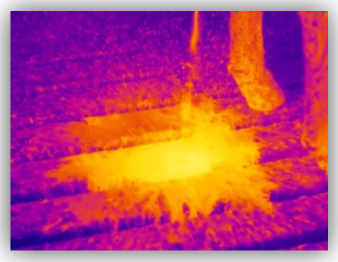
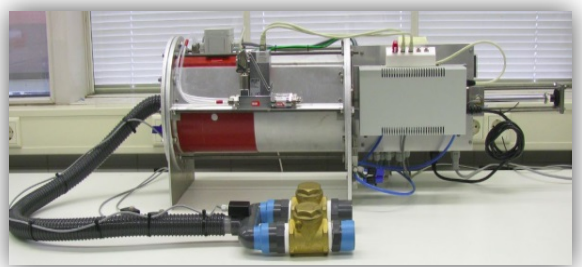
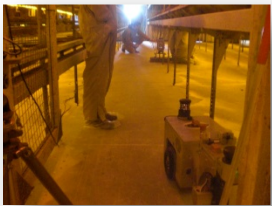
FARM TECHNOLOGY GROUP

ANNUAL REPORT 2013








WAGENINGEN UNIVERSITY
WAGENINGEN UR

Wageningen University

Farm Technology Group

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Contents

Preface

You are reading the annual report of the Farm Technology Group of 2013. The report contains contact information, mission and vision of the group, cv-'s of the staff, a short description of on-going PhD projects, finished MSc projects, a list of publications as well as a list of courses we teach in the BSc and MSc programmes Biosystems Engineering. We hope that you find what you need, that it may interest you and that new possibilities for cooperation may evolve.

The Farm Technology Group focusses on two main research areas, being:

1 Sensing, data processing and interpretation, followed by intelligent operations e.g. process management, manipulation, robotics and precision agriculture / precision livestock farming

2 Design of sustainable systems and technology, and development of improved methods

These two research areas address the following three societal issues:

- Limited availability and quality of labour in agricultural production systems,
- The health of men, plant and animals in production systems, and
- Integral sustainability of production systems and chains.

We address these issues using the following four scientific focus fields:

- knowledge and technology of sensing, and methods for data processing and interpretation,
- modelling of biosystems,
- technology & control systems for automation and robotics,
- development of design methodology for complex socio-technical biosystems.

The Farm Technology Group is a lively and growing group. With a growing number of PhD students we address the above topics yielding a growing number of scientific publications in peer reviewed journals and knowledge and experience that can be applied in agricultural practice.
Also, the Farm Technology group is one of the main suppliers of the BSc and MSc programmes Biosystems Engineering at Wageningen University, the only higher education study on engineering and technology for agriculture and biosystems in The Netherlands.

We hope you will enjoy reading this annual report. Feel free to contact us for more information on research and education or check our website: www.wageningenur.nl/fte .

Mission of the Farm Technology Group

Our mission

The members of the Farm Technology Group see it as their mission “To enhance, exploit and disseminate the potential of technology in primary agricultural production processes to fulfil the needs of mankind and nature in a sustainable way”.

Our vision of agricultural production

When it comes to needs of mankind and nature, the perspective has rapidly changed during the past decades. With a growing global population, the demand for food is increasing continuously and food production is and will be the key issue of agricultural production. However, the past decades have also shown a gradual diversification of the product portfolio in Western Europe. Feed, fuel and fibres are gaining importance besides food and flowers and productions of functional foods, pharmaceuticals, renewable resources from plants etc. will appear on the agenda. Also the character of farm enterprises is changing. Besides being a part of a worldwide production chain, nowadays farms in the Netherlands no longer only contribute to agricultural production but, as part of the society and the environment they operate in, contribute to recreation, nature conservation and health care. Meeting the growing and diverse demands of the global society puts strong pressure on nature with its limited available resources.

In the coming year’s key issues in this field will be: 1) efficient use of natural resources like energy, water, and chemicals, 2) welfare of animals and health of animals, plants and human beings (food safety), 3) reduction of the environmental impact of agricultural production, and 4) supporting, alleviating or replacing human labour. Enhancing and exploiting the potential of technology is the way to meet this complex and challenging set of objectives. We refer to our work as Biosystems Engineering.

Our core business: Biosystems Engineering

We define 'Biosystems Engineering' as a scientific approach that combines methods and tools from technical sciences with biological, environmental, agricultural and social sciences in order to study, understand, manage and design biosystems that encompass technical components and biological organisms (plants, animals) as well as human interactions with both these groups of entities.

The main scientific challenges in Biosystems Engineering are the complexity of production systems including many and usually non-linear interactions between the various entities. Additionally, variability of nature apparent through variation in position, size, shape and colour of objects as well as variability in the response of processes in time together with uncertainty in for instance the weather, pose considerable research challenges. Focus is not only on studying and understanding these complex systems, but typical for engineering, also on management, control and (re)design of such systems, with a special focus on the technology.

Our research instruments and expertise cover fields like sensor technology, data analysis, systems analysis, continuous time and discrete time modelling, systems engineering, integral systems design, systems optimization and management and control of production processes, mechatronics and precision agriculture techniques.

Being an intermediate between plant sciences, animal sciences, environmental sciences and sometimes social sciences on one hand and technology on the other hand, the group holds a unique position both within Wageningen UR and nationally. Many scientific challenges arise on the edge between nature and technology. It is the ambition of the Farm Technology Group to play a leading role in this scientific field, nationally and globally. We expect to achieve this through targeted networking and collaboration with research groups in related non-technological and technological fields to develop new scientific knowledge in support of the challenging field of Biosystems Engineering.

Exploiting the potential of technology, some examples

Systems engineering and systems optimization. Through networking with stakeholders, group members identify needs of mankind and nature as well as the pertaining sustainability issues and translate these in innovative system designs. Instead of focusing on single disciplinary solutions, with the paradigm of systems engineering and interactive methods the group is able to produce new farm system concepts based on a multidisciplinary approach. Examples of projects include the design of protected cultivation systems with for instance low inputs of fossil energy when focusing on the Netherlands. Another project, with a more global view, deals with the design of protected cultivation systems that are adapted to local climate and economic conditions. In a parallel project especially the ecological sustainability of organic laying hen systems is analysed and redesign of such systems is pursued. In past years a new system for laying hen production was developed, the so called Roundel. A pilot of that system is currently being built and under investigation. In 2014 the first practical pilot farm with the Kwatrijn concept for dairy cows will be built, combining improved welfare with reduction of the emission of ammonia.

Welfare of animals and health of animals, plants and humans. Assuring health of animals, plants and humans in agricultural production is of growing concern in the Netherlands and considerable costs are associated to maintain required health levels not to mention the input and potential emission and transfer to the food chain of chemicals to cure occurring diseases. One way our group tackles this issue is to design so called robust livestock systems in which implicit robustness of the system with animals reduces health problems. The group is involved in projects on the design of husbandry systems where welfare, health and environment are substantially improved. An alternative approach we take is to detect health issues for instance in plants as early as possible, so that timely and plant specific treatment is possible. Stress detection based on the emission of volatile organic compounds by the stressed plants is used as a cue in this line of research. This approach will be extended to livestock farming as well. Analysis of the dynamics of bio-signals like heart rate of pigs may reveal information about the stress status of an animal, and by that the ability to cope with future challenges.

High-tech automation and robotics. To maintain a healthy and productive crop, satisfy food safety concerns, reduce the use of chemicals and improve the efficiency of production, all within the limitations of the availability and cost of labour, requires automation and precision technology. A system has been developed for plant specific removal of volunteer potatoes in sugar beet fields to prevent spreading of *Phytophthora infestans*. It includes vision, perception and precision spraying. Such fundamental technical components are also used in other farm automation projects. The group developed a small robot WURking to be used for crop scouting in arable farming as well as a large autonomous robot called the Intelligent Autonomous Weeder (IAW). New challenges are encountered in a project to drive with autonomous robots in poultry houses for laying hens and broilers. Complexity and variability of the biological working environment are challenging issues.

We hope you will enjoy reading this annual report. Feel free to contact us for more information on research and education or check our website: www.wageningenur.nl/fte .

Prof. Eldert van Henten

Prof. Peter Groot Koerkamp

General information

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Plant Sciences Group
Farm Technology Group

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Group members - permanent staff

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The research network of the Farm Technology Group

Embedding in graduate schools

Research of the Farm Technology Group is embedded in the following graduate schools:

1. De Wit Graduate School of Production Ecology and Resource Conservation (PE&RC),
2. Wageningen Institute of Agricultural Science (WIAS),
3. The Netherlands Graduate School of Science, Technology and Modern Culture (WTMC).

Cooperation within Wageningen UR

The two current chair leaders also hold a part time position at DLO institutes within the Plant Sciences Group (Van Henten) and the Animal Sciences Group (Groot Koerkamp). The past years, this has resulted in many new, funded, collaborative research initiatives. There is a strong mutual interest to extend this collaboration. The DLO institutes show a strong interest in PhD projects to work on themes of long-term strategic interest. On the other hand, through the link with these institutes, the chair group is able to more proactively respond to and anticipate developments in primary production and society and to obtain research funds more easily. A strong collaboration also exists with various research groups within Wageningen University. Currently, more than 50% of the current (PhD-) projects are based on collaboration with groups within WUR. These groups are mainly located in the Plant Sciences Group and the Animal Sciences Group, to a lesser extent in the Environmental Sciences Group and occasionally in the Social Sciences Group and the Agrotechnology and Food Sciences Group.

