulations around emission and environmental impact.

An integrated farming system was laid out in 2004. Integrated means that pests and diseases are prevented or controlled with the least possible damage to the environment. Chemical control is only applied in the absence of an alternative and when economic crop yield is threatened. An organic farming system was added in 2005.

Both systems included two solution pathways for optimal soil health:

a. increasing organic matter content;

b. widening crop rotation.

a. Organic matter contents in the Dune and Bulb Area are low (< 1 per cent). Higher organic matter contents are stimulating soil life, in amount as well as in activity. A diverse and active soil life is assumed to increase soil suppressiveness against diseases. This may lead to a reduction of the amount of pesticides used. The field of the integrated farming system had an organic matter content of 0.7 per cent; the content on the organic field was 1.4 per cent. This last percentage was obtained by application of a peat mixture with 5 per cent farmyard manure. On a small acreage the organic matter content was doubled to about 4 per cent.

b. A wider crop rotation diminishes disease pressure. Intercropping with crops such as fodder radish and Tagetes are contributing to a better soil health. In the Dune and Bulb Area, however, bulbs are usually grown in a narrow crop rotation of 1 : 3 or 1 : 4.

Crop rotation was widened in Topsoil+ (Figure 10):

- in the integrated system to 1:7 tulip, daffodil, hyacinth, perennials, ornamental shrubs, summer flowers and intercropping
- in the organic system to 1:8 tulip, daffodil, hyacinth, summer flowers, perennials (biannuals), ornamental shrubs and intercropping.

A wider crop rotation also widens the export product package. A large part of the flower bulbs is exported to the United States. This could be supplemented by small-sized ornamental shrubs. Perennial plants and summer flowers are already grown in the area, but usually on specialised holdings.

[5] *Source: Reuler, H. van. Topsoil+; Systeeminnovatie voor een duurzame sierteelt op duinzandgrond, (Systems innovation for sustainable ornamental production on dune sand soil). Wageningen-UR PPO, 2010.*

Dune and Bulb Area

About 65 per cent of the flower bulbs in the world are grown in the Netherlands. Traditionally, the Dune and Bulb Area in the province South Holland is an important production area. Flower bulb cultivation thrived in this area through a particular combination of calcareous ('geestgronden') Located behind the dunes and favourable climatic conditions. Perennials and summer flowers or field flowers are grown besides flower bulbs.

