PRECISION FARMING: paradigm between technology push and demand pull

Oratie van prof.dr. J. Müller bij aanvaarding van het ambt van hoogleraar Agrarische Bedrijfstechnologie aan Wageningen Universiteit op 9 oktober 2003

Mijnheer de rector magnificus, dames en heren
Twee jaar geleden, toen ik vanuit Hohenheim naar Nederland kwam en ik ingewijd werd in de tradities en de gewoonten van de Universiteit, was het voor het eerst dat ik van een "inaugurele rede" hoorde en ook, dat men die rede geacht werd in het Nederlands uit te spreken!
Aldus besloot ik dat ik eerst de taal zou leren. Ik gaf mezelf daarvoor een jaar de tijd. Echter, al snel merkte ik dat er veel meer te leren was dan alleen de taal.

Daarbij hoorden ook een aantal fysieke vaardigheden:

- bijvoorbeeld, hoe zonder mes en vork een haring te eten zonder daarna onder de douche te moeten,
- of hoe, met een toga aan, een trap op te gaan zonder je nek te breken

Het was ook interessant om een ander land op cultureel terrein te verkennen. Ik leerde hier al snel:

- dat je voor een koffiehoek in het gebouw geen sta-tafels moet aanschaffen, omdat iedereen liever gezellig gaat zitten
- dat het belangrijkste Boek de agenda is, en dat je het niet moet wagen zonder dat boek je kamer uit te gaan
- dat er meer en prikkelender vormen van onderwijs zijn dan frontaal les geven, en dat PGO, PGSO en BVOB geen politieke partijen zijn!

Nog belangrijker echter was het om te leren:

- dat de meest waardevolle informatie in de wandelgangen wordt uitgewisseld en dat ook daar voor belangrijke beslissingen eerst een draagvlak moet worden geschapen
- dat de professoren niet de eerste viool spelen maar de managers in de tweede echolon
- en tenslotte, dat een universiteit geen instelling is verstard door tradities, maar dat het zich juist in een continu proces van vernieuwing en zelfontdekking bevindt, met als gevolg dat de gezichten in de directieraad soms sneller wisselen dan die van onze afstudeerders (die echt niet langer studeren dan anderen!),

Kortom, één jaar werd twee, en ik heb veel geleerd, maar niet so veel Nederlands. Ik denk dus dat U allemaal wel opgelucht zult zijn te horen dat ik mijn rede in het Engels zal voortzetten. De buitenlanders omdat ze dan eindelijk iets kunnen verstaan, en de Nederlanders omdat ik nu zal ophouden op zo'n vermoeiende manier met hun taal om te gaan.

As promised, now in English to the topic of my presentation.

Precision farming – a system approach

First, I would like to give a brief introduction to precision farming, trying to meet the needs of a multidisciplinary audience. A typical opening would be to present a definition. Although precision farming is a relatively young field of agricultural research – emerged in the last decade – it would be an easy task to select one of the plenty in literature. But, as professors would use the toothbrush of a colleague rather than his definition, I also would like to add another one:
Precision Farming is a system approach, based on detailed site-specific information, to manage farm operations according the spatial and temporal variability of growing conditions within a field for sustainable profitability.

The central message is that precision farming is a system approach. A Geographic Information System (GIS) forms a central component of the overall system. Roughly spoken it is a mapping software to handle, analyse and display data that are stored as parameter values linked to its geographic position. In precision farming all parameters are of interest that contribute to describing the characteristics of a field. These are soil parameters such as topography, soil texture, soil depth organic matter, nutrient status or salinity; crop parameters such as crop density, biomass, water stress, nutrient stress, yield or crop quality and of course hazard parameters such as weed, insect, nematode and disease infestation or wind and hail damage Values of each parameter can be stored as a data layer. Mathematical processing of raw data layers generates new layers. Finally the field characteristics can be described as a stack of data layers. To this set of field data the farmer is adding external data sources such as weather data or market information.

The crucial step is now decision-making, i.e. to generate application maps for the various farm inputs like tillage intensity, seed rate, fertiliser, pesticides or irrigation water. Here, Decision Support Systems (DSS) are valuable supporting tools, but still the farmer's personal knowledge base derived from his own experience is essential. The application maps are transferred to a computer on board the tractor that also has to be equipped with a positioning system indicating the precise coordinates in the field. The machines used for application of the farm inputs – also called applicators - are equipped with Variable Rate Technology (VRT), i.e. their application rate changes in response to their position in the field according to the set value prescribed in the application map. Sensors are measuring the actually applied rates of the machines to create an as-applied map that again forms a data layer in the central Geographic Information System.