Cooperation with universities and research institutes outside WUR

A growing number of projects are carried out in collaboration with groups outside WUR. In various modalities the members of the Farm Technology Group collaborate with the following universities and research institutes world-wide:

1. EU FutureFarm (University of Almeria, Spain; Helsinki University of technology, Finland; Aarhus University, Denmark; University of Copenhagen, Denmark; Aristotle University of Technology, Greece; Centre for Research and Technology, Greece)
2. EU CROPS (University of Leuven, Belgium; Ben-Gurion University of the Negev, Israel; University of Ljubljana, Slovenia; Umeå University, Sweden; Università degli Studi di Milano, Italy; Instituto de Automatica Industrial, Spain; Technical University Munich, Germany; Swedish University of Agricultural Sciences, Sweden)
3. RoboNed (TU Twente, TU Delft, TU Eindhoven)
4. EU Bio-Business (University of Leuven, Belgium)
5. Ehime University, Japan
6. IAM-BRAIN, Japan
7. Forschungzentrum Jülich, Germany
8. Public University of Navarra, Pamplona, Spain

9. China Agricultural University, China
10. Chinese Academy of Agricultural Sciences, Beijing, China
11. MIT, Boston, USA
12. Field Robot Event, University of Hohenheim, Germany and University of Applied Sciences, Osnabrück, Germany
13. University of Illinois, Urbana-Champaign, USA
14. CRA, Agricultural Research Council, Italy
15. University of Milan, Italy
16. Cranfield University, UK

Cooperation with industry

Science yields impact when results of research are really implemented and used in agricultural practice. Therefore the Farm Technology Group seeks support and collaboration with commercial companies in its research projects. The group collaborates with:

1. Agritechnics, Doetinchem, The Netherlands
2. Claas, Harsewinkel, Germany
3. Kverneland Mechatronics, Nieuw Vennep, The Netherlands
4. Rijk Zwaan, Fijnaart, The Netherlands
5. Tyker Technology, Wageningen, The Netherlands
6. Vencomatic bv. & Rondeel bv, Eersel, The Netherlands
7. GD, Deventer, The Netherlands
8. Commercial Farms
9. Monteny Milieu Advies, Renkum, The Netherlands
10. Swaans beton, Heeze, The Netherlands

People of the farm technology group

Prof.dr.ir. Peter (P.W.G.) Groot Koerkamp

Contact information:
Prof.dr.ir. P.W.G. Groot Koerkamp
Email: peter.grootkoerkamp@wur.nl

Affiliations

Professor of Biosystems Engineering

Senior scientist at Wageningen UR Livestock Research.

Education

1998 PhD, Wageningen University, Wageningen, The Netherlands

1990 MSc, Wageningen University, Wageningen, The Netherlands (with honours)

Expertise

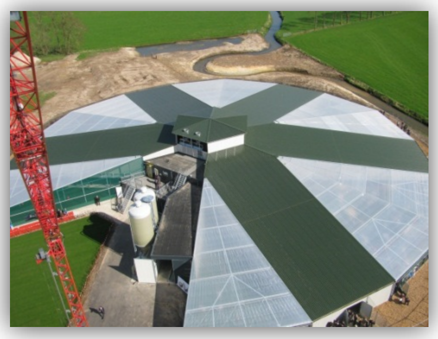
System thinking, production technology for animal production systems, innovation processes, sustainability of animal production systems, technology development, specialization in measurement of environmental aspects of animal production systems (gaseous emissions, dust, losses, energy), specialization in poultry and dairy production, statistical techniques for precision livestock farming. Special interest in animal health and welfare and design methodology for sustainable production.

Current activities

Management of Farm Technology Group, teaching, supervision of PhD, MSc and BSc students. Membership of editorial board of IJABE (China), Journal of the Science of Food and Agriculture, and member of several international professional organizations (president of NVTL, EurAgEng, WPSA, ISAH).

Contribution to courses

FTE12303/12803, FTE30306, FTE33806, FTE80436, FTE34306



Views of one of the Roundel houses for laying hens, that can be visited in Barnveveld, Wijchen and Wintelre.
Left: top view with 5 sections, right laying hens foraging in the day light area

Prof.dr.ir. Eldert (E.J.) van Henten

Contact information:
Prof.dr.ir. E.J. van Henten
Email**:** eldert.vanhenten@wur.nl

Affiliations

Professor of Biosystems Engineering

Head of Farm Technology Group

Education

1994 PhD, Agricultural and Environmental Sciences, Wageningen University, The Netherlands

1987 MSc, Agricultural Sciences, Wageningen University, The Netherlands (with honours)

Expertise

Protected cultivation, arable farming, sensing, modelling, design and (optimal) control of bio-systems, bio-robotics, high-tech automation, company logistics.

Current activities

Management of Farm Technology Group, project acquisition, teaching, supervision of PhD, MSc and BSc students. Member of editorial boards of Biosystems Engineering, Computers and Electronics in Agriculture and International Journal of Agricultural and Biological Engineering. Member of (inter)national professional organizations: EurAgEng, ASABE, ISHS (chair of working group on sensors, vision and robotics), BSHS, IFAC, IEEE Robotics and Automation Society (co-chair of the special interest group on agricultural robotics and automation), RoboNed (chair of the special interest group on agricultural robotics), NVTL.

Contribution to courses

FTE12303, FTE12803, FTE31306, SCO22306, FTE32806, FTE33306, YEI80812, FTE80436

Master-slave operation of two Claas Xerion tractors

Ing. Sam (S.K.) Blaauw

Contact information:
Ing. S.K. Blaauw
Email: sam.blaauw@wur.nl

Affiliations

Teaching assistant, Farm Technology Group

IT support officer at WUR Facilities and Services

Education

1989 Bachelor Dutch Agriculture (Specializations: agricultural engineering, IT) Prof. H.C. van Hall institute for higher agricultural education, Groningen (The Netherlands)

Expertise

Agricultural Engineering, Computers and Internet, CAD, Teaching

Current activities

Teaching various practical trainings, technical support of research projects of PhD and MSc students, IT support chair group, webmaster fieldrobot.nl and ieee-ras.nl, member field robot event team

Contribution to courses

FTE13807, FTE24806, FTE32806, FTE34306

Field robot event 2013, Prague (CZ)

Dr.ir. Jan Willem (J.W.) Hofstee

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Dr.ir. J.W. Hofstee
Email: janwillem.hofstee@wur.nl

Affiliations

Assistant professor, Farm Technology Group

Programme director BSc Biosystems Engineering (BAT) and MSc Biosystems Engineering (MAB)

Education

1993 PhD Agricultural and Environmental Sciences, Wageningen Agricultural University

1986 MSc Agricultural Engineering (with honours), Wageningen University, The Netherlands

Expertise

Machine vision, automation, precision farming

Physical properties of fertilizers, spreading fertilizers

Computer Integrated Agriculture

Precision detection and control of weeds

Yield mapping of potatoes with machine vision

Member of NVTL, EurAgEng, ASABE

Member of committee for assessment of technology for environmental issues (water quality)

Member editorial board Computers and Electronics in Agriculture

Member of the editorial Advisory Board of Agricultural and Food Science

Treasurer of NVTL

Current activities

Teaching courses, supervision of BSc, MSc and PhD students, research on precision farming, automation and machine vision.

Contribution to courses

BRD22306, FTE12303, FTE12803, FTE13303, FTE13807, FTE25806, YEI80324, FTE804nn, YMC60809

Automated detection and control of volunteer potato plants

Dr.ir. Willem (W.B.) Hoogmoed

Contact information:
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Affiliations

Assistant professor, Farm Technology Group

Education

Teaching and supervising thesis work of MSc students on various aspects of tillage and technology: sensors, precision farming, conservation tillage systems.

Setting up MSc programme in Sustainable Agriculture at Stellenbosch University, South Africa (NUFFIC project)

FTE24306, FTE32306, FTE33306, FTE50806

Expertise

Agricultural engineering with focus on soil tillage / soil technology; conservation tillage; soil structure; farm mechanization, including animal traction; soil sensors; soil physics

Technology aspects of mulch based cropping systems (in the framework of an EU-funded FP7 project "OSCAR")

Application of proximal (on-the-go) soil sensors for precision farming (PhD project)

Interaction between animal manure processing and tillage systems (PhD project)

Controlled traffic in Dutch organic farming

Conservation agriculture in Africa

Joris (J.M.M.)IJsselmuiden, MSc

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Joris IJsselmuiden MSc
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Affiliations:

Postdoc position at Farm Technology Group – agricultural robotics and automation

Education:

2013 – PhD in Computer Science, Karlsruhe Institute of Technology (to be defended on July, 17 2014)

2006 – MSc in Artificial Intelligence, University of Groningen

Expertise:

Robot cognition (modelling, reasoning, and planning)

Computer vision

Applied robotics

High-level reasoning based on fused heterogeneous machine perception

Human machine interaction

Programming skills: Python, Prolog, Qt, C++, Java, R, and more

Current activities:

Writing research proposals (e.g. on harvesting robots and autonomous, collaborative farm vehicles)

Supervision of BSc, MSc, and PhD students

Research towards scientific publications

Design and implementation of new systems in agricultural robotics and automation

Supporting role in the strategy, vision, and management of the Farm Technology Group

Greenhouse tomato production system (left, source: wimklerkx.nl) and three growth stages of a tomato truss (right); envisioned operation environment for a harvesting and plant nurturing robot

Dr.Ir. Simon (S.) van Mourik

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Dr.ir. S. van Mourik
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Affiliations

Assistant professor, Farm Technology Group

Education

2002 – MSc Applied Mathematics, University of Groningen.

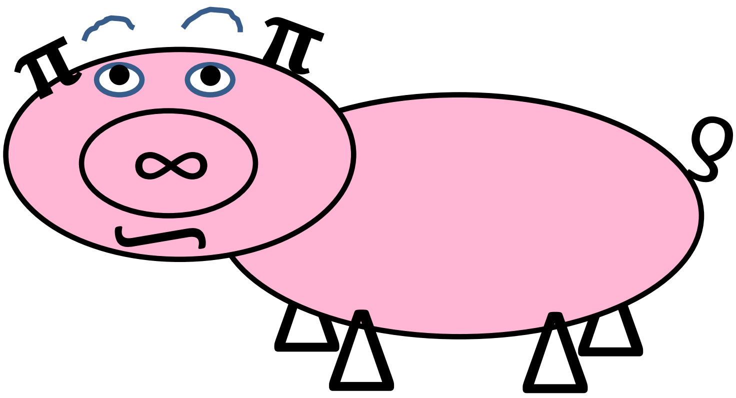
2003 – MSc Mathematics, University of Groningen.