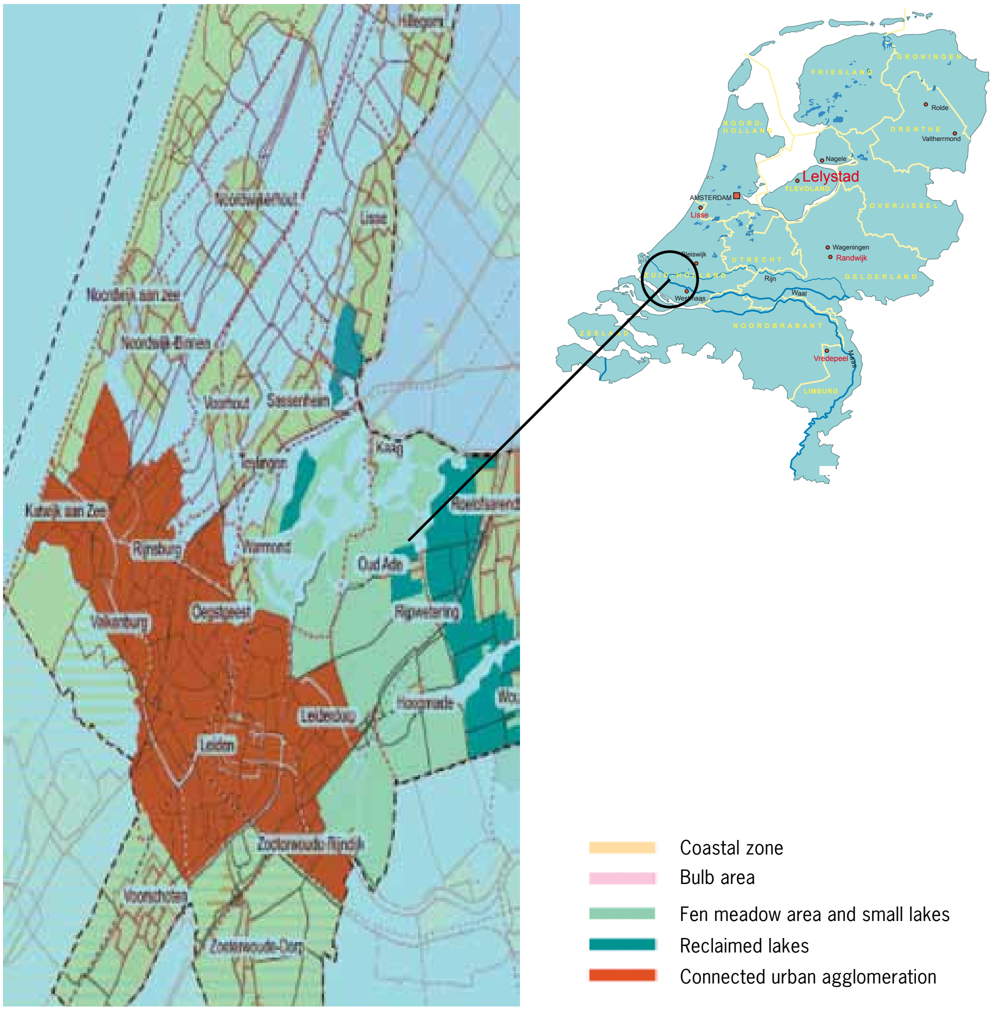

Figure 9. Dune and Bulb Area.

Research focussed on the following spearheads:
1 organic matter management and soil health;
2 new crops on new soil;
3 sustainable quality production in the integrated and organic farming system;
4 organic year-round;
5 perception year-round.

1 Organic matter management and soil health

There are indications that organic matter is degrading more rapidly on dune sand than other types of sandy soils. How much faster, however, is unknown. This is why a study was started into the organic matter cycle on sandy soils with specific attention for dune sand. This involved determination of the degradation rates of various types of organic manure in the integrated system. The experiment was started in 2007. The first results will soon be available.
The effect of crop rotation and organic matter content on suppressiveness against soil diseases was studied in bioassays. Pathogens were added to soil samples followed by crop growth measurement after some time. Crop growth is an indicator of suppressiveness against the pathogen. The effect of organic matter content and crop rotation on root knot nematodes (*Meloidogyne hapla*) in lettuce as test crop, on root rot (*Pythium*) in hyacinth, on *Rhizoctonia solani* in tulip, and on root lesion nematode (*Pratylenchus penetrans*) in daffodil was studied in three seasons – 2006-2007, 2007-2008 and 2008-2009.

Forcing hyacinths for determining bulb quality

2 New crops on new soil

A number of interesting ornamental shrubs, suitable for cultivation on dune sand, were selected together with trade and growers, focussing on small shrubs suitable for the export package for the American market.

3 Sustainable quality production in integrated and organic farming systems

The desired product quality of integrated and organic crops was determined together with the sector. Starting point was that the quality of flower bulbs grown in both systems should not be inferior to conventionally grown bulbs.

4 Organic ornamental cultivation

The acreage of organic ornamentals is very small. Growers are often mentioning weeds as bottlenecks besides pests and diseases. Is good quality production in an organic growing system possible?

5 Perception year-round

Because ornamentals are grown in an urban environment, societal acceptance of cropping operations, spraying in particular, is very important. Another development is that characteristic landscape elements such wooded banks