Precision farming as a holistic management system is covering the complete year cycle of farm operations such as tillage, seeding, weeding, fertilising, irrigation and plant protection. Of course, also the yield - as the real purpose of farming - is measured. For this purpose, combine harvesters are equipped with a yield monitor, measuring grain flow and moisture content to generate a yield map. Finally, knowing all inputs, prices, yield and sales a profit map can be derived, indicating areas in a field making or loosing money.

But there are also sub-cycles in the system. Each farm operation needs a cycle of data collection, analysis and decision-making to create an application map. Each applicator has to follow a control loop where the set value is prescribed by the application map, the actual value is measured by a suitable sensor and the deviation is minimized by a controller via an actuator that adjusts the application rate. To make precision farming a system and not just a conglomerate of technologies, the loops have to be closed and the cycles and sub cycles have to work in a gear. I will come back on this later.

Precision farming - a paradigm?

To attract your attention and to lure you into the Aula, I decorated the title of my presentation with some buzzwords. Paradigm is one of them. It is frequently used in the context of "new paradigm" or "shift of paradigm" to describe evolutions or revolutions in the way of people's thinking. So, why do I call precision farming a paradigm? In my introduction, I already briefly mentioned the variability of growing conditions. As growing conditions are mainly a function of climate and soil properties, a high variation is found around the globe, evident to everyone travelling through landscapes with open eyes. What is obvious on a macro scale of 1000 km is also valid on a micro scale of 100 m and less. Water and nutrient availability vary with soil condition and topography. Topography is also a prime determinant of local variation of microclimate in terms of wind speed, temperature and relative humidity and thus creating gradients in pest infestation pressure. After centuries of agronomic research, dependences and interdependences are investigated in a multitude of studies and publications are filling libraries. But long before that, these phenomena were part of the indigenous knowledge of early civilization. Farmers developed an understanding of the spatial variability of soil fertility. They learned where it's worth to plough, where to establish pastures and where better to keep hands off the forest. As the fieldwork was done manually or with draught animals the field size was restricted and the borders could be adapted to variations in topography and soil quality. In that way the variability within the field could be kept at a low level. The awareness of variability was deeply embedded in peoples' common knowledge and is even reflected as an allegory in The Bible:

Hearken; Behold, there went out a sower to sow:

And it came to pass, as he sowed, some fell by the wayside, and the fowls of the air came and devoured it up.

And some fell on stony ground, where it had not much earth; and immediately it sprang up, because it had no depth of earth:
But when the sun was up, it was scorched; and because it had no root, it withered away.
And some fell among thorns, and the thorns grew up, and choked it, and it yielded no fruit.
And other fell on good ground, and did yield fruit that sprung up and increased; and brought forth, some thirty and some sixty, and some a hundred.
(St. Mark 4,3-8)

The allegory of the sower is telling much more about precision farming as one might think at the first moment. Activities such as locating field borders (…*the wayside*), treating weed patches (…*the thorns*), managing soil variability (…*the stony ground*) and finally monitoring spatial differences in yield (*…some sixty and some a hundred*) are essential elements of precision farming.

It was only during the last decades that mechanization and rationalization reshaped agriculture and landscapes in Western Europe. Much bigger field dimensions and straight field borders were required, which was achieved by large-scale land consolidation. As a consequence, spatial variability of habitat conditions within the fields has increased a fair bit, but uniform treatment of fields based on mean values is still standard practice in contemporary agriculture.

In this context the awareness of variability within fields and the efforts to address these differences, in fact can be seen as a shift in paradigm. But it is not a new paradigm. High-tech application in combination with latest developments in various scientific disciplines finally allows site-specific farming in a modern agriculture – a shift to an ancient paradigm.

Precision Farming – a technology push?
Coming to technology push, the next buzzword in the title. At least in the Netherlands, this word is met with sarcasm. It is associated with the cliché of engineers' attitude such as: "We have developed a fascinating solution, now we are looking for the appropriate problems". Or even worse, characterising the attempt of forced introduction of new technologies that are not in line with or contradicting to societal demands.