Expertise

Systems analysis, systems biology, biosystems engineering, systems theory, control design, computational fluid dynamics, signal analysis, uncertainty analysis, statistics, numerical analysis, first principle models, empirical models, transport phenomena.

Current activities

Supervision of MSc and PhD students, development of BSc course on data analysis



Modeling biosystems

Ir. Bert (A.) van 't Oooster

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Affiliations

Assistant professor, Farm Technology Group

PhD student stationed at Wageningen UR Greenhouse Horticulture

Education

1984 – MSc Agricultural Engineering, Wageningen University (with honours)

Expertise

Agricultural engineering, Bio-systems design, Design methodology for sustainable agricultural production, Theory of inventive problem solving (TRIZ),

Horticultural production systems, greenhouse technology, crop growth, light control, balances, air treatment units, carbon dioxide enrichment, resource management for minimized use of heat, power, CO_2, and water, sustainable energy, energy buffering, irrigation,

Discrete-event simulation of crop operations in horticultural production systems,

Animal production systems, Indoor climate in agricultural production facilities, Dynamic indoor climate simulation in naturally and forced ventilated buildings, Ventilation and air conditioning, Psychrometrics, Insolation of shaded building surfaces, Active and passive solar energy use, Design and climate in cold stores, Energy demand of livestock houses.

Member of (inter)national professional organizations: ISHS, EurAgEng, NVTL, KLV.

Modelling in Matlab, Simulink, SimEvents, Visual Basic (VB and VBa), Visual Fortran, and Labview for education and research.

Current activities

Teaching and coordinating courses, supervision of BSc and MSc students, PhD research on Systematic design of automated sustainable horticultural production systems

Contribution to courses

FTE25303, FTE31306, FTE33806

Simulation of crop operations in horticultural production systems, pictures show sweet pepper harvest at a participating grower, Fa. van der Harg van Winden, Bemmel. Automated transport in main aisle (a), electrical trolley for in path operations (b)

Hanneke (J.C.A.M.) Pompe, MPS

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Affiliations

Lecturer, internship coordinator, Farm Technology Group

Education

1983 - MPS (Master of Professional Studies) Agricultural Engineering, Cornell University, Ithaca, New York, USA

1973 - BSc Horticulture, Higher Horticultural College, Utrecht, The Netherlands.

Expertise:

Relations between cow behaviour, labor requirement, technology and facility lay-out

Discrete-event simulation and logistics.

Current activities

Coordinating internships, process coaching, teaching, acquisition of ACT cases

Contribution to courses

FTE-25806, FTE-30306, FTE-70400, YAM-60312

Examples of cover pages of internship reports

Dennis (J.W.) Snoek, MSc

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Affiliations:

Teacher at Farm Technology Group

PhD candidate at Farm Technology Group

Education

2010 MSc Agricultural and Bioresource Engineering, Wageningen University, Wageningen, The Netherlands

Expertise

Ammonia emission

Emission modelling

Emission measurements

Dairy cow housing, especially floors and climate

Member of NVTL and EurAgEng

Treasurer of WAPS council (WIAS Associated PhD students council)

Current activities

Teaching Engineering Design, PhD research on the ammonia emission from dairy cow houses, and supervision of BSc and MSc students.

Contribution to courses

FTE - 24806, FTE - 30306

Urinating dairy cow = start of ammonia emission process on the floor in a dairy cow house

Bastiaan (B.A.) Vroegindeweij, MSc

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Affiliations:

PhD Student at Farm Technology Group

Education

2010 MSc Agricultural and Bioresource Engineering (with honours), Wageningen University, Wageningen, The Netherlands

Expertise

Path planning, localisation, machine vision

Automation, robot control

Design methods, livestock technology

Poultry production

Current activities

Performing PhD research, supervision of BSc and MSc students

Contribution to courses

YEI80324, FTE804nn

Research projects

Development of a sweet-pepper harvesting robot

Optimal management of energy resources in greenhouse production systems

Resilience in farm animals

Sensor data fusion for assessing soil properties

Design methods for sustainable production systems

Development of an automated poultry red mite monitoring system

Systematic design of automated sustainable horticultural production systems

Development of an assessment strategy to determine the ammonia emission from dairy cow houses

Mobile-based autonomous system for real time detection and removal of volunteer potato plants in sugar beet field

Moving beyond manure/integrated manure management to improve the environmental performance in the chain from animal to crop

Automation for poultry production

Anaerobic digestion of livestock wastes: optimising energy yield from segregated piggery faeces

Development and application of a novel design method to unify heterogeneous, and apparent contradictory, needs in animal production systems

Assessment of the methane emission of individual dairy cows at farm house level

Ir. Wouter (C.W.) Bac

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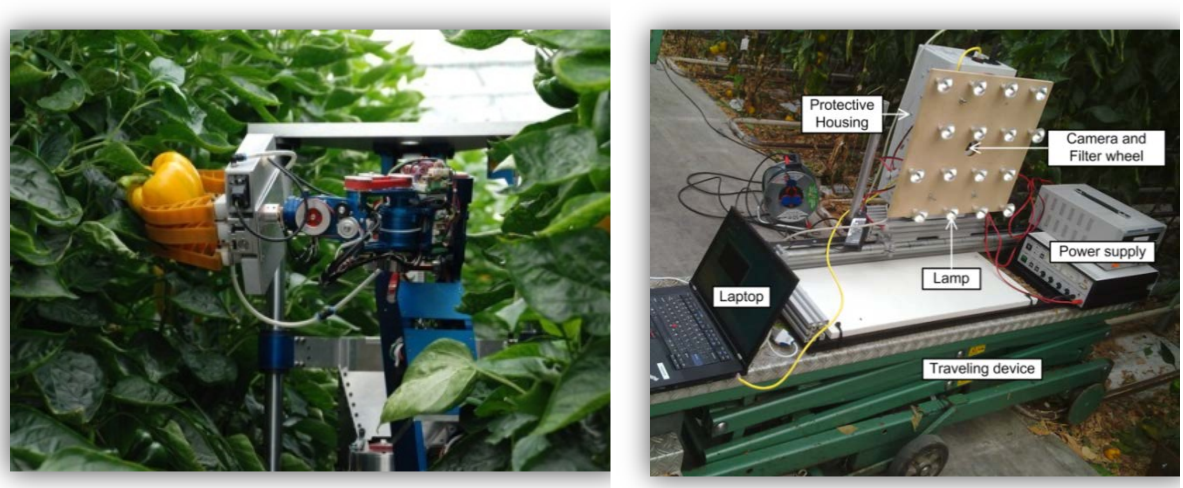
Supervisors: Prof.dr.ir. E.J. van Henten en Dr. J. Hemming
In collaboration with: Wageningen UR Greenhouse Horticulture

Development of a sweet-pepper harvesting robot

This PhD research is part of the EU funded CROPS project in which robotic systems are under development for apple harvesting, grape harvesting, sweet-pepper harvesting, spraying and navigation in forestry. Wageningen UR Greenhouse horticulture leads the development of a sweet-pepper harvesting robot and this PhD project is embedded in this development. The PhD project comprises four objectives. First objective is to review state-of-the-art literature regarding robotic systems for high-value crops. Robots are reviewed in terms of performance, design choices and algorithms used. Based on this data, bottlenecks and challenges are defined as a first step toward commercialization of robotic systems for plant maintenance operations in high-value crops. Secondly, an objective is to distinguish plant parts of a sweet-pepper plant by means of multi-spectral imaging and image processing algorithms. Plant parts such as stems and fruits are hard obstacles, which should be avoided by the robot arm and gripper. Leaves are soft obstacles that can be touched and pushed aside if required. The third objective is to develop a motion-planning algorithm that is able to avoid hard obstacles and can guide the arm toward ripe fruits. Finally, all hardware- and software components will be combined to perform a field test and to determine robot performance in terms of harvest success, damage rate and cycle time.



A sweet-pepper harvesting robot

Peter (P.J.M.) van Beveren, MSc

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Supervisors: Prof.dr.ir. E.J. van Henten, Dr. J. Bontsema (Wageningen UR Greenhouse Horticulture), Prof.dr.ir. G.van Straten (BRD)
In collaboration with: Wageningen UR Greenhouse Horticulture, Hortimax B.V., Lek Habo Groep B.V., Boonekamp Roses B.V.

Optimal management of energy resources in greenhouse production systems

This project is part of the Smart Energy Systems programme of STW. In the interest of reducing energy consumption and CO_2 emission while maintaining productivity, greenhouse growers have installed a wide range of auxiliary equipment, such as assimilate lighting, heat exchangers, short and long term heat buffers, co-generation units and heat pumps. The task of the grower to manage his equipment in the most economical way has become very complicated, not only because of the complex intrinsic physics of the greenhouse dynamics, but also because of the uncertainty in the weather, and, in addition, the strongly fluctuating market prices of energy. The aim of this project is to develop optimal scheduling or management procedures. Scientifically, this can be seen as a non-linear dynamic optimization problem with uncertainty in external prices and external influences. While under assumed prices and future weather the problem can – theoretically – be solved off-line by known numerical methods, the real challenge is to obtain feasible on-line optimal or near optimal operation strategies.