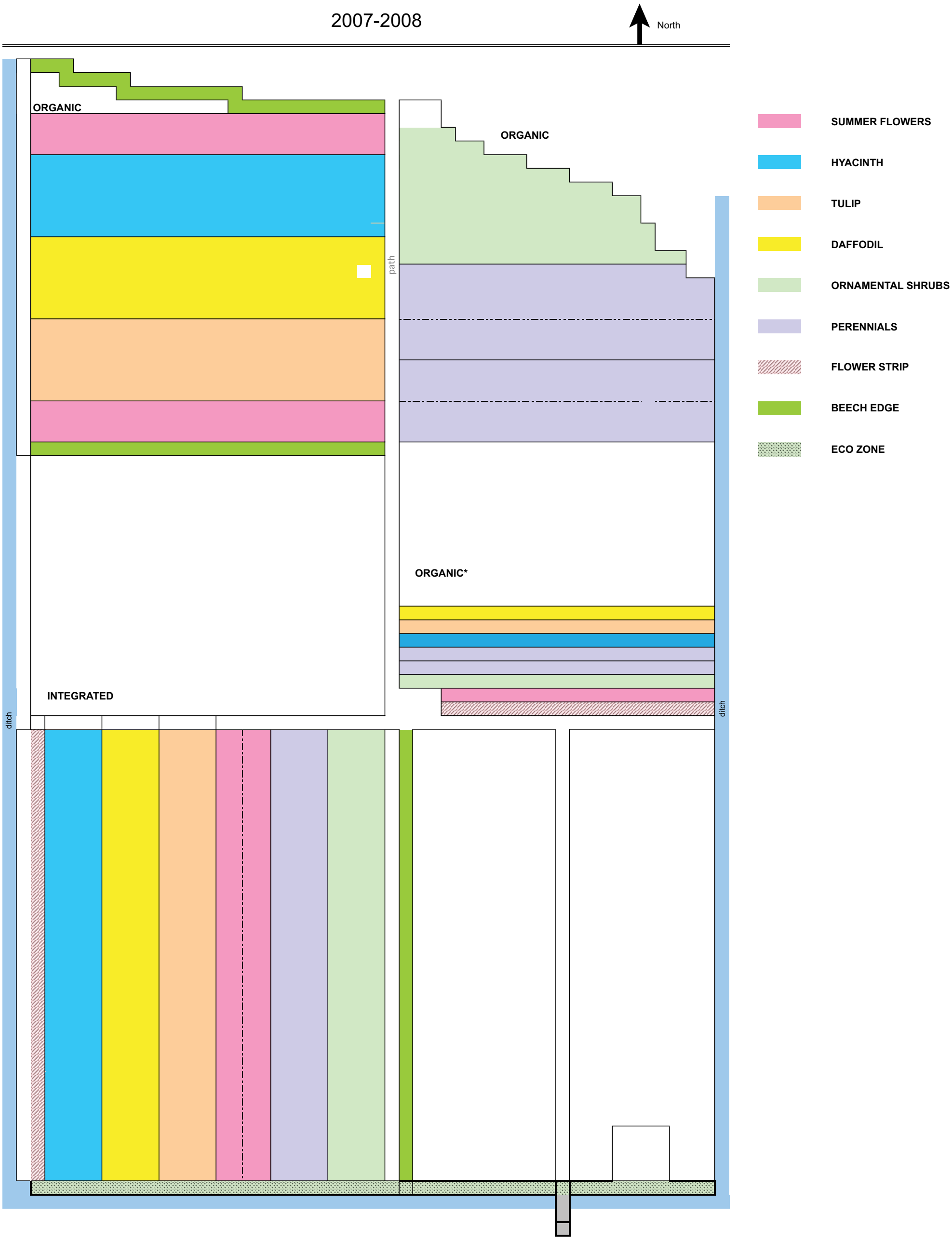

Figure 10. Cropping plan of the integrated and organic system in 2008.

and hedges are disappearing as result of the ever continuing scaling up. In spring, the perception value is very high and the region is attracting large numbers of tourists who come to see the flowering bulbs. There hardly is colour during the rest of the year. How can the region be made more attractive for a longer period of the year?

Results

1 Organic matter management and soil health

The bioassays showed that organic matter content had a clear positive effect on soil suppressiveness against *Meloidogyne hapla* (Figure 11). A field experiment with the perennial species Aconitum confirmed the results of the bioassay (Figure 12). Plants on the field with the highest organic matter content were clearly less infested than the plants on fields with a lower organic matter content.
Bioassays also showed that the preceding crop is playing a role in soil suppressiveness (Table 8). Soil-related diseases were hardly problematic in the field experiment, with widening of the crop rotation certainly having played a role.