In my understanding technology push means, that technology triggers further innovations and developments. In this context precision farming is a prime example for a technology push, in fact in two senses – passive and active. Passive, because it was pushed by the coincidence of emerging technologies and methods in other disciplines. Active, because now as a new technology it is pushing developments in various fields of agricultural sciences.

I want to illustrate this by some examples. The most obvious technology push that hit Precision Farming was the implementation of the global positioning system NAVSTAR-GPS by U.S. military authorities. Ten years ago the last satellites in a series of 24 were installed on their orbits about 20.000 km above ground. The arrangement of the orbits makes sure that the signals of at least four satellites can be received at any location and at any time of the day. The signal contains the position of the satellite in space and the precise time. The signal is travelling in speed of light and arrives at the receiver with a time-delay that is proportional to the travelling distance.

Now a virtual circle can be plotted on the ground surface, each point on the circle having the same distance to the satellite. The same procedure is done with a second and a third satellite, having a different position in space. The intersection of three circles will show the position of the receiver and the signals of further satellites will increase accuracy, as the earth is not a flat sphere and as the signals might be biased by the impacts of the atmosphere.

Developed for military purposes, the signals initially were protected enviously. A bias signal restricted the accuracy for civil navigation to ± 100 m, which is somewhere between your left or right neighbours field under typical European conditions. In May 2000 the bias signal was switched off, increasing the accuracy to ± 10 m. Coming down to a grid size in cm-range requires an additional GPS receiver at a known ground location to generate a correction signal - a method that is called differential GPS or DGPS. Meantime real-time correction signals can be purchased at various providers. A new business is flourishing because GPS technology not only pushed Precision Farming applications but also navigation of modern higher- and middle-class cars – or even pedestrians, in case they are using an advanced cellular phone. Anyhow, tractors with standard installed GPS receivers are no longer science fiction.

A less palpable technology push for precision farming was the development of yield monitors for combine harvesters. As contractors more and more do the harvest of cereals, farmers settling the bill are not only interested in the harvested acreage but also in the efficiency of the operation, i.e. the percentage of the yield actually ending up in the grain tank of the combine. Consequently, yield monitors have been developed, measuring the grain flow at a suitable location within the elevator system of the combine. The earliest commercially available measurement systems were based on the extinction of gamma radiation by the volume flow. As the disposal of the radiation source at the end of the useful life of the combines turned out to be a problem, focus has shifted to systems based on light barriers measuring the filling level of the elevator cups or load cells measuring the impact of the grain flow at the outlet of the elevator. As this measurement principle provides continuous information about the grain flow it was self-evident to combine it with the signal from a positioning system to create a yield map.

An intrinsic problem is still the accuracy of the measurement. While the accuracy of satellite navigation systems improved steadily, providing now a resolution in cm-range, the working width of he combines that determines the grid size also increased, reaching 6 m and more. Moreover, the actual working width is not constant because of overlap in driving. Consequently, the development of guidance systems was pushed or the application of sensors to measure the effective working width. Also sensors for continuous measurement of grain moisture content have been developed to derive mass flow values from the volume flow measurement. A further source of inaccuracy is the time delay between cutting the stalks and arrival of the grains at the sensor. In spite of these shortcomings, a high percentage of combines in USA and Europe are sold with yield monitors, many of them without positioning systems, just to get information about the grain moisture content or to record the total yield per field.

Anyhow, yield maps have been the first offspring of the upcoming precision farming technology. Difference in yield within a plot is one of the most obvious phenomena of variability and also the one most closely related to profitability in farmers' perception. No wonder that scientists, consultants and farmers tried hard to deduce management decisions based on these observations - mainly for following season's fertiliser application. These early approaches often caused disappointment, especially if the yield maps were used as exclusive site-specific information. It took some years to realize that the spatial yield pattern is changing from season to season and needs additional information for interpretation. During this time, precision farming - although still being in its infancy - lost a good part of its glamour. A good example of negative side effects of technology pushes. Also the fact, that precision farming – as driven by yield monitors - mainly focused on cereal production was less favourable in terms of potential benefits.

Precision Farming – waiting for a demand pull?