The main challenge of this project is to formulate and solve this optimization problem and to develop optimal scheduling or management procedures. The optimization problem is split into two parts; first the total energy input to the greenhouse is minimized, and secondly the energy scheduling will be optimized. In order to minimize the total energy input to the greenhouse, a dynamic climate model for greenhouse air temperature, humidity, and CO_2 concentration was developed and validated with measurement data. Optimization (minimizing the total energy input to the greenhouse) is done with constraints on the temperature, humidity and CO_2 concentration.



Drs. Ingrid (I.D.E.) van Dixhoorn

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Resilience in Farm animals

The main objective of this research is to identify and quantify generic measures that indicate the capability of individual animals (at a particular moment) to cope with (infectious) disruptions. This is referred to as the resilience, or more precisely *the precariousness*, of individual farm animals and it will be quantified by describing the dynamics of one or more physiological variables (referred to as biomarkers) which can be measured easily and repeatedly in growing piglets.

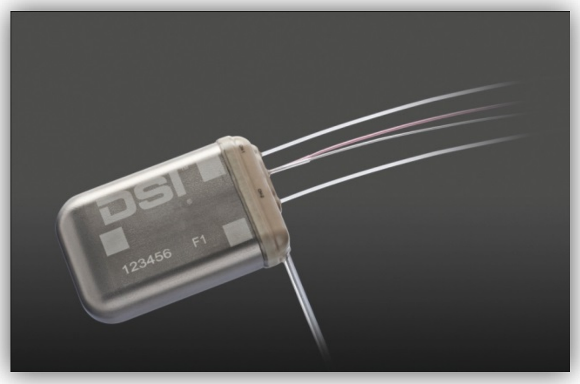
The hypotheses that will be tested in this research are:

1. There are biological variables within the complex system of an animal that can be used as indicators for the resilience concept of precariousness and can be measured continuously during (long) periods of the life time of an animal

2. The continuous dynamic signal of this indicator can be analysed and modelled so that the characteristics of the biomarker can be assessed.

3. The biomarker varies in time and between animals, and has a predictive value with respect to the ability of the animal to respond to infectious disturbances and other perturbations.

4. The theory of critical slowing down as assessed by Scheffer *et al.*, (2009) on population dynamics can be applied to individual animals. Precariousness is reduced whenever critical slowing down is approaching, meaning that it is more difficult for these animals to adapt after only small perturbations.



Sultan (H.S.) Mahmood, MSc

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Sensor data fusion for assessing soil properties

Precision agriculture is an emerging high-technology agricultural management system whose fundamental aim is to increase the profitability of crops, to optimize the use of agricultural inputs and to reduce potentially negative environmental impacts by localized management based on the quantification of in-field spatial and temporal variability. The development of various types of soil sensors is expected to increase the effectiveness of soil characterization in precision agriculture. There are different satellite-based, airborne and ground-based soil sensors used to characterize important soil properties. Satellite or aerial remote sensing suffer from inadequate spatial and temporal resolution, while the proximal remote sensing methods may give fine-scale information on soil properties of interest. Therefore, the conventional laboratory methods are being replaced or complemented with proximal or ground-based soil sensors as analytical soil sensing techniques. Keeping in view the above facts and issues, it was hypothesized that:

1. The fusion of multiple soil sensors (combining the outputs of different sensors) will improve the accuracy of predictions of various soil properties and permit their application over a greater range of soil physical and chemical properties.
2. Sensor data fusion system for sensing soil properties can form an integral component of technology in precision agriculture.

The overall objective of this PhD study was to use a multiple soil sensors data fusion technique for modelling important soil properties and to assess and evaluate its significance and scope in precision agriculture. In this study three different types of soil sensors with different measuring principles have been used. They include an EM38 (an electromagnetic induction sensor), a visible-near infrared spectrometer and a gamma radiometer. Data handling and analysis was done by applying different multivariate statistical techniques. Defense of the thesis took place on July 4, 2013.

Use of EM38 in the field

Use of VNIR (visible-infrared) sensor in the laboratory

Hanneke (A.M.) Miedema, MSc

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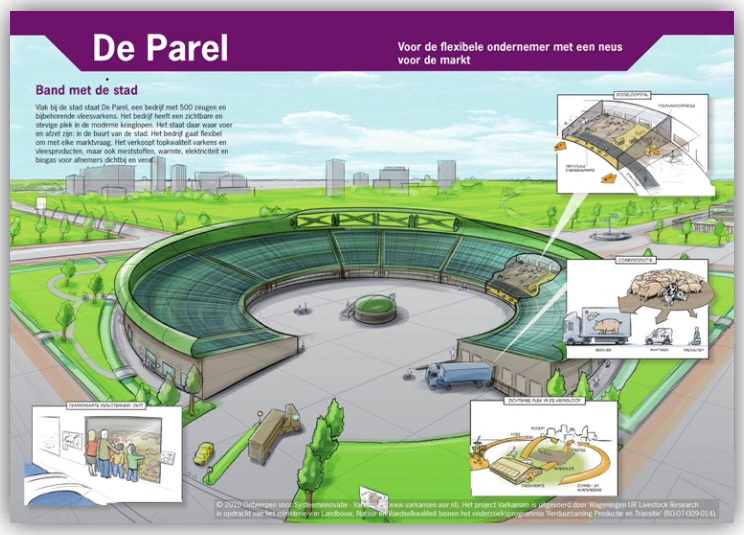
Design methods for sustainable production systems

Hanneke's research is about the design of sustainable animal husbandry systems. Wageningen UR Livestock Research Institute developed a design approach in which several scientific disciplines are brought together to design sustainable animal husbandry systems, the so-called RIO approach. RIO – a Dutch acronym for Reflexive Interactive Design – aims at system innovation in animal husbandry by following an interactive approach with multiple stakeholders. It forms a platform where a practical realisation of reflexive modernization as a social phenomenon is carried out, and where reflective learning processes of individual participants may take place.

During a particular RIO project, called Varkansen, data are gathered to understand the relationship between reflexive modernization as a social phenomenon and the individual learning process. Furthermore an analytical tool is developed to analyse those data and scrutinize the theoretical and practical connexion between reflexive modernization and reflective learning in a project setting. Based on those insights recommendations can be made for the outline of future projects aiming at system innovation.



A result of the interdisciplinary design project Varkansen

Ir. Monique (M.F.) Mul

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Supervisors: Prof.dr.ir. P.W.G. Groot Koerkamp, Prof. Dr. M. Dicke, Dr. ir. B.G. Meerburg, Dr. D.R. George

Development of an automated Poultry Red Mite monitoring system

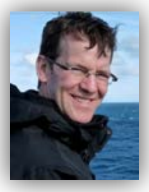
The Poultry Red Mite (Dermanyssus gallinae) is the most common ectoparasite in poultry farms worldwide and can be a true pest as a Poultry Red Mites (PRM) infestation may result in high economic losses, veterinary risks and allergic reactions among farm workers. PRM feed on blood of poultry and sometimes humans in order to develop to the adult stage and reproduce. In Europe, there is a large number of outbreaks due to increasing resistance of PRM to some acaricides and a ban on other chemical pesticides. Therefore, recent research has been focused on more sustainable control methods such as the use of natural enemies, attract and kill methods using fungi and development of a vaccine. Application of these methods is most effective when applied in poultry houses with relative low numbers of PRM. For an effective, timely and place specific application of most control methods, monitoring of the size, place and the development of the PRM population is necessary. Currently, existing monitoring methods for poultry red mite are labor intensive, mostly applicable to one poultry housing system and fit for research purposes only. Thus, we aim to develop an automated monitoring device for poultry red mite in layer farms which is composed of an automated counter of PRM and a dynamic adaptive model. This monitoring device assesses the PRM population in 1) the actual situation, 2) after a treatment (effect) and 3) in future situations (necessary to indicate timely future treatment).

The idea and the development of the automated mite monitor is unique due to the cooperation of researchers working in very many different fields; Animal Husbandry, Entomology, Technology and Statistics. The best ideas of all fields come together in this research and therefore real new products can be developed.

Present labour intensive way of mite monitoring

Future mite monitoring

Ir. Bert (A.) van 't Ooster



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In collaboration with: Wageningen UR Greenhouse Horticulture

Systematic design of automated sustainable horticultural production systems

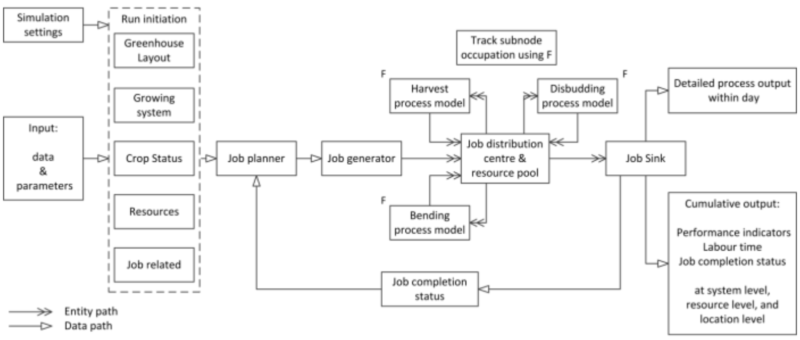
Growers face numerous competitive challenges, which urge them to continuously improve labour efficiency and to innovate crop operations. Within this project, the discrete event simulation model GWorkS on labour use in crop operations was developed to find effects of organizational and technical modifications in crop operations as well as to verify the operation of horticultural production systems for effective use of resources and efficient task execution. The project aims to contribute to cost effective well equipped greenhouses with effective execution of crop operations and optimal internal logistics.

In 2013, the GWorkS model was extended for simulation of labour processes in multiple crop operations using a limited number of employees and trolleys. Employees were optionally given equal or individual properties. The GWorkS model handles job planning, job routing, resource allocation, prioritisation of tasks in time and place, as well as simultaneity of task execution. GWorkS was used for integrated simulation of harvest, bending and disbudding in cut-rose cultivation and for selection of a best scenario. It was additionally used to simulate harvest of sweet pepper.