2 New crops on new soils

A total of 25 different shrubs were tested. Yields were variable. Some species such as Cotinus (smoke tree) did very well. Wisteria, on the other hand, did not grow at all on dune sand.

3 Sustainable quality production in integrated and organic growing systems

The target values for flower bulb production were reasonably attained. The number of flowers was taken as quality criterion for bulbs from the various growing systems. Forcing quality was average to good.
Yield target values for perennials and summer flowers were also reasonably attained. Lower yields of perennials were to be attributed to the low quality of the propagation material.

4 Organic ornamental cultivation

The target values set for organic cultivation were lower than those for the integrated system. The values for the organic system were generally

Perennials (Phlox) in rotation with bulbs, summer flowers and shrubs

Flower strips are stimulating natural enemies and increase the perception value of the landscape

attained. Pests and diseases hardly caused problems. Weeds, in particular perennial weeds, and nitrogen nutrition were the most important bottlenecks.
Various cover materials were tested for weed control in perennials and ornamental shrubs. Chopped straw and compost scored best on effectiveness as well as price.
Some buyers of organic products demand that no blood and bone meal is used during production. A number of alternatives for bone meal, such as Monterra malt, have successfully been tested.
Organic bulb cultivation uses a thick layer of straw to prevent weed germination. This hinders supplementary nitrogen application during cultivation. Application of vinasse potassium with a spike wheel applicator was tested in Topsoil+. This brings the fertiliser directly into the soil through the straw layer. The method worked well. The relatively low nitrogen content and the relatively high potassium content of vinasse potassium, however, is a problem.

5 Perception year-round

Colour in the landscape was taken into account in the preparation of the cropping plan (Figure 13). The experimental site also included a number of hedges and wooded banks. In the past, these landscape elements were frequently present in the area but mostly disappeared as result of scaling up. The ditch banks that are partly surrounding the experimental site are maintained in a nature-friendly way (ecozone).
The province South Holland is endorsing the significance of landscape elements such as wooded banks by stimulating the establishment of such elements. Demonstrations for mechanical hedge maintenance were organised together with the province.

Application of the results in practice

The solution pathways – increased organic matter content and a wider crop rotation – offer perspectives for a non-chemical approach of soil health in ornamental cultivation on (dune) sand. Stimulation of general and specific soil

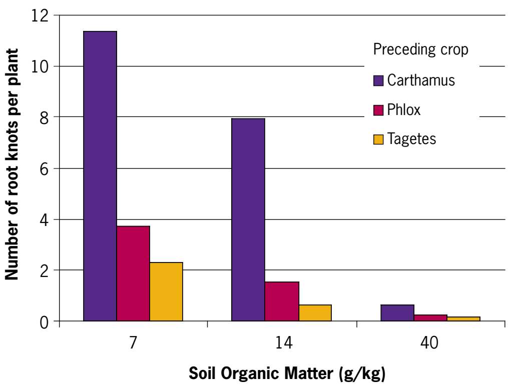

Figure 11. Effect of preceding crop and organic mater content on Meloidogyne hapla infestation in a bioassay with lettuce as test crop.

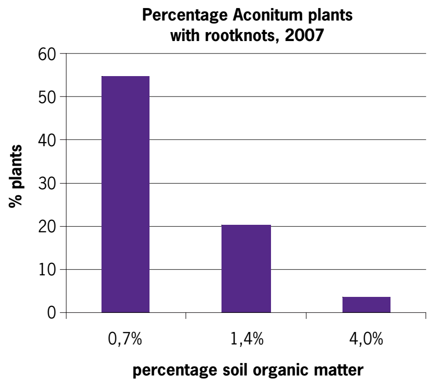

Figure 12. Infestation of Aconitum by Meloidogyne hapla in a field experiment with various organic matter levels.