"Benefits" is the keyword to descend – or should I better say to ascend - to the last buzzword in my title: demand pull. Of course a demand pull only can develop, if there are distinct benefits to be expected. First let us have a look at conventional agriculture, where farm inputs like seeds, fertiliser or irrigation water are still spread on the surface at a constant rate and where Agricultural Engineers are expected to develop applicators for doing this in a maximal spatial uniformity. The application rate is calculated to meet the mean value of the fields' requirement. In spite of the variability of growing conditions within fields, the mean value is generally accepted as optimum – the myth of the mean.

To explore how Precision Farming is contradicting the myth of the mean, I would like to invite you for a small mind game. We assume that the growing conditions and hence the yield potential is known at any spot of a field. Furthermore, we assume that the yield potential is following a normal distribution. From yield functions, we can now derive the required farm inputs for any location in the field. If we now divide the field into infinitesimal squares and arrange the squares on the x-axis of a chart in the order of their input requirement, we will get a sigmoid curve. The input requirement of half of the field will be below the mean value, whereas the other half will be above it. Uniform treatment of the field can now be drawn as a horizontal line at mean input requirement. The enclosed area on the left shows surplus application of farm inputs, whereas the enclosure on the right shows the deficits in application. The inclination of the sigmoid curve and thus the size of the mismatch depends on the variability of input requirements. To adjust different levels of variability we will use the coefficient of variation - in short CV - that relates the standard deviation to the mean value of the input requirement. Increasing CV in our chart from 10 to 20 and 30%, clearly demonstrates how the areas of mismatch are increasing. At deficit application the yield potential is not used to its full extent causing loss of profit. Surplus application causes costs for inputs without generating additional yield and even will lead to a yield reduction as typical yield response curves show a parabolic shape with a maximum.

Perfect Precision Farming – remember we are in a mind game! – would allow the application of inputs exactly according to the requirements at any location of the field. Application would follow the sigmoid curve and thus avoiding surplus as well as deficit application or in other words: the surpluses on the left would be reallocated to balance the deficits on the right and the enclosed areas of mismatch in our chart would vanish. Thus, inputs are not reduced in total, but distributed much better. In our example, no benefits have to be expected by savings of inputs. Thus, benefits - if present - have to come from higher yields.

To investigate yields in our mind game, we want to exclude stochastic impact parameters like weather and pests. Then – taking perfect Precision Farming for granted - yield will exactly meet the yield potential as already known from above. So, for comparison we still have to calculate the yield at uniform treatment. Here, the application rate for each field square equals the mean input requirement. Therefore, the input will only be optimum for that square representing the mean input requirement. Leaving this point to the left or to the right, the difference in yield between uniform treatment and perfect Precision Farming will increase. The total difference in yield depends on the variability of the yield potential within the field. Calculating a scenario for fertiliser as input, the yield would increase by 30, 120 and 260 kg/ha if CV would be 10, 20 or 30% respectively.

In studies under practice conditions in Germany the benefits of precision N-fertilising were found to be 25 and 50 €/ha (Schmerler et al., Griepentrog et al.). Higher benefits are to be expected if precision farming technology is applied on high value crops - a statement that sounds quite trivial. Nevertheless, a large joint research project in Germany involving more than 50 scientists is focusing on winter wheat – not exactly what I would regard as high value crop.

For farm inputs like herbicides and pesticides the conditions are slightly different. At least during the initial stage weeds or pests are not distributed uniformly across a field but occur in patches. To prevent a further spread, the whole field is sprayed namely in a dosage sufficient to fight the weeds or pests in the patches. That means, maximum rates are applied instead of mean rates. Precision Farming in this context doesn't mean the reallocation of inputs but to treat exclusively the infested areas. This leads to a reasonable reduction of applied chemicals, saving money and protecting environment. During on-farm field tests savings in herbicides between 20 and 30% have been recorded (Wartenberg et al., 2000).

More investigations about the economy of precision farming have been done in U.S.A. One of the most comprehensive reviews of economic studies was conducted by Purdue University. Considering more than 100 articles, it was found that 63% reported profits and only 10% indicated negative results (Lambert & Lowenber-DeBoer, 2002).

Hence, proof of economic and environmental benefits is present, but what about the adoption of this technology by farmers? First let us have a look to the U.S.A. Here in 1996, 16% of the area planted with corn was harvested using a yield monitor. In the year 2000 this percentage had increased to 30%. Similar values are found for soybean. For wheat only 10% of the acreage was yield monitored (Daberkow et al., 2002).