For cut-rose several labour management scenarios were simulated. A real labour management scenario as applied in a Dutch cut-rose grower company was used as a reference. Harvesting, disbudding and bending represent more than 90% of crop-bound labour time. The model calculates the labour time in these processes well with 10.9 per s rose in the simulation and 11.5 s per rose in practice.

The scenarios showed that labour management is important because difference in labour time for harvest, disbudding and bending was up to 5 s per cut-rose. The maximum difference in labour costs was € 7.1 m-2 per year. The best scenario showed labour cost saving of € 4 m2 per year compared to practice.

So far, three papers were published and one paper was prepared for publication.



GWorkS - Integrated simulation of crop operations in a cut-rose production system

Dennis (J.W.) Snoek MSc

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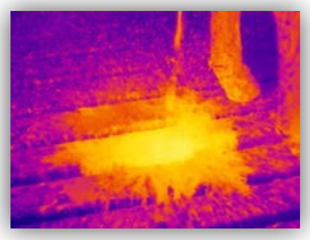
In collaboration with: ASG – Wageningen UR Livestock Research

Development of an assessment strategy to determine the ammonia emission from dairy cow houses

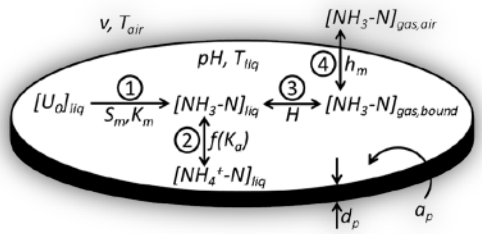
National (Netherlands) and international policy aim to decrease the ammonia emission from dairy production. Measures to reduce emissions are under development, e.g. feeding strategies, covering of slurry pits, and new designs of floors for walking alleys in dairy cow houses. For various reasons good assessment of the emission reduction, and by that the effectiveness of a measure, is difficult and costly. In addition, the emission from traditional, apparently the same, cubicle houses varies strongly.

In the ideal situation the ammonia emission from an arbitrary cubicle dairy cow house can be assessed with sufficient accuracy and with limited time and costs. The house is either traditional or with reduction measures. Moreover, the assessed emission level can be corrected for 1) standardized outdoor climate conditions and 2) effects of specific circumstances, in order to 3) distinguish the effect of specific reduction measures from other effects and sources of variation. This PhD is a first step towards this final goal.

Focus of this PhD, and the main objective, is to develop an ‘ammonia assessment strategy’. This strategy is an emission model in combination with measurements of key variables of the ammonia emission processes under practical circumstances. Key variables at the floor are, in order of importance: puddle pH, puddle depth, puddle Urea concentration, puddle area and puddle temperature (Snoek et al., 2014, accepted for publication). The goal of this strategy is to determine the ammonia emission in a precise and cost effective way in a dairy cow house. The strategy should apply for any dairy cow house with a specific design, at a specific location, with specific climate conditions.

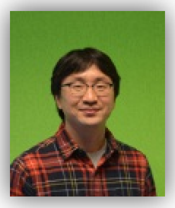


Dairy cow urinating at a slatted floor. Light (yellow) is warm and dark (purple) is cold.



Schematic representation of the ammonia emission process in a urine puddle including parameters and process steps (Snoek et al., 2014, accepted for publication)

Hyun (H.K.) Suh, MSc



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Supervisors: Prof.dr.ir. E.J. van Henten, Dr.ir. J.W. Hofstee
In collaboration with: EU SmartBot

Mobile-based autonomous system for real time detection and removal of volunteer potato plants in sugar beet field

This research, funded by EU Smartbot Project, is to develop an automated system based on mobile platform for fast and effective control of volunteer potato plants in sugar beet field. A major need for an automated weed control system together with consideration of environmental issues and concerns leads to develop small and lightweight, but self-guided and fully autonomous, mobile based system for efficient control of volunteer potatoes in the field. The work mainly consists of three procedures such as detection unit development, weed removal unit development, and integration into mobile platform with Robot Operating System (ROS). Throughout the year of 2013, crop field images were acquired in two experimental sugar beet fields in Wageningen. More than 5,000 images were obtained, as a manually controlled mobile-device was driven through the fields, at various times during daylight in June, August, and October 2013. Several different illumination conditions including extreme illumination scenes caused by direct sunlight and shadow were taken into consideration to build a robust image processing algorithm for the discrimination of sugar beet and volunteer potato in natural field condition. ColorChecker® images were also acquired on different days under different outdoor illumination conditions.

A discrimination algorithm is currently being developing for an universal solution for vision-based agricultural field applications.

Automated detection and control of volunteer potato plants

Ir. Jerke (J.W.) de Vries

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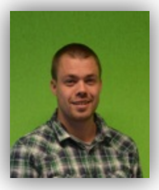
In collaboration with: Animal Production Systems

Moving beyond manure/Integrated manure management to improve the environmental performance in the chain from animal to crop

Intensification of animal and crop production systems in the past 50 years has led to disintegrated farming systems resulting in displacement of crop and livestock farming and higher environmental impact. Manure and fertilizer management are key areas in the related environmental impact of modern farming systems. Innovations in crop and animal production systems, such as anaerobic digestion of manure for energy production and processing of manure into liquid fertilizer, have emerged, which can partly counter negative environmental side effects. However, little research has been done on the integration of measures addressing more managerial aspects and including multiple environmental effects in the chain from animal to crop. This research aims at improving the environmental performance through reductions of nitrogen, phosphorus and carbon emissions, in the chain from animal to crop by: tailoring manure products and management, and soil management to crop production needs. Managerial aspects included in the study are: manure product and quality, application amount, timing, placement and application technology in addition with soil tillage. By setting environmental goals and by using a methodical approach to engineering design, new chains from animal to crop and management approaches are designed aiming at low environmental impact. Life Cycle Assessment (LCA) is applied as a methodology to quantify the environmental consequences of these designed chains. Environmental indicators included in the assessment are greenhouse gas emissions, acidification potential, eutrophication potential, fossil fuel depletion and particulate matter formation. Final results of the research give fundamental insight in the environmental consequences of applying several combinations of manure and soil management techniques in the chain from animal to crop.

High-tech manure processing (courtesy of Animal Sciences Group)

Ir. Bastiaan (B.A.)Vroegindeweij



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Supervisors: Prof.dr.ir. P.W.G. Groot Koerkamp, Prof.dr.ir. E.J. van Henten

Automation for Poultry Production

As a result of the current change to loose-housing systems with more freedom for the animals, also working methods and management strategies are changing. In modern poultry housings for example, farmers have to manage a flock instead of a housing as with the traditional cages.

Next, also some old problems reoccur, like the presence of misplaced eggs, caused by hens placing their eggs outside the laying nests. These eggs create an extra workload for the farmers and reduce their profits. A lot of research has been done to decrease the number of floor eggs, but a solution to overcome this problem was not yet found.

Current measures to deal with these issues all rely on manual labour and control. For example, the (preventive) collection of these floor eggs is currently done by the farmer by hand. It is a physically and time demanding job, so that there is a need to ease and improve this collection. During the Field Robot Event of 2007, the idea of collecting floor eggs (outer-nest eggs on the litter) with help of a robot emerged.

The research is about working on the evaluation of current and new technology for use in automation on their potentials when dealing with such problems. Target is to come up with new solutions for further automation of poultry production, and more specifically for a vehicle that collects floor eggs autonomously and with special attention for the characteristics of this problem.

Specific examples are the testing of localization methods on their accuracy inside modern aviary housings and modelling floor laying behavior and using this to perform path-planning for the collection of floor eggs. The latter one is designed specific for the complex task of gathering floor eggs, but can also be used for other purposes like cleaning areas or searching for objects. Another important issue is object recognition, which can be used for performing desired tasks as well as ensuring operational safety of the vehicle. Finally, also the financial aspects and the machine-animal interactions are taken into account.


Acquiring data and a position reference inside an empty poultry house

Phuong Thuy (P.T.) Vu, MSc

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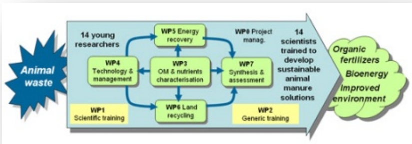
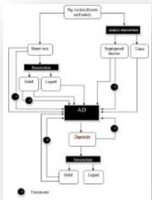
In collaboration with: Livestock research and Sub-department of Environmental Technology, Wageningen UR
Fund: ReUseWaste – An Initial Training Network project funded under the Marie Curie action of the EU-FP7-PEOPLE-2011 program.

Anaerobic digestion of livestock wastes: Optimising energy yield from segregated piggery faeces

The project "*Anaerobic digestion of livestock wastes: Optimising energy yield from segregated piggery faeces*" is one of 12 PhD projects of the Marie Curie training network named Reuse waste started in January 2012. The project gathers 8 EU research groups of leading universities, research institutes, companies from the regions with the most intensive livestock production in Europe that focuses on manure management systems.





Scheme of research activities of the Reusewaste network (Source: Reusewaste.eu)

Options for managing the manure with AD treatment technique

The PhD project aims to develop new anaerobic digestion methods for optimal energy yield and nutrient use from animal manure. The idea is to use the segregated faeces of piggery waste that is high in dry matter content as the feedstock for digester. The first experiment is to evaluate the biogas production potential and nutrient speciation of segregated faeces. Afterward, the effects of thermal chemical pre-treatment of segregated faeces and thermal post-treatment of digestate on biogas yield and digestate composition are tested. The developed anaerobic digestion process then will be validated by experiment with continuous stirred tank reactor (Figure 2). After 1 year and 3 months, the highlights of the work have been the successful completion of the trial experiments, which gives more insight into the methane production potential of different substrates. Furthermore, the results provide input for the design and performance of the planned future experimental studies.