Demonstration of mechanical weed control in perennials

suppressiveness is the main element. General suppressiveness means that the 'good' micro-organisms are successfully competing for food and space, leaving no chance for pathogens. Specific suppressiveness means that harmless micro-organisms are parasitising or eating a pathogen or produce substances that eliminate the pathogen. The organic matter content does in any case play a role in the build-up of general soil suppressiveness. Influencing specific suppressiveness is much harder.
A field experiment showed that soil suppressiveness against root knot nematodes (*Meloidogyne hapla*) in perennials increases with a higher organic matter content. In addition, the highest organic matter content showed increased suppressiveness against root rot (*Pythium*) and free-living root lesion nematodes (*Pratylenchus penetrans*). Increased organic matter contents are only effective when other factors such as chemical and physical soil conditions are in order.

Increasing organic matter content
Organic matter contents can only be increased very gradually. Low-mineral organic manure, such as compost, is the best material to maintain and possibly increase soil organic matter content. Farmers and growers are wondering whether a good quality production can be attained with compost. The current phosphate application standard of 85 kg/ha is a major bottleneck. This bottleneck will become even larger when the phosphate application standard would in the future be determined on basis of the phosphate status of the soil.

Widening crop rotation
Widening of the crop rotation offers perspectives. Topsoil+ yielded indications that the preceding crop increases soil suppressiveness against three of the four investigated soil-related diseases but the results are not unambigu-

Table 8. Effect of preceding crop and increased organic matter content on various soil diseases in the bioassays.

Disease	**Organic matter content (%)**		**Preceding crop**
	1.4	**4**	
Pythium	-	+	+/-
Rhizoctonia	-	-	-
Meloïdogyne hapla	++	++	+/-
Pratylenchus penetrans	-	+	+/-

+ positive effect; - no effect; +/- no unambiguous effect

ous. The general trend in the region, however, is a further specialisation of holdings which makes widening of the crop rotation on the same farm less likely. Exchange of land with colleagues offers more perspective. Such an exchange is already taking place and can be scaled up.
Large-scale inclusion of ornamental shrubs in the crop rotation does not seem to be an option. Only a restricted assortment is giving a good quality production on dune sand, resulting in a too high risk of market saturation.

Freshly harvested tulip bulbs

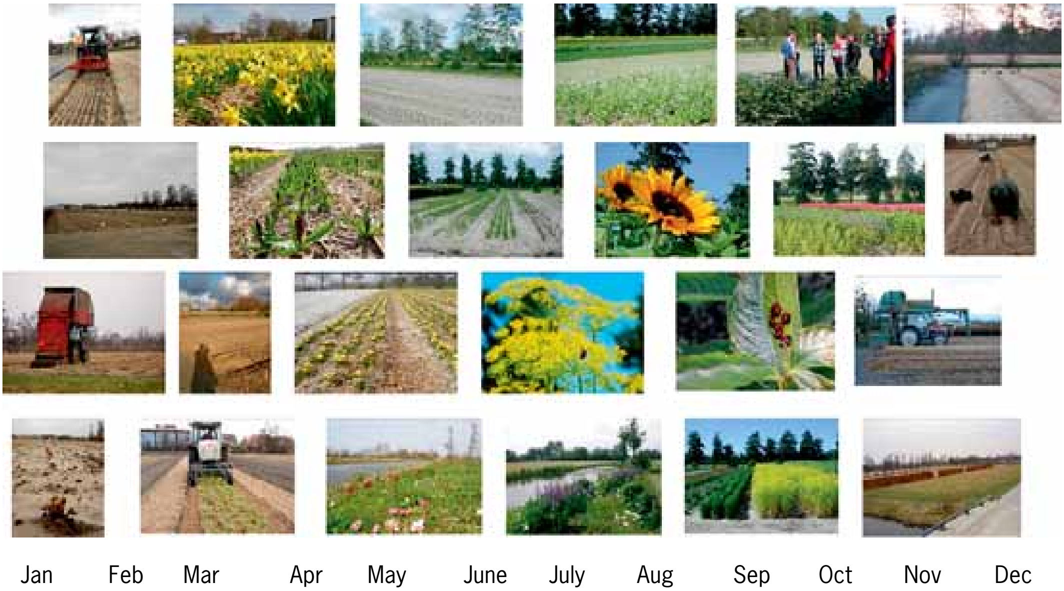

Figure 13. Impressions of the Topsoil+ site throughout the year.

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