In Europe, yield monitor use is not given in percentage but still in absolute numbers. In United Kingdom and Denmark, where adoption of precision farming technology in the mean time is furthest advanced, 400 yield monitors are counted, in The Netherlands they almost can be counted on the fingers of one hand: it has been six (Stafford, 2000). In a Dutch study the number of farms using GPS was estimated to be between 10 and 20 (Janssens & Smit, 2000). Not just how one might imagine a demand pull.

It is evident, that the benefit of precision farming depends on the degree of variability. When viewing the flat Dutch landscape with its apparently uniform fields it is understandable, why the enthusiasm for precision farming is limited here. But are the soil characteristics really as uniform as the landscape? Land reclamation of the polders for example generates an intrinsic variability because there is a gradient in soil texture from older to younger parts of the land.

The value of precision farming technologies already has been recognized by the Koninklijke Maatschap de Wilhelminapolder: in his lecture on the European Conference of Precision Agriculture this year June in Berlin, Jan Paul van Hoven claimed extra research efforts, especially to investigate costs and benefits of the new technology (Van Hoven, 2003). Additional demand pull is coming from outside the farm world. Legislation and consumer pressure is enforcing increasing traceability throughout the food chain from soil to supermarket shelf. Precision farming provides the means for precise application, recording the treatments, tracking through operations and allocation to the harvested product.

Anyhow, Dutch conditions are only representative for a small part of the globe. University research has to focus on international level where research in precision agriculture is blooming and where Wageningen UR cannot afford to miss the connection.

Precision farming – still a lot to do

Opening my speech, I characterised precision farming as a system approach. Regarding the state of the art, I rather should claim: it still has to become a system approach. Screening the WebPages of the global players amongst the manufacturers of agricultural machinery indeed will mediate the impression that the complete system of precision farming technology including software is on shelf, just waiting for an order and immediate use in the field. A comprehensive study of the practicability of contemporary technology conducted in the framework of *pre agro*-project in Germany showed that the communication between the components - which makes a conglomerate to a system – was still far from optimum (Weltzien, 2002). Especially in this context Wageningen scientists of Agrotechnology and Food Innovations – some of you might still remember the name IMAG - are making an important contribution. Under direction of Dr. Daan Goense, hard- and software for the exchange of data between implements and tractor is standardized according ISO 11873. These activities are known to be accepted worldwide.

But there are still a lot of gaps in the cycle of precision farming that have to be closed by the international research community. Consequently, a good part of the research program of the Farm Technology Group is focusing on closing the loops. The fact that I am delivering this speech two years after my arrival, gives me the opportunity to illustrate the research program with some examples of ongoing research activities.

Yield monitors for sugar beet and potato

As I have mentioned above, precision farming should focus on high value crops to be profitable. In The Netherlands this means sugar beet and potato. Although the development of yield monitors for these root crops is still in the beginning on international level, research activities supervised by Jan Willem Hofstee were already present in the Farm Technology Group when I arrived. In cooperation with Agrotechnology and Food Innovations, a sugar beet harvester was equipped with various sensor systems for measuring the mass flow of the beets. In combination with a GPS receiver data was collected via a CAN-bus into a data logger and it was possible to create a yield map. It turned out that the variability of yield was surprisingly high and showed correlations with soil properties (Medema et al., 2000). Beside pure yield also the quality of the beets e.g. in terms of sugar content is an important parameter. Encouraged by successful on-the–go quality measurements with NIRs on field choppers, it would be worth to harness this method for quality mapping in sugar beets. For yield mapping of potatoes a different way was chosen. Instead of any kind of force measurements, non-contact image processing methods are used to calculate the volume of the potatoes when they pass a camera mounted above the harvester's conveyor belt. An essential advantage of image processing compared to methods based on weight measurement is the possibility to estimate the soil tare. First results are promising and the research is going on (Hofstee, 2002).