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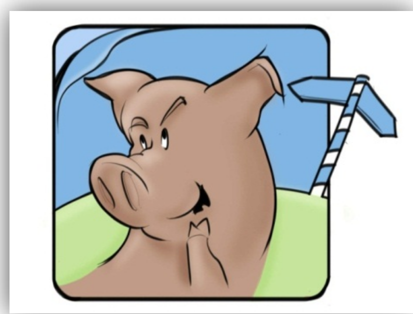
Dr. M.B.M. Bracke, Dr. A.J.A. Aarnink

Development and application of a novel design method to unify heterogeneous, and apparent contradictory, needs in animal production systems

Is it possible to achieve an in all aspects sustainable animal-based food production? Which means that all the different requirements and needs of all the different sustainability aspects, people, animal and environment are unified. An ambition that can only be achieved when you acknowledge the different needs during the design process of new and alternative systems. It appears that the animal plays a central and crucial role. Not only is the animal a product, user, stakeholder, but a possible contributor to system goals and functions as well. By letting the animals do what they are inclined, naturally motived to do, you can profit from that on other sustainability goals. How we can make this work in a structured design methodology is one of the challenges of this research.
In this project research is done on the often perceived contradictions between animal welfare and the environment. Especially in our current production systems with the current chosen solutions contradictions between these two sustainability aspects, animal welfare and environment, is an issue. To be able to circumvent these contradictions in the design of future alternative systems, a new design methodology is set-up. A design methodology that acknowledges all the different stakeholders and is able to unify the complexity of needs in new integrated solutions. A leading principle is to deploy the animal better, so we all can benefit from what comes naturally for the animals, in terms of the welfare of the animal itself as well as human welfare, environment and profit. Taking this principle as guidance we propose that this is an opportunity to overcome some significant contradictions current animal-based food production experiences.



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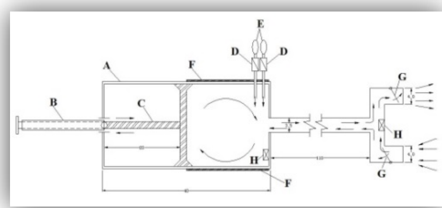
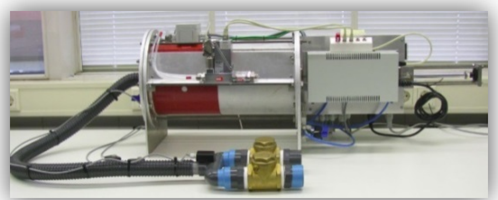
Supervisors: Prof.dr.ir. P.W.G. Groot Koerkamp, Dr.ir. N.W.M. Ogink

Assessment of the methane emission of individual dairy cows at farm house level

Methane emission from dairy cattle accounts for a significant portion of the global CH_4 budget which is a substantial contributor to the Global Greenhouse effect. Also as a by-product of microbial fermentation process, methane generation results in about 6-10% loss of the gross energy intake (GEI). In this project we shall design, test and validate an assessment method to determine the methane emission of individual dairy cattle at farm house level. Herewith we measure the variation of the methane emission between a large numbers of cows in practice. Through understanding and evaluating methane emission from individual dairy cattle in large numbers, the methane conversion expressed as the methane emission per unit of milk production can be assessed within the dairy cattle. This information can be used for breeding dairy cattle with low methane conversion which contributes to reducing the environmental impact of dairy farms and increasing the productivity. Besides breeding, also the effect of other mitigation measures can be assessed at animal level, like feeding measures. This project includes following studies: 1) Design and construct the measurement equipment & set-up for methane emission from individual dairy cattle and test under experimental small-scale condition; 2) Evaluate and validate different set-up measurement methods under practical conditions by measurements with real cows; 3) Carry out a proof of principle under practical conditions (up to 50 cows) where methane emission and conversion will be measured during a long period. Strengths and weaknesses of each method were evaluated what further research should be undertaken to improve the methodology according to measurement requirements at farm level.

In 2013, we designed and constructed an artificial methane cow to simulate the methane production progress as real cows. We tested the mass balance of simulator with different methane production levels. Moreover, we measured the methane concentration pattern created from the artificial cow and compared with the results measured from real cows. Therefore, we can use it as a reference method to develop and evaluate other measurement methods, instead of using complicated respiration calorimetric chamber methods.





Schematic overview of artificial cow (left) and practical photo (right)

BSc projects completed in 2013

Alders, B.P.G.J. (August 30)
Oorzaken van verminderde voeropname van drachtige zeugen in groepshuisvesting met voerstations

Dueren den Hollander, A.W. van (July 08)
Ontwerpen van een zeewieroogstinstallatie

Duisterwinkel, M.H.P. (July 08)
Nitrogen sidedressing in seed potatoes on the basis of reflectance measurements and an advice system

Haanstra, L.J. (June 26)
Greenfertilizer. Towards producing anhydrous ammonia on the farm

Haperen, M.J.A.M. van (February 18)
Positiebepaling van een autonoom voertuig door middel van een laserscanner in een voliërestal

Huting, M.G. (March 25)
Assessing sustainability of agricultural regions

Lieshoud, C.W. van (August 30)
The opportunities for Agri 2.0 Precision Farming in Poland

Miedema, T.H. (February 07)
Ammoniakonderzoeken voor het ontwerpen van een emissiemeetbox voor vrijloopstallen

Mol, J.C. (July 02)
The behaviour of diffuse light in vertical plate reactors for algae cultivation

Niessen, K. (October 28)
Stereovisie en het onderscheiden van aardappelopslag en suikerbietenplanten

Saglibene, M.J. (July 12)
The canyon effect: Decay of diffuse light between vertical plates

Schaik, C.G. van (November 07)
Emissiemetingen in vrijloopstallen

Steenbergen, G. van (August 13)
Navigation of the Husky in a sugar beet field – Optimization of row detection

Thiessen, M.B.E. (June 27)
De betekenis van de aggregaatstabiliteit als indicator voor de fysische bodemkwaliteit

Thomassen, G. (August 29)
Design and evaluation of a system to remove and separate broiler litter

Tielen, A.P.M. (August 22)
Implementatie in de praktijk van een autonome besturing ten behoeve van autonoom aardbeien spuiten

Verhoijsen, W.J.M. (January 10)
Probleemanalyse vleeskuikensector en bepaling van herkenningstechnieken voor dode kuikens

Visser, A.C. de (June 18)
Local sustainable hydrogen production

Voois, J.P. (August 26)
Analysis of the current control strategy in a modern rose greenhouse

MSc projects completed in 2013

Booij, J.A. (August 26)
Design and implementation of a generic steering and testing software for real time path following control in a master slave system

Boonman, J.C.P. (December 19)
Improving vision based classification between sugar beet and volunteer potato plants using regular plant spacing features

Fransen, T.S. (August 26)
Technical and economic feasibility of a CO_2 enrichment system in free air production of agricultural crops

Honcoop, P. (July 8)
Economic evaluation of soil compaction in wheat harvesting

Hoog, D.C. de (April 4)
Design evaluation of a sweet pepper harvesting manipulator using experiments and simulations

Jager, M.G. de (July 1)
Colour constancy in machine vision under varying natural lighting conditions

Kool, F. (November 26)
Validation of a new HRV analysis model for application in pigs

Koolen, D.J. (December 9)
Path generation of headland turns

Leijdekkers, C.M.M. (May 29)
Evaluation of algae production systems in Dutch greenhouses in practice

Okenna, Obi-Njoku, (August, 29)
Developing energy autonomous farms in Nigeria, based on a case study

Olst, R. van (April 4)
Mobile robot localization in Non-cage poultry housing

Oomen, M.A.R.M. (June 17)
Model based disease detection in dairy cows with the use of individual bioprocess signals

Ou, X. (August 29)
Design a sustainable Chinese solar greenhouse – a simulation study

Roorda, T. (December 19)
Motion planning for a redundant manipulator to harvest sweet-pepper

Schutte, J.J.W. (August 30)
Growth monitoring of rearing calves using a 3D camera

Simons, J.C.A. (October 29)
Vision based control for grasping vine tomatoes with a robot

Straver, J. (March 4)
Simulation of workflows and internal logistics on crop handling operations other than harvest in a conventional growing system

Veldhuisen, A. (December 17)
Development of a safety system for autonomous agricultural vehicles

Ven, T.A.J. van de (April 4)
Validation and application of a cow positioning system

Vollebregt, M.J.P. (May, 28)
Texture based discrimination between sugar beet and volunteer potato

Education

The Farm Technology Group offers a wide range of courses related to biosystems engineering on BSc and MSc level. The group is a main contributor to the BSc and the MSc Biosystems Engineering.

Education of the Farm Technology Group

The Farm Technology Group offers a wide range of courses on bachelor and master level. The course offer ranges from basic engineering principles in the course Engineering 1 for the BSc to the advanced courses for the MSc as for example Greenhouse Technology or Automation for Bioproduction. Many courses are general engineering courses with many examples from the biosystems engineering domain. The course offer also comprises research methods courses for the BSc Biosystems engineering and – in cooperation with several other chairs - an introduction course for the BSc Biosystems Engineering. In addition to the courses there are also thesis and internship courses.

An important part of the work of the group is design in the biosystems engineering context and several courses taught by the group are related to this. Engineering Design as introduction for the bachelor students and Biosystems Design and Quantitative Analysis of Innovative Biosystems courses for the MSc. In addition to these more general courses the group offers advanced technology courses for the MSc on livestock, greenhouse, automation and soil.