On-the-go soil sensors

In the opinion of many authors, the precision farming cycle starts with yield mapping. Though it is disputable whether one can talk about a starting point in a full cycle, I feel this should be the creation of soil maps. Reliable information about soil depth, physical soil properties as well as water, nutrient and biological status is essential for the interpretation of yield variability. Taking soil samples for physical and chemical laboratory analyses is the currently used method but this is expensive and time consuming. Therefore, grid size of sampling shouldn't be finer than necessary. The question is what is "necessary". An economic analysis showed, that the added value of precision farming technology is increasing logarithmically with the number of soil samples per unit area (Bullock et al. , 2000). As the cost of sampling is increasing proportionally with the number of samples, an economic optimum can be found. Due to the high costs of the labour intensive laboratory analyses, which are more likely to increase rather than decrease, the grid size will remain coarse using the conventional methods. Therefore, scientific interest is more focused on approaches, where surrogates are measured electronically on-the-go. A variety of sensors is already in test stage, but Willem Hoogmoed is focusing on the possible application of a new and exiting measurement principle that uses the relation between particle size and geochemistry (radiometry). The characterisation of soil is based on the coupling of the physical properties of soil particles to a set of geochemical characteristics, the radio nuclide concentration. With a non-contact sensor, information on soil texture and related parameters can thus very quickly be collected *in situ*.

Opmerking: State of the art is typically used for "latest, most sophisticated" or "modern"

Weed control

For precision weed control vision systems are in development to distinguish between crop and weed. The information can either be mapped for a consecutive weeding operation or used online in a control loop for sensor based weeding. In chemical weed control this technology can be applied as patch spraying, i.e. single nozzles are switched on and off on demand. Worldwide, several scientific groups are working on patch spraying. Recently the Farm Technology Group quasi went shopping for all this knowledge and much more by filling an assistant professor vacancy with Lie Tang, who is also a specialist in automation and robotics. In non-chemical weed control, which is a main issue in organic farming – the task is more challenging. The weeding devices – also called actuators – have to be manoeuvred with high precision to prevent crop damage. As this is a time consuming operation that lowers efficiency, efforts are made to install such sensor/actuator systems on autonomous vehicles being able to work in the field day and night without driver. Since 2001, in cooperation with the System and Control Group Tijmen Bakker is working in a PhD-project on robotic weed control. Central question in robotic weeding is the source of energy used for the actuators, as the load capacity is limited. Amongst known methods, Dirk Kurstjens is testing a new one, bedewing the weed plants with combustible liquids such as methanol before striking. Lab experiments are promising, waiting for continuation in practice.

Disease control

Even more difficult than the detection of weeds is the sensing of diseases. Prophylactic spraying of fungicides is common practice to prevent outbreaks. That applies above all for Phytophthora infestans that is one of the most dangerous fungal diseases in potatoes. Entomologists of Wageningen and Göttingen University discovered by Electro Antenno Graphy, that colorado beetles are able to detect volatile emissions of infested plants and tubers. Funded by LNV the Farm Technology Group is now starting a project to investigate the feasibility of a biosensor based on the insect antennas for detection of infestation. Selection of infested plant potatoes in store houses and early detection of infestation in the field for control via patch spraying will be objectives of future projects.

Livestock farming

Until now I talked about precision farming reserving the term precision agriculture as an umbrella for combining arable and livestock farming. Also in livestock farming animals are no longer treated as a herd but as individuals with their own needs. Prof. Metz – part time professor in the Farm Technology Group – is working on animal welfare aspects of robotic milking and Hanneke Pompe on precision feeding of cows, based on automatic measurement of body condition scores.

Now that I briefly mentioned most of the scientific staff members, I don't want to miss out Wim Huisman working on renewable energy and post-harvest technology, Jos Koolen working on urban green and Bert van't Ooster working on climate control in farm building and greenhouses all representing working fields where special precision was required long before the rush in precision agriculture.

It is obvious that all the mentioned research activities require interdisciplinary approaches. A soil sensing method never would be a success without the expertise of soil scientists and a biosensor for detecting Phytophthora cannot be developed without the contribution of entomologists and phytopathologists. But these are just examples of sub-cycles of precision agriculture. Closing the whole cycle would involve much more of Wageningen scientists but it would require streamlining the activities in a network. A holistic system approach of precision agriculture closing the gap between arable and livestock farming is still missing and I hardly could imagine a better place for it than Wageningen UR. The first knots are knotted and I do hope that some of my words *fell on good ground…*

Education

When I arrived in Wageningen two years ago, I was curious how a student would find his way to Wageningen – or more precise - to the courses of the Farm Technology Group. So I contacted the university in the same way, as a high school student would do. I honestly filled the forms on the WUR Web Page and in spite of my age and my German degree, I got a nice set of brochures together with a friendly letter. The service of the student advice office was excellent. The brochure that came closest to the study I was looking for was that of *Technologie en Milieumanagement*. Amongst photos of water treatment plants and waste dumps, I also discovered a few showing agricultural machinery. In the study handbook, I tried to learn more about the contents of the courses that carried long names. Most of the texts described a vague mixture of anything. I couldn't find what I was looking for and blamed that to my weak language capabilities. But it turned out that Dutch high school students seemed to have similar problems. What was going on? After a decreasing enrolment in *Landbouwtechnische wetenschappen* in the late 90s, the fusion with *Milieutechnologie* was decided upon in order to increase the number of students. Unfortunately, the total number remained the same as Landbouwtechnische wetenschappen alone, what means that each of the former programs lost a good part of its students. In 2001, only four 1st-years students with interest in Agricultural Engineering remained. Early in 2002, the programs were split again and *Agrotechnologie* was born. But it was not just a renaissance of the former program. A project team consisting of students and staff members designed a new structure that also fitted in the BSc/MSc-system. Addressing also international students, the MSc-program is taught in the English language and consequently has an English name: *Agricultural and Bioresources Engineering*. A second time within a short period the teaching staff of the involved chair groups was busy to develop new courses, now focusing on the challenges Agricultural Engineers are facing today and in the future. All the efforts were rewarded. The enrolment of 1st-years students increased to seven in 2002 and twelve in 2003. Also the secondary enrolment in the MSc-program is rising. I think, it is a not too optimistic extrapolation to expect 20 1st-years students and another 10 MSc-students per year until 2006.

Anyhow, as a global trend in Europe and the U.S.A., student numbers in Agricultural Engineering are decreasing in spite of a good job market for graduates. Technically oriented high school students prefer studies that are more related to high-tech disciplines and Information Technology. Precision Agriculture includes both aspects and offers a good opportunity to attract more students. Especially the combination of "serious" and "playful" aspects of robotics are appealing to the upcoming student generation. That offered a good opportunity to continue the work of my predecessor Prof. Speelman – now rector magnificus – who gave his own inauguration the title *van zaaier tot robot*. We invited high school and university teams to enter an international open-air field robot contest. Students were expected to construct their own field robot. To allow unlimited creativity no rules were given in terms of the design, beside being able to navigate autonomously in a standard maize field and solving some special tasks. Universities and schools were encouraged to support their student teams with technical and financial backstopping. Finally, June 5th and 6th eight student teams came to Wageningen, some even from abroad from France, Denmark and Germany to compete on a specially established maize field on the IMAG compound. The creativity of the students has been amazing, already expressed in the names like *corn2Bwild*. Our own students presented two teams Agrobot I and II but as twist of fate and without my intervention the team of Hohenheim University - my *alma mater* - won.

In an interview amongst the competitors the learning effect of the event was appreciated by students and docents likewise. Following a design process from the first idea to a functional product mediates valuable technical hands-on experience and also off-curriculum skills like communication, teamwork, time management and fundraising. The 2nd Wageningen Field Robot Event 2004 is already scheduled and several European Universities expressed their interest to host the event in the years to follow.

Concluding remarks
It is a tradition in Wageningen to spend some time during the inauguration on one's personal background and academic debts. I would like to combine this with my thanks to my university teachers.

The dream of my younger days was to become a veterinarian. I started to study Agricultural Sciences at Hohenheim University just to fill the waiting time, I had to accept for vet medicine. Soon during the propaedeutic phase I came in contact with introductions into Agricultural Engineering. The clear style of the courses was the trigger to continue the study wholeheartedly in this specialisation. Enthusiasm increased with every semester and my initial dream faded painless. For my M.Sc.-thesis I joined Prof. Mühlbauer, head of Agricultural Engineering in the Tropics and Subtropics, who sent me to the island Crete to investigate the performance of an innovative greenhouse cooling system. Self-reliable experimental field research in a foreign cultural environment fitted perfectly to my preferences. Furthermore, Prof. Mühlbauer turned out to be a mentor in the best meaning of the word. So, in 1985 it was an easy decision to stay at Hohenheim University as a research assistant, starting a PhD-project about the use of solar energy for drying of medicinal plants. Based on my experience from greenhouse cooling and a fruitful cooperation with my former supervisor Gerhard Reisinger, a solar greenhouse dryer was designed. The matter didn't stop after successful testing of a prototype, but several units were sold in Germany and abroad and soon the question was to establish a spin-out or to focus on an academic career. I voted for the latter. This was in 1992, the same year when Prof. Köller was appointed to broaden the work field of the chair group. I joined Prof. Köller and was commissioned to set up the discipline of *irrigation technology*. Research projects on water- and energy saving irrigation methods followed in Egypt and Thailand. In 1997, I was appointed assistant professor and started additional activities in precision farming.