The following courses are offered by the group:

FTE-12303 Introduction Biosystems Engineering part 1 (Dutch)
FTE-12803 Introduction Biosystems Engineering part 2 (Dutch)
FTE-13303 Introduction to Engineering 1 (Dutch)
FTE-13807 Engineering 2 (Dutch)
FTE-24306 Research Methods Biosystems Engineering 1 (Dutch)
FTE-24806 Engineering Design (Dutch)
FTE-25303 Building Physics and Climate Engineering (English)
FTE-25806 Research Methods Biosystems Engineering 2 (Dutch)
FTE-30306 Livestock Technology (English)
FTE-31306 Greenhouse Technology (English)
FTE-32306 Advanced Soil Technology (English)
FTE-32806 Automation for Bio-production (English)

FTE-33306 Advanced Biosystems Engineering (English)

FTE-33806 Biosystems Design (English)

FTE-34306 Evaluation and Redesign of Biosystems (English)

FTE-50806 Conservation Agriculture (English)

FTE-704nn MSc Internship Farm Technology (24, 27, 30, 33, 36, 39 credits)

FTE-804nn MSc Thesis Farm Technology (24, 27, 30, 33, 36, 39 credits)

BRD-22306 Sensor Technology

YEI-80324 Bachelor thesis Biosystems Engineering

FTE-12303 Introduction Biosystems Engineering part 1 (Dutch)

This course is the introduction course to the domain biosystems engineering. Students get an overview of the technology used in different biosystems for the production of food and non-food and they will get a good insight into the role of the different courses in the study programme.

Systems approach is the connecting thread in the course and the course will start therefore with an introduction to systems theory and analysis. The course then continues with lectures, tutorials, and practicals on topics relevant in nowadays biosystems engineering: automation, energy, environment and welfare, climate control, and (agro)production chains and logistics. Special attention is given to the importance of the (agro)production chain for technology in biosystems. Students work in small groups on calculations and computer simulations related to real problems in the area of biosystems engineering. Excursions are organized to make the technology visible to the students on different levels in the production chain (farm, processing industry, wholesaler) visible.

The course also incorporates some skills modules. The module CCI makes the students acquainted with the more advanced functions of office applications (Word, PowerPoint and especially Excel). The module Information literacy makes the students acquainted with retrieval of information from different sources. Students have to prepare a report on relevant technology in the framework of biosystems engineering. An introduction to oral presenting is also part of the course and at the end of the course the students have to give a brief presentation on the report they prepared.

The first part consists of the introduction to systems theory and analysis, two of the five relevant topics, the module CCI and the introduction of the module information literacy.

FTE-12803 Introduction Biosystems Engineering part 2 (Dutch)

This course is the continuation of FTE-12303 Introduction Agrotechnology part 1. See the description of that course. This second part covers the remaining three relevant topics, the module oral presenting and the preparation of the report.

FTE-13303 Introduction to Engineering 1

In this course the students are introduced to selected engineering topics that demonstrate how engineers approach problem solving and arrive at correct solutions. These subject areas are common to most engineering disciplines that require the application of fundamental engineering concepts. Subjects in the course are engineering solutions, presentation of technical information, engineering measurements and estimation, dimensions and units, mechanics, material balance, energy, and electrical theory. Students will also follow some practicals at ptc+ in Ede. Attention is also paid to the engineering profession. This course includes some excursions to relevant companies. The students also have to prepare a brief internship to be spent (in the next period) at a relevant company or organization in the field of biosystems engineering.

FTE-13807 Engineering 2 (Dutch)

This course is a continuation of the course Engineering 1. This part contains modules on CAD (Computer Aided Design), and electronics, and lectures and tutorials on mechanics. There are also some excursions to relevant industries or organizations and students have to fulfil a brief internship. At the end they have to prepare and present a poster on their experience and inform the other students on their experience.
In the mechanics part the students are introduced to the topics stress and strain and the relation between them. Main focus will be on the calculation of the deformation of a structural member, based on the size, acting forces, and moments. The required size of a structural member, based on design constraints as limiting stress or deformation will be calculated too. In the CAD module the students learn the basic principles of CAD. It starts with making sketches of simple technical objects and continues with the learning of a 3D modelling programme AutoDesk Inventor). In this programme parts of technical systems are modelled and technical drawings documented. Finally, calculations on mechanical stress will be done. Here the theory from the lectures and the tutorials is integrated in the 3D modelling program.

The module electronics gives an introduction to the basics of modern electronics. From the basic elements (resistors, capacitors and coils) circuits will be built and analysed with a focus on the frequency response. The theory of diodes and transistors will be explained and tested in practice. All this being the start of more advanced elements like the operational amplifier in both feedback and non-feedback applications. Furthermore the production process (steps and techniques) of integrated circuits (chips) will be presented. In the course students will also learn about basic digital circuits (gates, flip-flops) forming the fundamental base of modern digital computers.

FTE-24306 Research Methods Biosystems Engineering 1 (Dutch)

In this course the students learn the different steps of doing research: problem analysis - problem definition - objective of the research - research questions - project proposal - execution of the research - presentation of results - discussion - conclusion. The students will exercise these different steps by a number of related assignments.

Included in the course are practical exercises where the students are faced with biological and natural variability and where they are instructed how to approach this phenomenon typical for most biosystems.

Part of the course is the module Information Literacy B in which the students learn how to perform a proper literature search in (scientific) databases.

Students will participate in a professional assessment and, supported by staff, will translate these outcomes in the context of their current programme and future choices..

FTE-24806 Engineering Design

In this course the students learn six consecutive steps of the structured design methodology according to Cross. They practice application of these steps and their related tools in groups of two or three students in a case study. Each group chooses a pre-defined simple (agro)technological design problem. They start analyzing the problem and in the end of the course they present their solution and hand in a report.

Each step of the methodology starts with a lecture with the theory, an example, and a small exercise. After this the groups apply the theory to their case. They get 2 to 4 days to finish the case work. After these days all groups have to hand in discussion points, a small report, and a presentation. Two groups are selected to present their result, followed by a general discussion. In step five each group selects systematically a solution for their problem. During the sixth step they model the selected solution in CAD, apply motion, and check for collisions. From the CAD model, drawings, pictures and videos are produced to be used in the final presentation and the final report.

The course includes an excursion to a manufacturing industry to show the students the practice of engineering design and manufacturing in industry.

FTE-25303 Building Physics and Climate Engineering (English)

This course is closely related to the course Physical Transport Phenomena (BRD-22803) and has the objective to introduce the students to the climate engineering items relevant for the bachelor Biosystems Engineering (BAT). The following subjects are part of the course:

- building physics - thermal insulation of constructions and thermal stability of constructions and room systems;
- psychrometrics - Physical properties of humid air and air conditioning processes;
- comfort areas for indoor climate;
- ventilation requirement calculation;
- design and evaluation of air distribution systems;
- energy demand for agroproduction in buildings;
- solar energy - passive and active for solar energy collection and use;
- (data processing in Excel).

FTE-25806 Research Methods Biosystems Engineering 2 (Dutch)

In this course the students have to execute in groups a small research project. The projects are pre-selected. The students start with making a proposal for their project and subsequently execute this project as a team. They also have to search for scientific literature related to their project and incorporate the literature in the report. In the end, students have to prepare a well-structured report on their project according to scientific standards and present the results orally. Explicit attention in this course will be given to the different aspects of group work (team activities, organisational, social).

FTE-30306 Livestock Technology (English)

Sustainability and sustainable development of animal production systems form the start of this course. This course focuses on the interaction between engineering and technology on the one hand, and biology and animals on the other hand in on-farm animal production systems. The course is organized along four themes, with one theme per week: 1) animal welfare and health (animal needs) and overview of sustainability issues of livestock production and production chains, 2) building physics and indoor climate (management and ventilation of the aerial environment of the animal), 3) current engineering topics in livestock research (air quality & dust, emissions, waste, animal health, design), and 4) farm management of automation and logistics (sensors, precision livestock farming). For each theme current systems and technology are described, in depth knowledge on the technology is presented, management and control of related problems are dealt with as well as the latest innovations in each area to support sustainable development of production systems.”

FTE-31306 Greenhouse Technology (English)

The content of the course focuses on engineering aspects of greenhouse horticulture systems in relation to crop growth and development. The course aims to prepare for a major on Greenhouse Engineering and puts emphasis on calculation and analysis. In depth topics of the course are crop response and growth factors, physics of the greenhouse climate, cultivation systems, greenhouse construction, aerial environment, root environment, greenhouse climate and equipment for climate control, new and smart technology.

As a student you will be confronted with theoretical backgrounds and with methods that are generally used in protected cultivation. You will use this knowledge in exercises (both manual and model based) and in analysis of an integrated system. Focus is both on the Dutch and on the international protected cultivation.

FTE-32306 Advanced Soil Technology (English)

This course offers an in-depth treatment of various aspects of soil technology and tillage, such as:

- soil physical characteristics and conditions which are crucial for an understanding of the effect of mechanical manipulation of the soil and for processes in the field such as compaction and erosion;
- methodologies and techniques for measuring soil physical, mechanical and dynamical parameters, both in the field and in the laboratory;
- state-of-the-art approaches for research in tillage and soil mechanics, including modeling the effects of tillage on soil structure and related parameters (water, gas, strength, erosion).

Each student studies a scientific paper and reports on the approach, methodology and findings to fellow students, followed by discussion.

In addition to this common part, each student :

- chooses a topic related to soil technology and writes an essay/literature review which is presented to fellow students by a poster; assesses various scenarios of soil management under different soil, terrain, crop and climate conditions with respect to crop yields, soil structure and erosion

FTE-32806 Automation for Bio-production (English)

Agriculture is challenged to overcome increasing labor costs, decreasing availability of labor and increasing demands concerning precision, product quality and reduction of environmental and animal load. As can be seen in Western Europe an important solution is to replace human labor by automation in areas such as arable farming, livestock farming, and horticulture. Examples of automation are milking robots, GPS steering of tractors, autonomous vehicles and automated harvesting in greenhouse production. The design and implementation of such automated systems is expected to be at the heart of agricultural innovation the next decades.
The guideline for this course is taken from the robotics domain and is stated as: 'Robotics is the intelligent transformation of perception into mechanical action'. To realize these transformations sensors, actuators, manipulators, vehicles, computers and decision systems, are important components. These components and how they may be applied to design automated agricultural systems constitute the contents of this course.
The theoretical part of this course will be presented during lectures. Practical assignments concern the design, programming and control of robot manipulators and autonomous vehicles.

FTE-33306 Advanced Biosystems Engineering (English)

This course is the introductory course for the MSc Biosystems engineering. The central theme for the course is how society is going to be prepared in the post-fossil fuel area for the production of food, fuel, and biomaterials. The main objective is to introduce a systematic approach to technology development and engineering of systems for a biobased society. The starting point is the technology for sustainable (future) production of biomass for food or non-food. An important connecting thread throughout the course is the development of alternative systems for the production of biomass where system boundaries may move. Today's production of biomass is organized on-farm and the processing is off-farm but this may be challenged in the future to reach a more optimal and sustainable system. Chains and cyclic processes are important since solutions are expected to arrive from approaches beyond farm level.

The course also gives an overview of the different techniques available for a biosystems engineer and provides a link to different other courses in the programme.

FTE-33806 Biosystems Design (English)

In the course the students apply a structural engineering design method to a typical biosystems engineering related design problem with a focus on system innovation. Sustainability aspects of ecological, economical and social order play an important role in the course. The problems / cases in this course are more complex and on a higher systems level than in the course Engineering Design (FTE-24806). It includes an extensive state-of-the-art analysis (semantic search, patent and knowledge research, market exploration and innovation trend analysis). Important aspects of the course are also the organizational aspects of the design project, e.g. the role of stakeholders and collaborative design teams. The design methods taught in FTE-24806 are starting point and extended with methods like technology landscaping, theory of inventive problem solving and intellectual property (IP).
Some typical case studies of technological innovations in biosystems have to be studied and will be presented and discussed. Students have to apply the theory and the ideas behind it to their own design case. The case results are reported in oral presentations and in written team reports.
Part of the course is a multiple day excursion in which relevant organisations, universities, and industries in the Netherlands and surrounding countries are visited. The students have to write a report of this excursion. This multiple day excursion is organised together with the excursion in the course FTE-34306 Evaluation and Redesign of Biosystems.

FTE-34306 Quantitative Analysis of Innovative Biosystems (English)

This course focuses on the quantitative analysis of new design concepts, innovative ideas and technology for biosystems. The analysis of biosystems is performed at farm level or parts of it. Sensitivity analysis is applied to biosystems with greenhouse production or dairy production. The students will learn to analyse the effects on various aspects of sustainability issues: costs and benefits of investments, various environmental impacts, animal welfare, labour requirement, and product quality. The results of the analysis covers 1) type of effects or relationships, 2) pros and cons, 3) limiting and/or critical factors and variables, and 4) options for improved performance. A full assessment of all aspects of the design concepts is characterized by limited availability and uncertainty of information and students have to consult experts and various information sources to make best educated assumptions. Students work in small groups on case studies (dairy or horticulture), analyse the feasibility of innovative farm system designs, and reflect on the chosen assumptions and calculation methods. The course comprises a multiple day field trip with visits to relevant organisations, universities, and industries in the Netherlands and surrounding countries. The students have to write a report about this field trip. This multiple day field trip is jointly organized with the field trip in the course FTE-33806 Biosystems Design. Methods of engineering design will not be covered during this course, but we do expect that students are able to apply these methods.

FTE-50806 Conservation Agriculture (English)

This course examines the concept of Conservation Agriculture (CA) and its effects on ecosystem services. CA is a system based on integrated management of available soil, water and biological resources, combined with as little external inputs as feasible. CA relies on three principles, which must be considered together for appropriate understanding, design and application:

- a (semi-)permanent organic soil cover in order to protect the soil physically from sun, rain and wind and to feed the soil biota;
- minimal disturbance to the soil through no or reduced tillage, and;
- crop rotations to optimize the use efficiency of natural and external resources. CA is spreading rapidly in Europe and abroad as a potentially powerful basket of technologies, applicable in a wide range of environments to achieve sustained production, reduce environmental and economic risks and protect land and water resources. However, its effect on soil ecosystem services generally receives little attention.

Course components:

- replacement of mechanical by biological tillage (soil micro-organisms, roots and soil fauna taking over the tillage function)
- biological soil fertility management and water balancing through soil cover and crop rotation management
- trade-offs between various uses of crop residues;
- the choice and management of (cover) crops and crop rotations are meant to ensure sufficient biomass production of food and other crops, livestock feed and residue cover for the soil.

Crop residue management is meant to stimulate soil structure formation by the soil biota, improve soil fertility and soil water management and help to control diseases, pests and weeds with less dependence on pesticides. Novel technologies and equipment for field operations CA implies the design and use of modern precision agriculture technologies such as the use of RTK/GPS and adapted equipment to cultivate the land without trafficking;

Management and management options at farm level;

CA demands a different, unconventional way of making choices on crops and crop rotations, and needs to consider alternative and additional factors for taking decisions on how to manage the farm Soil ecosystem services

CA claims to be beneficial in terms of reduction of soil erosion and water run-off and the sustained provision of ecosystem services, such as water storage and supply under conditions of water surpluses and shortages, respectively; the retention of nutrients; the reduction of soil-borne pests and diseases; and the sequestration of carbon.

The course critically addresses the above issues by discussing and studying the various components of CA, with special emphasis on management and soil. It will analyse the bottlenecks in application of CA in order to find an explanation of the successes as well as the failures..

BRD-22306 Sensor Technology

Sensing is an important part of automation in agriculture and the Farm Technology Group provides major contributions to this course. The focus of the course is on a proper usage of sensors. Therefore this course presents briefly a number of different sensors to measure pressure, temperature, pH, velocity, acceleration, position, distance and angles etc. This course teaches you how to obtain information concerning accuracy and disturbances from datasheets and other documentation that comes with any sensor. Different types of sensor errors and ways to suppress them can be distinguished and are addressed in this course. This course also teaches different measurement principles such as compensation and Wheatstone bridges. These principles guide the engineer when designing a measurement set-up. The accuracy of sensors can often be improved by calibration that is also considered in this course. Signal conditioning, analog to digital (A/D) conversion and sampling (frequency spectrum, Shannon' s theorem, spectral analysis of signals) are important issues treated in this course as well as related phenomena as aliasing and filtering.

Considerable attention will be given to imaging sensors. Imaging sensors are a very special, sophisticated type of sensors that are being used to obtain 2 or 3 dimensional information of a system. These sensors become increasingly important in agricultural automation. The processing of the resulting images using computer vision techniques constitutes an important part of this course.

Scientific publications 2013

Refereed article in a journal

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Mahmood, H.S., Ahmad, M., Ahmad, T., Saeed, M.A., Iqbal, M. (2013). Potentials and prospects of precision agriculture in Pakistan – a review, Pakistan Journal of Agricultural Research, 26(2), 151-167.

Mahmood, H.S., Bartholomeus, H.M., Hoogmoed, W.B., van Henten, E.J. (2013). Evaluation and implementation of vis-NIR spectroscopy models to determine workability, Soil & Tillage Research, 134, 172-179.

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Strappini, A.C., Metz, J.H.M., Gallo, C., Frankena, K., Vargas, R., de Freslon, I., Kemp, B. (2013). Bruises in culled cows: when, where and how are they inflicted?, Animal: an international journal of animal bioscience 7(3), 485-491.

Upton, J., Humphreys, J., Groot Koerkamp, P.W.G., French, P., Dillon, P., Boer, I.J.M. de (2013). Energy demand on dairy farms in Ireland, Journal of Dairy Science, 96(10), 6489-6498.

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van 't Ooster, A., Bontsema, J., van Henten, E.J., Hemming, S. (2013), Sensitivity analysis of a stochastic discrete event simulation model of harvest operations in a static rose cultivation system, Biosystems Engineering, 116 (4), 457 – 469.

van 't Ooster, A., Bontsema, J., van Henten, E.J., Hemming, S. (2013), Simulation of harvest operations in a static rose cultivation system, Biosystems Engineering, *in press*.

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Mahmood, H.S. (2013). Proximal soil sensors and data fusion for precision agriculture, WUR Wageningen UR, promotor: van Henten, E.J., co-promotoren: Hoogmoed, W.B., pp. 205.

Shah, G.A. (2013). Improving the agro-environmental value of solid cattle manure, WUR Wageningen UR, promotor: Groot Koerkamp, P.W.G., co-promotoren: Lantinga, E.A., Groot, J.C.J., pp. 193.

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Groot Koerkamp, P.W.G., Bos, A.P., van Weeghel, H.J.E. (2013). Design approach to solve welfare and environmental aspects of loose housing systems for laying hens: The Roundel house and other examples. Abstract, Symposium International Research Center for Animal Environment and Welfare, October 19-22, 2013.

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van Beveren, P.J.M., Bontsema, J., van Straten, G., van Henten, E.J. (2013). Optimal management of energy resources in greenhouse crop production systems, Poster at 1st NWO, SES Programme Meeting, 5 June, 2013, The Hague.

van Beveren, P.J.M., Bontsema, J., van Straten, G., van Henten, E.J. (2013). Optimal management of energy resources in greenhouse crop production systems, Proceedings 1st NWO, SES Programme Meeting, 5 June, 2013, The Hague, Oral presentation.

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van Dixhoorn, I.D.E., André, G., Lambooij, E., Kemp, B., Groot Koerkamp, P.W.G. (2013). Individualized on-line monitoring tool to analyse the complex physiological signal of heart beat fluctuations in pigs, Proceedings of the Joint European Conference on Precision Livestock Farming, 10-12 September, 2013, Wageningen, The Netherlands, p. 801-811.

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