Professor Mühlbauer cannot partake today, because a case of illness in his family and Professor Köller is on a journey through Eastern Europe. I would like to express my thankfulness to both of them, for everything I could learn under their supervision – and this has been a lot more than pure expert knowledge. I also want to thank for their confidence to give me enough space and freedom to develop in an own academic carrier.

Colleagues Gerrit van Van Straten, Wim Rulkens, Gerard Bot and Udo Perdok: When I arrived in Wageningen, our groups were in the middle of move from de Dreijen to the Mansholtlaan and very busy trying to find out whether we should and could merge with each other and with IMAG, and if so, how to implement this. As we all know, developments have since gone in directions that were again different from what we envisaged then, but I would like to thank you all for being supportive and understanding. Udo, in the meantime you decided to retire earlier and I thank you for the establishment of the close contacts between our groups.

Staff members of Farm Technology Group and Soil Technology Group, two years ago I started quite inexperienced in terms of language and culture and it was also the first time I took responsibility in leading a chair group. I thank you for welcoming me in an open atmosphere and for your willingness of cooperation. After two month you collectively switched from English to Dutch, forcing my linguistic ambitions in the right way – your way. Special thanks to Wim Huisman who invested much time and energy to introduce me into the business during the first couple of months.

Students of L60, TM and Agrotechnology, thank you for your creativity and enthusiasm that makes me loving my profession. Last year I encouraged you to contribute in the competition of young scientists of the

EurAgEng congress in Budapest. I promised that the Farm Technology Group would pay for the journey if one of you would be accepted. At the end, nine have been accepted, cutting deep in our budget and making me travelling by train and sleeping in a youth hostel. Nevertheless, you made the first and second price and we have had a great time. Don't forget to submit your ideas for the upcoming EurAgEng congress next year in Leuven – which will be much cheaper.

Liebe Tabea, lieber Tobias, durch meine Verpflichtungen bekommt ihr mich recht wenig zu Gesicht. Aber ihr beiden habt euren Weg ganz gut gefunden und schmunzelnd muss ich feststellen, dass ihr schon mit den selben Waffen zurückschlagt: ihr habt beide an eurer Schule zusätzliche Verantwortung übernommen und seid deshalb heute aufgrund wichtiger Termine verhindert – afwezig met reden, wie wir hier sagen.

Liebe Ulrike, wenn ich Vorträge halte, dann rede ich meist über die Dinge, die gut laufen. Aber mit dir kann ich auch über Dinge reden, die weniger gut laufen. Das ist mir viel wert und oft hast du aus einer unbefangenen Sicht einen nützlichen Rat der schon so manchen gordischen Knoten gelöst hat, ohne ihn durchzuhacken.

Liebe Eltern, vielen Dank, dass ihr den weiten Weg aus Süddeutschland nicht gescheut habt und heute hier seid. Das gibt mir die Gelegenheit, euch auch einmal öffentlich zu danken. Zusammen mit meinen Brüdern Klaus und Siegfried und meiner Schwester Heike hatte ich eine glückliche und geborgene Kindheit. Ihr habt uns alle Möglichkeiten eingeräumt, zu lernen ohne uns jemals zu zwingen. Euer Haus stand immer gastfreundlich offen - auch für unsere Freunde - und noch heute bildet es den Mittelpunkt der Familie. Anstatt mit vielen Worten zu danken, möchten wir viel lieber versuchen, diese Geborgenheit an unsere Kinder weiterzugeben

Tot slot de Raad van Bestuur van Wageningen Universiteit en Researchcentrum en de door haar ingestelde benoemingsadviescommissie: bedankt voor het in mij gestelde vertrouwen – Ik zal mijn best doen, om het vertrouwen waard te zijn.

Meneer de rector, dames en heren
Ik dank U allen voor Uw aandacht.
Ik heb gezegd.

References